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THE HIDDEN RELATIONSHIP BETWEEN ERGONOMICS AND QUALITY

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KEYWORDS
Performance, TQM, Work environment, Disturbances, Production

SUMMATIVE STATEMENT
There is strong evidence that insufficient ergonomics cause quality deficiencies in production. Despite this, it has not yet been accepted that ergonomics is an important production factor. Reasons for this situation and possible actions are discussed.

La relation cachée entre l'ergonomie et la qualité

MOTS-CLÉS
Rendement, gestion de la qualité totale, milieu de travail, perturbations, production

SOMMAIRE
Les preuves sont suffisantes pour établir que lorsque l'ergonomie n'a pas été suffisamment prise en compte, cela entraîne des lacunes sur le plan de la qualité dans la production. Malgré cela, on ne se fait pas encore à l'idée que l'ergonomie est un facteur de production important. Les raisons de cette situation et des mesures possibles seront abordées.

PROBLEM STATEMENT

The scientific literature reports many examples of relationships between ergonomics and quality. However, this knowledge has not been sufficiently systematized for ergonomics to become generally accepted as a production factor.

RESEARCH OBJECTIVE

The objective of this paper is to summarize different perspectives on the relationship between ergonomics and quality, and to discuss the formation of this knowledge on a generalized level.

RESULTS

There is a large number of studies and reviews that have identified strong relationships between the quality performance of individuals and different ergonomics aspects such as light, noise, vibration, ventilation, climate, cognition and physical ergonomics. Further, there are also a large number of studies that have identified a relationship between ergonomics and quality output for the organization in different production settings. There are also examples when causality has been shown. All together, this evidence point to that good ergonomics is a precondition for quality performance, in other words an important production factor.

DISCUSSION

The strong relationship between ergonomics and quality might be accepted within the ergonomics discipline, but not as a production factor and not in working life. TQM and Lean address quality and some aspects of work design as important production factors. There are many reasons why it is not generally recognized that ergonomics is an important production factor. Some of them might be that the research literature is not explicit on this point, the ergonomics knowledge is not spread to the production discipline, and that ergonomics is seen an additional luxury for the employees, provided when the economy of the organization is sufficiently strong. Still another reason might be that there are also examples of how ergonomics improvements can be shown to be unprofitable for the organization.

CONCLUSIONS

A large number of research studies show strong evidence that insufficient ergonomics cause quality deficiencies in production, both on an individual and on an organizational level, confirming that ergonomics is a production factor. It is a problem that this knowledge is not formed, disseminated and accepted by production engineers and managers.

Symposium A: A participatory approach to Total Worker Health® developed by the Center for the Promotion of Health in the New England Workplace

Symposium A: Une approche participative à la santé globale des travailleurs élaborée par le Centre pour la promotion de la santé dans les milieux de travail de la Nouvelle- Angleterre

A PARTICIPATORY APPROACH TO TOTAL WORKER HEALTH® DEVELOPED BY THE CENTER FOR THE PROMOTION OF HEALTH IN THE NEW ENGLAND WORKPLACE

Une approche participative à la santé globale des travailleurs élaborée par le Centre pour la promotion de la santé dans les milieux de travail de la Nouvelle-Angleterre

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KEYWORDS
Participatory ergonomics, macroergonomics, Total Worker Health, integration, organizational readiness

ABSTRACT
The goal of Total Worker Health® (TWH) programs is to integrate protection from work-related safety and health hazards with promotion of injury and illness prevention efforts to advance worker well-being. Researchers in the Center for the Promotion of Health in the New England Workplace (CPH-NEW) have developed a set of tools for planning, implementing and evaluating a TWH program. Participatory action research involving four diverse work organizations was used to develop this set of programmatic tools through an iterative design process (R. Henning). Assessment of the intervention design process, evaluation of intervention outcomes, and various indicators of program success informed several revisions (S. Nobrega). Lessons learned from these efforts helped CPH-NEW refine our metrics of TWH "integration," which can be used to guide intervention design efforts and evaluate program outcomes (L. Punnett). In addition, a means for organizations, practitioners and researchers to assess organizational readiness for implementing a TWH program has been developed to help identify potential obstacles and plan any necessary steps to overcome these obstacles (M. Robertson).

RÉSUMÉ
L'objectif des programmes Total Worker Health® (TWH) est d'intégrer la protection contre les risques liés à la sécurité et la santé au travail en favorisant les efforts de prévention des blessures et des maladies pour accroître le bien-être des travailleurs. Les chercheurs du Center for the Promotion of Health in the New England Workplace (CPH-NEW) ont élaboré un ensemble d'outils visant à planifier, mettre en œuvre et évaluer un programme TWH. Une recherche participative regroupant quatre organisations différentes a été utilisée pour mettre au point des outils grâce à un processus de conception itérative (R. Henning). L'analyse du processus d'élaboration des interventions, l'évaluation des résultats des interventions, et divers indicateurs de réussite du programme ont fait

l’objet de plusieurs révisions (S. Nobrega). Les leçons tirées de ces travaux ont permis au CPH-NEW de raffiner les paramètres d’intégration TWH qui peuvent servir à orienter les efforts d’élaboration des interventions et à évaluer les résultats du programme (L. Punnett). De plus, des moyens ont été définis pour que les organisations, les praticiens et les chercheurs puissent évaluer l’état de préparation de l’organisation à mettre en œuvre un programme TWH et pour les aider à identifier les obstacles possibles ainsi qu’à planifier les mesures nécessaires pour les surmonter

ITERATIVE DESIGN OF A PARTICIPATORY ERGONOMICS TOOLKIT FOR TOTAL WORKER HEALTH

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KEYWORDS
Participatory ergonomics, Total Worker Health, Toolkits

SUMMATIVE STATEMENT
Growing interest in Total Worker Health® (TWH) programs to advance worker safety, health and well-being motivated development of a toolkit to guide implementation. This presentation focuses on participatory action research conducted by the Center for the Promotion of Health in the New England Workplace (CPH-NEW) to develop and test a participatory ergonomics (PE) based toolkit across a diverse set of work organizations.

Un processus itératif pour concevoir une trousse d’outils d’ergonomie participative pour la santé globale des travailleurs

MOTS-CLÉS
Ergonomie participative, santé globale des travailleurs, trousse d'outils

SOMMAIRE
L'intérêt croissant pour les programmes de santé globale des travailleurs (Total Worker Health® - TWH) dans le but de favoriser la sécurité, la santé et le bien-être des travailleurs a suscité l’élaboration d'une trousse d’outils pour guider la mise en œuvre d’un tel programme. Cette présentation est axée sur une recherche-action dirigée le Center for the Promotion of Health in the New England Workplace (CPH-NEW) afin de concevoir et de tester une trousse d’ergonomie participative dans les milieux de travail diversifiés.

PROBLEM STATEMENT
There are few programmatic tools available for employers, particularly in the United States, to engage employees in Total Worker Health initiatives. Furthermore, there is very little evidence-based guidance for how best to incorporate PE within TWH programs, or within workplace management systems dedicated to advancing employee safety, health and wellbeing.

RESEARCH OBJECTIVE / QUESTION
To determine if iterative design in combination with participatory action research can serve as an effective means to develop a toolkit for implementing TWH programs in which PE serves as the primary means for workers to actively participate in the design of workplace interventions.

METHODOLOGY

A PE-based toolkit was developed and tested at four diverse employer organizations over a 3-year period. A two-committee structure, consisting of an employee Design Team and management Steering Committee, was implemented at two of the four test sites; a single-committee structure was implemented at the remaining two sites. During each of two distinct stages of each field test, the program start-up period and the intervention design period, design aspects of the prototype toolkit that warranted redesign were identified based on user feedback from the three program facilitators as well as program participants. Iterative design was used to rectify any toolkit shortcomings, and new tools were developed where needed.

RESULTS

The need for toolkit redesign and development as well as additional tools became evident during both the program start-up period and the intervention design period. For example, better training tools were needed for the design team and steering committee on how PE can be used to design TWH interventions. During the intervention design period, the need for a more structured approach to intervention design became obvious, which led to the development of the Intervention DEsign and Analysis Scorecard (IDEAS) Tool which offers a step-by-step design process consisting of root causes analysis, solution finding, solution selection, implementation and evaluation, and the iterative design of interventions when needed.

DISCUSSION

Iterative toolkit design efforts depended on systematic collection of process feedback information throughout the program start-up and implementation phases of the project.

CONCLUSIONS

Participatory action research and the use of process evaluation was found to be an effective means to identify shortcomings in the TWH program toolkit, and made it possible to rectify these effectively through iterative design existing tools, or the design of new tools.

ACKNOWLEDGEMENTS

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FIELD TESTS OF A PARTICIPATORY ERGONOMICS TOOLKIT FOR TOTAL WORKER HEALTH

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KEYWORDS
Participatory ergonomics, Total Worker Health, Toolkits

SUMMATIVE STATEMENT
Growing interest in Total Worker Health® (TWH) programs to advance worker safety, health and well-being motivated development of a toolkit to guide their implementation. Process outcomes of the PE-based toolkit implementation are described for four employer test sites.

Essais sur le terrain d'une trousse d'outils d'ergonomie participative pour la santé globale des travailleurs

MOTS-CLÉS
Ergonomie participative, santé globale des travailleurs, trousse d'outils

SOMMAIRE
L'intérêt croissant pour les programmes de santé globale des travailleurs (Total Worker Health® - TWH) dans le but de favoriser la sécurité, la santé et le bien-être des travailleurs a entraîné l'élaboration d'une trousse d'outils. Les résultats de la mise en oeuvre de cette trousse d'ergonomie participative auprès de quatre employeurs sont décrits.

PROBLEM STATEMENT
There are few programmatic tools available for employers, particularly in the United States, to engage employees in Total Worker Health efforts. Similarly, there is very little evidence-based guidance for applying participatory ergonomics (PE) principles in the context of TWH programs, or within workplace management systems for safety and health.

RESEARCH OBJECTIVE/QUESTION
Evaluate the relative success of a TWH programmatic toolkit approach that incorporated PE in four varied employer organizations. Assess the outputs and outcomes of using the program tools for design team formation, employee needs assessment, and engaging employees in a systematic, participatory process for designing integrated TWH interventions.

METHODOLOGY

RE-AIM[1] process evaluation was used for capture outputs (activities and who participated) and short term outcomes (what happened as a result of participation) during each of two distinct stages of the field test study: program start-up period, and intervention design period.

RESULTS

Two of the four employer test sites implemented a two-committee structure (employee Design Team, management Steering Committee). This provided advantages over a single, multilevel committee structure, and enhanced the planning, communication, and teamwork skills of participants. The All-Employee Survey and focus group tools revealed a broad range of physical and psychosocial health/safety concerns for possible interventions. Integrated interventions (consistent with Total Worker Health approach) were formulated by Design Teams more fully in sites with a two-committee structure. Program success depended on regular design team meetings and consistent training of all program participants. Design Team members from all four organizations reported high engagement and satisfaction with the participatory program.

DISCUSSION

Management commitment to time and resource allocation, and a skilled program facilitator are vital for successful implementation of the PE-based TWH program. Resource constraints and organizational instability from external economy can be obstacles to program success. Implementation tools and training must provide attention to these critical success factors and pitfalls to help aid in successful adoption, implementation, and sustainability of participatory, Total Worker Health programs.

CONCLUSIONS

The PE-based TWH toolkit was effective for engaging front-line employees in participatory design of integrated interventions that addressed both work organization factors and aspects of individual behavior, consistent with TWH principles.

ACKNOWLEDGEMENTS

This research was supported by the National Institutes for Occupational Safety and Health Grant Number Grant Number 1U19 OH008857.

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EVALUATING TWH PROGRAMS: A RATIONALE FOR FOUR KEY METRICS

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SUMMATIVE STATEMENT
A key paradigm of the Total Worker Health® concept is to integrate occupational safety and health protections with other workplace programs to enhance well-being. Criteria for defining "integration" should be distinct from generic criteria for predicting or evaluating the success of a workplace health or safety program. CPH-NEW researchers propose a set of four TWH-specific metrics that address both program content and process.

Évaluer les programmes de santé globale des travailleurs (twh) : la justification de quatre paramètres essentiels

SOMMAIRE
Un paradigme majeur du concept Total Worker Health® (santé globale des travailleurs) est d'intégrer des protections en matière de santé et de sécurité à d'autres programmes en milieu de travail afin d'améliorer le bien-être. Les critères pour définir le terme « intégration » doivent être distincts des critères génériques visant à prédire ou évaluer la réussite d'un programme de santé ou de sécurité au travail. Les chercheurs du CPH-NEW proposent un ensemble de quatre paramètres spécifiques à la TWH qui tiennent compte du contenu et du processus du programme.

PROBLEM STATEMENT
The Total Worker Health® (TWH) program at the U.S. National Institute for Occupational Safety and Health (NIOSH) evolved out of the concept of integrating traditional occupational safety and health protections with other workplace health programs intended to enhance health and well-being (Schulte, et al., 2012). Investigators at the NIOSH TWH Centers of Excellence and elsewhere have developed a variety of research programs and approaches for different workforce populations, health and safety targets, and organizational contexts. Definitions of "integration" are not uniform among these investigators and projects. Similarly, there is no consensus as to which outcomes are most salient, or which ones are necessary for a project to qualify as "Total Worker Health."

Agreement about the dimensions of "integration" would be useful because it would facilitate comparison of these diverse programs and research studies, and even more fundamentally it would reduce ambiguity about which of them actually belong under the TWH umbrella (Feltner et al., 2016; Lax, 2016).

Specific criteria should be developed to define "integration," which are distinct from generic criteria for predicting or evaluating the success of a workplace health program. Our research group has developed a set of criteria for defining integration and four metrics that are specifically oriented toward these criteria.

RESEARCH OBJECTIVE/QUESTION

CPH-NEW pursues an integrated approach that is based fundamentally in employees' own knowledge and experience of the workplace. What are the essential elements of a worker health and safety program that define "integration" and also reflect this front-line experience? We focus here especially on the question of which dimensions should be assessed. Two important secondary questions are: which characteristics are important to measure in each of those dimensions; and what method(s) to use to assess those factors. This is not a peripheral issue, as the results might be quite different if assessed by manager interview, qualitative analysis of written documents, surveys of workers, or researchers' interpretation of observed events (to name only some of the possibilities). Process evaluation is a critical component; a global quantitative assessment will not necessarily disclose the changes underway.

METHODOLOGY

First principles have been enumerated to identify salient and necessary features of integration. Critical assessment of the investigators' own experience with TWH program implementation since 2006 has suggested criteria and provided empirical evidence. The literature on TWH, participatory ergonomics, and workplace change has also been reviewed for candidate metrics.
We tested each candidate against the core concept of combining approaches from two domains of activity that have predominantly been implemented separately, until recently. We argue that the concept of integration has little meaning if the label can be applied to merely instituting parallel programs, without each one informing and influencing the other.

RESULTS

CPH-NEW investigators have selected the following four indicators of program "integration:"

1. **Assessment** activities are designed to identify both work and non-work hazards impacting employee safety, health, and well-being.
2. **Interventions** seek to mitigate workplace contributors to poor health, safety, or well-being, such as improving organizational policies and practices.
3. **Coordination** of programs and activities is achieved for the occupational safety and the health promotion functions, e.g., with a common reporting structure or formal coordination of program goals and activities.
4. **Participatory engagement** processes empower workers to collaborate in prioritizing goals, decision-making about choice of activities and design of programs, and interpretation of findings.

We posit that these criteria encompass the core TWH principles: the inter-connectedness of work, environment and health; the role of healthy work organization as the starting point for health promotion in the workplace; and the importance of participatory workforce engagement for achieving continuous improvement in workplace safety, health and well-being while avoiding unintentional negative consequences. The initial focus is on making the work environment and work organization health-promoting.
The emphasis on participatory processes is a particular feature of CPH-NEW. It is more nuanced than obtaining "buy-in" from management and workers (Henning, et al., 2009; Robertson, et al., 2015). Participatory methods and measures for workforce participation are adapted from participatory ergonomics (Henning, et al., 2009; Punnett, et al., 2013) and action research (Cherniack, et al., 2016) and re-configured to define "integration" in terms of process as well as content. We have built our approach on a foundation of engaging workers in the entire process, from needs assessment to selecting health and/or safety goals, to prioritization of intervention alternatives, to program evaluation and learning from the results

to inform the next effort. This understanding of the critical importance of program process informs our approach to program design and goals, as well as evaluation.

We advocate the utilization of participatory methods to engage employees in problem-solving activities to alleviate psychosocial stress and other workplace safety issues. These are important, far-reaching potential effects of TWH that go beyond the immediate impact of specific workplace interventions. The involvement of line-level employees in design teams is also important for determining gaps in needs, because they are more aware of specific job characteristics and work processes that influence their health, safety, and well-being and may represent obstacles to participating in specific activities or being able to utilize knowledge and resources.

These criteria have been operationalized and are applied across the Center's research and outreach activities (Dugan, et al., 2016; Robertson, et al., 2015). They are also incorporated into workplace program evaluation materials of the Healthy Workplace Participatory Program and its on-line toolkit (www.uml.edu/Research/CPH-NEW/Healthy-Work-Participatory-Program).

DISCUSSION

TWH program evaluation criteria will always need to include some which are tailored to the particular intervention goals. However, there is also a need for criteria which can be used across programs and are specific to TWH principles, to facilitate meaningful comparisons among studies and systematic reviews of the TWH literature.

The needs addressed by workers themselves are often common across workplaces, but the solutions may be unique to each setting because of its particular features and the ability to customize offered by a participatory program design. The involvement of line-level employees in design teams is important for determining obstacles and gaps in needs, because they are more aware of specific job characteristics and work processes that influence their health, safety, and well-being.

Next steps include evaluation of the extent to which baseline assessments of these domains predict the extent to which programs succeed in addressing both work-related and extra-occupational risk factors.

CONCLUSIONS

By using these criteria for program design and evaluation, workplace safety and health practitioners can align their activities with TWH principles, regardless of the diversity in final content and approach.

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DEVELOPMENT OF AN ORGANIZATIONAL READINESS INSTRUMENT BASED ON THE TOTAL WORKER HEALTH APPROACH

SYMPOSIUM TITLE: PARTICIPATORY APPROACHES TO TOTAL WORKER HEALTH: A MODEL OF ONE CDC TWH CENTER FOR EXCELLENCE

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KEYWORDS
Organizational readiness; Total worker health; Participatory ergonomics; Change Management

SUMMATIVE STATEMENT
Total Worker Health (TWH) is a programmatic approach focused on integrating work-related safety and health protection with prevention efforts to advance overall worker well-being. This is still a relatively new concept, although similar approaches are seen in Europe, and research findings on the best programmatic ways of achieving TWH in a cost-effective manner remain rather limited. The basis of Total Worker Health is policies, programs, and practices to be implemented by an organization to prevent injuries and promote health. Few methods have been published specifically for assessing TWH organizational readiness, which evaluates if employees within an organization are ready to implement or participate in those policies, programs, and practices. This paper will discuss the application of organizational readiness constructs to the development of a diagnostic, organizational readiness instrument for employers implementing Total Worker Health programs.

Élaboration d’un instrument de préparation organisationnelle fondé sur la démarche de santé globale des travailleurs

MOTS-CLÉS
Préparation organisationnelle, santé globale des travailleurs, ergonomie participative, gestion du changement

SOMMAIRE
La santé globale des travailleurs (TWH) est une démarche programmatique visant à intégrer la sécurité et la protection de la santé au travail grâce à des initiatives de prévention pour

améliorer le bien-être général des travailleurs. Bien que ce concept soit relativement nouveau, on a observé des démarches semblables en Europe. Toutefois, les résultats de la recherche portant sur les meilleurs programmes pour atteindre la TWH de manière rentable restent modestes. La TWH repose sur les politiques, les programmes et les pratiques à mettre en œuvre par une organisation afin de prévenir les blessures et de promouvoir la santé. Peu de méthodes ont été publiées spécifiquement sur l'évaluation de la préparation organisationnelle à la TWH, qui permet d’évaluer si les employés d'une organisation sont prêts à mettre en œuvre ou à participer aux politiques, programmes et pratiques. Cette communication abordera les concepts d’application de la préparation organisationnelle afin d’élaborer un instrument de diagnostic et de préparation organisationnelle pour les employeurs qui mettent en œuvre des programmes de TWH.

PROBLEM STATEMENT

Organizational readiness is defined as, “The extent to which individuals are cognitively and emotionally inclined to accept, embrace, and adopt a particular plan to purposefully alter the status quo, and the organization’s capacity to successfully undertake those changes” (Armenakis et al., 1993, 2007). Peer-reviewed literature on organizational readiness shows various ways to measure readiness in different contexts, and even how to conceptualize or operationalize readiness prior to change efforts. These divergent perspectives need to be clarified so researchers studying organizational readiness and practitioners assessing it in the field have a common guide to follow.

RESEARCH OBJECTIVE / QUESTION

The current study will ground a TWH organizational readiness instrument in the change management literature, identify actionable steps to be taken in employer organizations, and validate a new approach through field work.

METHODOLOGY

A literature review was conducted to tease apart the conceptual ambiguity in organizational readiness within and across fields, including occupational safety and health, change management, and information technology. We identified common variables/factors/indicators in organizational readiness assessments, and we used that information to create subject matter expert interview questions.

RESULTS

There were limited publications in the area of organizational readiness measures and workplace safety/ergonomics and human factors/well-being change initiatives. Readiness for change does, in part, depend on the specific change, which is the content. Still, everyday functioning in the workplace will have much effect on change efforts even though they may seem unrelated, which involves context. Together, the content and the context will influence individuals’ motivation to change, attitudes toward change, and behaviors to change.

DISCUSSION

The results of this systematic literature review will lead to the development of an integrated approach to understanding organizational readiness and employees’ capacity to change. We will design an organizational diagnostic, organizational readiness survey that will prepare organizations to manage well-being and safety workplace initiatives and changes.

CONCLUSIONS

A systematic literature review was conducted using scientific databases that specifically integrated multidisciplinary peer-reviewed theoretical and empirical work, which will lead to the creation of an integrated well-being and safety workplace readiness assessment guide for researchers and practitioners.

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Technical Session 1: Integrating healthcare & macroergonomics issues

Séance technique 1: Intégration des enjeux de santé et de macroergonomie

A SOCIOTECHNICAL SYSTEM APPROACH TO ADDRESS HOME CARE PROVIDER INJURIES

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KEYWORDS
Sociotechnical, Home Care Aide, Overexertion, Falls, Injury Reduction

MAIN MESSAGE
Home care aide (HCA) injury rates are more than quadruple the U.S. average for all occupations (Bureau of Labor Statistics, 2009). To understand the complex Washington State home-care system, we used a sociotechnical system approach (Emery and Trist, 1965; Hendrick, 2010) to define factors contributing to home care worker injury and develop risk-mitigation strategies. Challenges were identified in all sociotechnical system domains: organization, people, physical environment, tools and technology, tasks and processes, as well as the external environment. The understanding of system challenges allowed the development of both short- and long-term strategic planning to address overexertion and fall injuries among HCAs.

Une approche de systèmes sociotechniques pour s’attaquer aux blessures chez les fournisseurs de soins à domicile

MOTS-CLÉS
Sociotechnique, soins à domicile, surmenage, chutes, réduction des blessures

MESSAGE PRINCIPAL
Le taux de blessures chez le personnel de soins à domicile est quatre fois plus que la moyenne américaine dans l’ensemble des professions (Bureau of Labor Statistics, 2009). Afin de comprendre le système complexe des soins à domicile dans l'État de Washington, nous avons utilisé une approche reposant sur les systèmes sociotechniques (Emery et Trist, 1965; Hendrick, 2010) pour définir les facteurs contribuant aux blessures chez les travailleurs de soins à domicile et élaborer des stratégies d'atténuation des risques. Des lacunes ont été repérées dans tous les domaines du système sociotechnique : l'organisation, les personnes, l'environnement physique, les outils et la technologie, les tâches et les processus, ainsi que l'environnement externe. La compréhension de ces lacunes nous a permis d’élaborer une planification stratégique à court terme et à long terme pour prévenir le surmenage et les blessures causées par les chutes dans le secteur des soins à domicile.

PROBLEM
As the world’s population is aging, more demand is created for in-home care (Bercovitz, et al., 2011). To meet this need, Home Care Aides (HCAs) assist with activities of daily living (ADLs) to help people with disabilities and the elderly remain in their homes. However, as such work frequently includes physically-demanding tasks, state (Howard and Adams, 2010; Washington State Labor and Industries, 2015), national (Bureau of Labor Statistics, 2009); and international (e.g., Baumann, 2001; Health and Safety Authority, 2016) claims data

indicate that HCAs suffer alarmingly high injury rates, with overexertion and falls being the most common injuries.

The challenge of high rates of overexertion and fall injuries among HCAs became central to the SEIU 775 Benefits Group (Benefits Group), based in Washington state. When reviewing both worker's compensation as well as medical claims data, it was noted that many claims related to ailments were indicative of overexertion and fall injuries. A reduction in the number of claims from overexertion and fall injuries would reduce workforce turnover, decrease absenteeism, improve worker and client quality of life, and decrease costs of workplace injuries addressed in the medical setting. However, in initial discovery of the problem, the Benefits Group found little data that outlined the contextual factors for the overexertion and fall injuries.

CONTEXT

The level of infrastructure for home care depends, in part, upon the location. In Washington State, the larger organizational structure that supports the work of HCAs is complex. SEIU 775, a part of the larger Service Employees International Union, was formed in 2001 when Washington state voters passed Initiative 775, which allowed home care workers to form a union. This initiative formed separately managed and funded organizations that provide training, health, and retirement benefits. Health benefits include health insurance and health promotion programs (stress reduction, injury prevention, cancer screening, etc.) to HCAs. The Training Partnership provides training and career development. A newly-formed retirement trust seeks to ensure that workers have income past the time when working is feasible. The Department of Social and Health Services (DSHS) governs the Medicaid funds to administer the state's Home Care Program; approves HCA training curriculum; administers the program for certification and testing; and is responsible for assuring adherence to the Washington Administrative Code (WAC) as prescribed by law.

HCAs in Washington State are a unionized workforce that perform home care as agency employees or independent contractors. Agency Providers (APs) are employed by Home Care Agencies, which are privately owned businesses that provide HCA services. Independent Providers (IPs) work independently and are employed directly by the client and paid by the state of Washington. Approximately 80% of HCAs are IPs. Almost half of IPs care for immediate family, extended family, or close friends or neighbors. Workforce training and delivery of home care services occur in the context of rapidly growing demand, a multi-cultural workforce, a highly variable client population, heterogeneous work environments and geographies, and complicated state and federal policies and procedures.

ACTIONS

To determine the appropriate components and content for an injury reduction program, an initial scan (Hendrick and Kleiner, 2001) was conducted of the home care system in Washington. Figure 1 depicts the sociotechnical system (STS) framework for complex organizational work design applied. The STS framework recognizes the interaction among people, technology, tasks, the physical environment, and the organization, which includes the safety culture, climate, and values in workplaces (Holden, et al, 2013). This framework aids in uncovering relationships and interactions within a system, which then facilitates the development of interventions to improve the performance within the system (Fox, 1995).

Figure 1. A sociotechnical system.

The approach is not novel to healthcare or, specifically, home care. Carayon and her colleagues (e.g., 2007, 2011, 2012) have advocated for a systems approach to understanding and addressing patient safety issues in, primarily, hospital-based healthcare for the past decade based upon the STS paradigm (Emery and Trist, 1965; Hendrick, 2010). Beer et al. (2014) utilized this “human-systems” approach when interviewing Certified Nursing Assistants and Registered Nurses who worked in the home care sector. With this project, the sociotechnical systems approach was unique in its intention – namely that the Benefits Group was working to use the data gathered to inform short- and long-term strategic planning to reduce incidents of overexertion and fall injuries.

The initial effort was conducted over a two-month period, with additional data being collected and added over the past two years. The methods and number of data sources as of this writing are summarized in Table 1.

Table 1. Data collection methods and sources used to gain system information.

Methods	Number of Sources
Interviews: Home Care Aides	53
Interviews: Service Employees International Union (SEIU) 775, Health Benefits Group, and Training Partnership, Trainers	19
Interviews: Home Care Agency's Leadership/Management	4
Interviews: WA State Department of Social and Health Services, WA Case Managers	25
Results of HCA Survey	583 respondents
Focus and Research Groups about Injury and Injury Prevention	5
Literature review	3 material sources
Data Review: WA State Labor and Industries	3 analysis sources
Document Review: Relevant SEIU Materials	8
Document Review: Relevant Washington State Materials	3
Training Material Review	3
Past Project Information	1
Information on Concurrent Initiatives	5
Stakeholder Working Group	1

OUTCOMES

Through data collection and analysis, we identified 21 core challenges that undermine the goal of reducing HCA overexertion and fall injuries and span the system domains of organization, tools and technology, tasks and processes, physical environment, people, and external environment. Two examples are provided to demonstrate the utility of the STS approach and the way the information was incorporated into the Benefits Group's strategic plan.

Limited Use of Assistive Devices and Other Technology Directed at HCAs

Results from this evaluation suggest that a Client may not have the assistive devices in the home that would promote the highest level of safety for the HCA or that the devices are available but not being used. This is especially notable given the risks inherent in many typical HCA work tasks. During the intake process for a new Client, the Case Manager assesses the Client's need for durable medical equipment, not the HCA's need for equipment. Many items are covered under Medicare and Medicaid (e.g., walkers, wheelchairs, raised toilet seats) although many are not (e.g., transfer board, ramps, gait belts). Items may also be covered under the Medicaid state plan. Clients have varying degrees of support to advocate on their behalf and varying degrees of financial resources to obtain items that they may need. As HCAs are low income, purchasing needed equipment directly is often prohibitive.

There are several possible reasons why a Client might not be getting the assistive devices that they need or those that the HCA needs to safely care for the Client, including limitations of DSHS recommendations (they are unable to obtain an assistive device solely because it would help the HCA); a difference in perception of Client need between the Case Manager and the HCA; an unmet or delayed need for a re-evaluation after Client's health appears to be declining; and Client preference to not use a specific assistive device. Under the state's mandate of "consumer-directed care", if a Client does not wish to use an assistive device, then the Case Manager would have no need to acquire it. There are also anecdotal reports of long delays in acquiring equipment, as much as six-months, for example, for a lift chair. This information is a focus of future work.

At times, equipment in the home is not being used. For instance, a client may refuse the use of a patient lift for fear of falling or an HCA may choose not to employ a patient lift due to lack of training on the device (no standard training is offered on patient lifts, such as Hoyer lifts).

The current analysis revealed other gaps in use of equipment for home care. Clients may not have all non-durable supplies needed for their care, such as gait belts and transfer boards, which may be necessary for safer handling practices. Additionally, HCAs themselves may not own supplies needed to avoid injury, for example, appropriate non-slip footwear to avoid falls.

To address these gaps, the Benefits Group has worked several short- and long-term initiatives into their strategic plan to address the equipment gap. In the short term, the Benefits Group is pilot testing programs to give low-cost safety tools to HCAs. For example, a pilot program is underway to provide non-slip shoes, backpacks, gait belts, and similar tools to HCAs during training.

In the summer of 2016, the Benefits Group spoke at contract negotiations between Washington state Department of Social and Human Services (DSHS) and SEIU 775 about the risks of on the job injury to HCAs and their clients. As a result of that discussion, the Benefits Group and DSHS will partner to conduct a study on the potential of slip-reduction rated shoes to decrease pain and injury from falls as well as increase safety-related behaviors in the workforce. That study will begin in summer of 2017 and end in summer of 2018. If a positive impact of shoes is observed, the state has agreed to scale a shoes benefit to the workforce starting in the late 2018.

Some work has also been conducted to understand the true lag time between when a need for safety equipment provided by the state is identified and when it is delivered to the client for use. This work has been challenging, but has elucidated the complexity of the system and the many players (medical provider, Medicare, Medicaid) and steps (prescription, vendor identification, order placement, delivery, etc.) that make up the complex process.

Limited Injury Reduction Training and Education
Results from the evaluation offered background on HCA training requirements and training process, and indicated specific areas where more targeted education and training were needed. The analysis identified several new education topics to consider for expansion, including HCA self-advocacy and conflict resolution with a Client; advanced safety skills; transfer kinesthetics; how to identify and address hazards both with and without use of a checklist; when and how to use assistive devices; and how to avoid HCA (as opposed to Client) falls. Evaluation findings also point to a lack of opportunities for HCAs to learn from each other. While training provides essential background and foundational skill building, HCAs may benefit from ongoing learning from the real-world experiences of other HCAs. Finally, findings suggest a need for real time support in the home to address specific and urgent needs faced while on the job.

To address some of these needs, the training partnership has developed training modules on motivational interviewing and the Benefits Group tested a training module on how HCAs can avoid falls at an HCA convention; this module is now under formal development.

Conversations are underway to best leverage peer mentorship as well as video-conferencing via smart phones, a technology ubiquitous to most HCAs, to help with real time problem solving. Issues related to Client privacy to make such processes feasible and compliant will be critical.

DISCUSSION

As stated, the STS framework aids in uncovering relationships and interactions within a system. In this study, 21 major challenges were identified related to overexertion and fall injuries. The thorough definition and understanding of the challenges, and the contribution of each system domain, facilitated the development of interventions to improve the performance within the system. Some solutions are simple and short-term, such as the pilot to provide non-slip shoes to HCAs. Others are much more complicated and longer-term, such as the effort to understand and eventually aid in the streamlining of the equipment procurement process. Importantly, our work demonstrates a need for greater collaboration between the state, agencies, union stakeholders, Home Care Aides, and their Clients. The systems viewpoint facilitates that collaboration and expedites progress.

CONCLUSION

Obtaining this sociotechnical system view of complex organizations was time-intensive, requiring access to multiple sources of information. Nonetheless, the insights we gained from this approach greatly expand the opportunities for safety improvement and injury reduction. We have already begun to leverage some of these insights in the design, testing and evaluation of pilot programs to reduce the prevalence of on-the-job injury in HCAs. We anticipate that we will continue this work for up to four years to more comprehensively study the system and address the needs identified through programs that keep HCAs safe at work.

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DEVELOPING AND EVALUATING A MULTIFACETED PATIENT HANDLING PROGRAM AMONG NURSES TO IMPROVE SAFETY CULTURE: A PILOT STUDY

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KEYWORDS
Musculoskeletal disorders, safe patient handling, safety culture, nurses/nursing, acute care hospital

MAIN MESSAGE
Patient handling places nurses at a high risk for injury. A pilot quasi-experimental pre/post study with a control group was conducted on two surgical nursing units at Mount Sinai Hospital. Results suggest that a multifaceted patient handling program involving engineering, administrative and practice controls may be feasible and potentially effective at increasing staff self-efficacy, safety social norms, and knowledge of safe patient handling, with the opportunity for long term work disability cost reduction.

Élaboration et évaluation d’un programme de manutention des patients à facettes multiples auprès du personnel infirmier afin d’améliorer la culture de sécurité : une étude pilote

MOTS-CLÉS
Troubles musculosquelettiques, manipulation sécuritaire des patients, culture de sécurité, personnel infirmier, hôpital de soins actifs

MESSAGE PRINCIPAL
La manipulation des patients expose le personnel infirmier à un risque de blessure élevé. Une étude pilote quasi expérimentale (avant/après) comprenant un groupe témoin a été réalisée dans deux unités de soins infirmiers chirurgicaux à l’hôpital Mount Sinai. Les résultats indiquent qu'un programme de manipulation des patients à facettes multiples – combinant des mesures techniques, des mesures administratives et des mesures de pratiques de travail – peut être possible et s’avérer efficace pour accroître l'auto-efficacité du personnel, les normes sociales de sécurité et les connaissances en matière de la manipulation sécuritaire des patients. Le programme pourrait aussi réduire les coûts d'invalidité de longue durée.

PROBLEM

Patient handling is a complex high-hazard task leading to an increased risk for musculoskeletal disorders (MSDs). Task variables include a patient's size and weight, level of cooperation, and medical condition. Unlike conventional manual materials handling tasks, patients are not inanimate objects and therefore cannot be handled the same way; i.e., they do not have an even weight distribution,, and may react unexpectedly. Other considerations include the nurse-to-patient ratio, time constraints, space limitations, and the ability to use equipment and safe body mechanics. Changes in patient population and care practices have led to an increase in the number of acute/bariatric patients. Coupled with high patient turnover rates, patient handling demands have increased.

Most programs attempting to reduce the hazards associated with patient handling MSDs have not been as successful as expected (Tullar et al., 2010). The systematic review on prevention programs for health-care workers by Tullar and colleagues concluded that future research should consider multi-component patient-handling interventions that involve: a change in policy at the work site, the implementation of new patient handling equipment, and training (Tullar et al., 2010). They further found that previous multifaceted approaches primarily considered administrative outcomes, which may not capture the effect of a program on individual workers. Nelson et al. (2006) noted countless studies on single approaches or classes in body mechanics that were found to be ineffective at preventing MSDs or with only short-term benefits.

CONTEXT

Mount Sinai Hospital is a 442-bed acute care hospital supported by nearly 5,000 staff. Consistent with statistics provided by WSIB (2015), over the last three years at Mount Sinai Hospital, sprains and strains have represented close to 40% of allowed lost time claims. These injuries can have direct impacts on patient care, staff productivity, quality of life, and operational costs. The average cost over the lifetime of a lost time claim is estimated to be $30,000, with total costs estimated to be five times greater once indirect costs are considered (WSIB, 2011). Nurses represent over a quarter of the Mount Sinai Hospital's staff and are the primary workers responsible for patient handling tasks. The study was approved by the Mount Sinai Hospital Research Ethics Board.

ACTIONS

A quasi-experimental pre/post pilot study with a control group was conducted on two surgical nursing units to evaluate the effectiveness of a multifaceted patient handling program focussing on increasing staff self-efficacy, safety social norms, knowledge, and injury reporting.

The intervention targeted high-risk patient handling tasks (repositioning, lie-to-lie transfers between the bed and stretcher, and transfers up from the floor) and consisted of engineering, administrative, and practice controls. A 32-bed surgical unit caring for reconstructive orthopaedic, gynecology, head and neck oncology, oral maxillofacial surgery, dentistry, and ophthalmology patients served as the intervention group and consisted of 28 full-time, 9 part-time, and 3 casual nurses. An adjacent comparable 34-bed surgical unit caring for predominantly oncologic orthopaedic patients served as the control group and consisted of 26 full-time, 6 part-time, and 5 casual nurses. Baseline equipment was similar across the units and included ceiling lifts, slider boards, repositioning sheets, and various repositioning wedges. Measures of incident counts and lost and modified work days were collected from the Hospital incident database at 0 (baseline) and 4 months.

Engineering controls introduced on the intervention unit consisted of additional equipment that were selected by the intervention unit and project lead (AC), based on an inventory of existing equipment, current unit needs, and types of equipment as recommended by Hignett (2003): 1 mobile patient lift, 2 air-assisted devices, 2 lateral transfer boards with slider sheets, and 15 repositioning sheets (12 standard width, 3 bariatric width). The administrative controls included the existing organizational safe patient handling policy, newly revised training with resource binder, and newly developed unit-specific decision-making algorithms. The resource binder included a copy of the safe patient handling policy, roles and responsibilities of the Safety Champions with photographs to identify them, patient assessment tools, decision-making algorithms adapted from The Winnipeg Regional Health Authority's Safe Patient Handling and Movement Program (Winnipeg Regional Health Authority, 2016), competency and practice checklists, as well as relevant equipment information (descriptions, inventory, locations, cleaning procedures, and maintenance and repair procedures). Practice controls included four staff Safety Champions who worked within the intervention unit and were selected by unit manager. The role of the Safety Champion was integrated into their regular roles and responsibilities. Safety Champions received additional training on equipment use, patient assessment, and peer coaching during a 5-hour session facilitated by a staff Physiotherapist. Together with the unit manager, Safety Champions created their own roles and responsibilities, with some tasks including conducting an inventory of equipment and confirming that equipment is in good working order, acting as a champion and cheerleader to support safe utilization of safety equipment, and providing education, updates and feedback during staff meetings.

Subjects were recruited from the nursing staff of the two units and informed consent was obtained. Individuals were excluded if they had work restrictions or modified duties that precluded them from performing patient handling tasks. The managers of each unit supported the research project and subjects were offered incentives (coffee cards) for participating and completing surveys. Surveys were administered by the project lead (AC). Ratings of self-efficacy (related to patient handling), safety social norms (relative to supervisor and co-workers), and patient handling and musculoskeletal hazards and controls knowledge test scores were collected at 0, 1 and 4 months using paper-based self-report questionnaires that took less than 10 minutes to complete.

Data were entered into excel spreadsheets and imported into SAS© for analysis. Data were inspected for normality and did not substantially violate assumptions allowing us to conduct a repeated measures ANOVA for all outcome variables. The test of significance of the intervention was a test ($p<0.05$) of the interaction term for group vs time (0, 1, 4).

OUTCOMES

The two groups were quite similar with no significant differences in work tenure or employee height. The control group (n=22) had 4 part time staff and the intervention group (n=26) had 3 part time staff. The participation rate for the two groups was also very similar (intervention group rate for each survey was 42.5%, 30.0%, and 32.5%, respectively and control group for each survey was 43.2%, 27.0%, and 35.1%, respectively). Overall, only 6 employees in the intervention group completed all three questionnaires and 8 completed the baseline questionnaire and at least one follow-up questionnaire.

Table 1 shows the mean scores for each outcome by group and over time. Repeated measures analysis revealed no significant differences in self-efficacy or safety norms between the groups over time. The self-efficacy scores did increase over time in the intervention group whereas they remained the same in the control group suggesting a trend of improvement over time (see Table 1). Similarly, for safety norms the intervention group scores increased over time whereas the control group stayed the same or decreased. There was a significant difference (F=3.57, p< 0.05) between the groups over time for the knowledge test scores where the intervention group did not decrease over time while the control group did.

Increased patient handling-related incidents were reported to the Occupational Health, Wellness and Safety department in the intervention group, but none of the 4 incidents proceeded to claims. No incidents were reported in the control group.

Table 1: Mean scores for outcome variables for intervention and control groups by measurement time. Higher scores reflect better outcomes for all variables.

Outcome	Time	Intervention group: mean (SD)	Control group: mean (SD)
Knowledge score[a]	0	67.6 (14.0)	76.5 (13.3)
	1	65.6 (20.7)	46.0 (22.3)
	2	62.5 (16.9)	61.5 (17.7)
Self-Efficacy[b]	0	5.25 (0.59)	5.37 (0.65)
	1	5.60 (0.63)	5.41 (0.74)
	2	5.71 (0.69)	5.49 (0.59)
Safety Norms (Supervisor)[b]	0	6.82 (3.94)	10.21 (2.97)
	1	7.50 (3.15)	8.22 (3.03)
	2	9.77 (3.49)	9.54 (4.20)
Safety Norms (Co-Worker)[b]	0	5.75 (2.79)	6.21 (4.46)
	1	7.80 (1.55)	6.50 (3.16)
	2	7.92 (5.69)	5.75 (2.63)

[a] significant time*group interaction F=4.22, df=2, p< 0.05
[b] time*group interaction not significant at p< 0.05

DISCUSSION

Overall, we implemented a multi-level multi-component intervention intended to reduce patient handling injuries in an acute care hospital over four months. The intervention led to improved self-efficacy in patient handling scores and social norm scores but these improvements were not statistically different from the control group, where scores either did not change or dropped. The lack of statistical significance could be a sample size/power issue. Knowledge scores did not change for the intervention group but dropped for the control group and this difference was statistically significant. This finding suggests better retention by the intervention group than the control group over four months. We also found that the intervention resulted in more injury reports to the Occupational Health, Wellness and Safety department. This is not unexpected since often interventions raise employee awareness and reporting. The pilot study results are promising and suggest the multi-level multi-component intervention should be more rigorously evaluated with a larger sample and if possible, a randomized field experiment.

Strategies for implementing and evaluating a new program in a fast-paced acute care hospital setting need to be further developed. Competing priorities at the hospital during the time of the study may have affected outcomes (e.g., hospital mergers, supervisor and staff turnover, functional program changes, and other hospital surveys and initiatives taking place during the time of the study). These changes likely had an impact on staff morale. Participation levels were lower than anticipated. Rotating schedules and the combination of full-time, part-time, and casual staff, made scheduling of training and survey distribution challenging to coordinate. It is difficult to determine if the participants provided a representative sample of the unit. In working with external parties, several administrative tasks including the submission of ethics, setup of contracts, and creation of financial accounts, need to be considered to prevent delays or progress of the study. Improved data collection and implementation techniques to address these challenges may help to yield further significant findings over time.

CONCLUSION

A multifaceted patient handling program showed positive short-term trends and was feasible to implement. Future research with long term outcomes and a larger sample is recommended to determine effectiveness of this type of intervention on patient-handling injuries. A key element of future research will be improved data collection techniques and careful attention to program implementation. The intervention appears promising for improving self-efficacy and safety culture.

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ENHANCING PUBLIC COMPREHENSION OF PATIENT EXPERIENCE INFORMATION IN EMERGENCY DEPARTMENTS

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KEYWORDS
Healthcare, public reporting, website usability, comprehension testing.

MAIN MESSAGE
By providing information to Albertans, a website (http://focus.hqca.ca/) recently released by the Health Quality Council of Alberta (HQCA) intends to 'foster conversations' that can lead to quality improvement and a better healthcare system. Albertans cannot have the right conversations if they don't understand the information. Usability and comprehension testing was performed while designing the website. Design modifications were iteratively made which enhanced the public's comprehension of information such as wait times and length of patient hospital stay compared to the Canadian average.

Améliorer la compréhension du public quant à l'information sur l'expérience des patients dans les urgences

MOTS-CLÉS
Soins de santé, rapports destinés au public, convivialité des sites Web, test de compréhension

MESSAGE PRINCIPAL
Le Health Quality Council of Alberta (HQCA) a récemment lancé un site Web (http://focus.hqca.ca/) dans le but de renseigner les Albertains et de favoriser des conversations qui pourraient entraîner une amélioration de la qualité des services et un meilleur système de santé. Les Albertains ne peuvent pas avoir de conversations pertinentes s'ils ne comprennent pas l'information. Des tests d'utilisabilité et de compréhension ont été effectués lors de la conception du site Web. Des modifications ont ensuite été apportées de façon itérative afin d'améliorer la compréhension des informations par le public (p. ex., les temps d'attente et la durée du séjour hospitalier) comparativement à la moyenne canadienne.

PROBLEM
The website is the first public reporting initiative of its kind in Canada and reports on information that historically has not been publically reported in Alberta. Ensuring that members of the public and healthcare providers can understand the information included in the website and navigate through the website is critical to ensure that conversations are evidence based.

CONTEXT
The HQCA has a legislated mandate to measure, monitor, and report on the quality and safety of Alberta's healthcare system. As part of this mandate, and for transparency, the HQCA has developed the website to publically report emergency department patient experience data using administrative data and survey data for the 16 busiest emergency departments in the province. This website is about starting conversations between healthcare providers, decision-makers, and the public they serve.

ACTIONS
Three phases of usability testing were performed with members of the public to assess public comprehension of emergency department data and website usability. The third phase of usability testing also included healthcare leaders and decision makers.

OUTCOMES
Phase one findings revealed significant challenges regarding public comprehension of some measures. For example, participants incorrectly interpreted 59% of graphs reporting on what was formerly titled 'Actual length of patient stay compared to the expected length of stay'. Ambiguous wording in the title and description of the measure (i.e., expected length of stay) as well as difficulty interpreting ratios contributed to challenges with comprehension. A number of modifications were made, including changing how the data was reported (percent instead of ratio), modifying the title and definition of the graph (i.e., now titled 'length of patient hospital stay compared to the Canadian average LOS'), as well as including visual aids ('better' arrow and pop-up descriptive text for all data points) to enhance comprehension. Retesting of this measure in phase two after information design modifications were made improved comprehension rates. Specifically, the percent of incorrectly interpreted graphs for this measure dropped from 59% to 0% (see Table 1).

Table 1. Improved comprehension rates following modifications based on phase 1 learning to enhance comprehension.

Measure	Incorrect interpretation	
	Phase 1	Phase 2
Patients' time to see an ED doctor (90th)	65%	22%
Patients' time to see an ED doctor (median)	29%	0%
Length of patient hospital stay compared to Canadian average LOS	59%	0%
Alternate level of care (ALC) percentage	12%	0%
Total length of patient's ED stay	N/A	0%
Patients who LWBS by an ED doctor	N/A	0%
Length of time admitted patients wait in the ED	N/A	0%

At the same time, findings from phase two indicated additional opportunities with respect to comprehension of other measures as well as website usability. Phase three indicated that how members of the public were using the data was consistent with how healthcare leaders and decision makers were using the data (i.e., comparison within and between hospitals, assessing variability, identifying trends over time, etc. – see Table 2).

Table 2. Coded verbalizations indicating how usability participant were using the data.

Verbalized uses	Emergency department experts	Members of the public
Compared to other sites	100%	100%
Compared to a benchmark	100%	100%
Trend over time	100%	75%
Peaks and variability within a site	75%	75%
Appropriateness of individual data point	50%	83%
Thought about causes and solutions	75%	83%

DISCUSSION

Usability testing started very early in the project using paper versions of the charts and descriptions. This allowed specific design requirements to be communicated to the website developer. Secondly, the testing was performed iteratively which allowed for refinements and retesting.

CONCLUSION

Website usability and public comprehension were prioritized website development principles of this project. This was supported by both leadership and project teams. It facilitated a decision making process when designing the website that accommodated for the diverse users of the website.

Technical Session 2: Physical ergonomics 1

Séance technique 2: Ergonomie physique 1

ASSESSMENT OF PROLONGED STANDING WORK IN FOOD SERVICE WORKERS

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KEYWORDS
Prolonged standing, food service industry, wearable insole sensors and center of pressure (COP)

SUMMARY STATEMENT
Understanding the impact of prolonged standing on industrial workers will help to improve work protocols for these workers. Food services workers were utilized to study potential methods of collecting prolonged standing data. The pre and post data showed no significant difference for the parameters selected in this study with a 4 hour work time. Further research will be conducted to try to determine parameters that can be measured to capture fatigue effects in standing.

Évaluation du travail en position debout pendant de longues périodes chez les travailleurs de la restauration

MOTS-CLÉS
Station debout prolongée, industrie de la restauration, semelles dotées de capteurs, centre de pression

SOMMAIRE
Comprendre l'impact de la station debout prolongée sur les travailleurs de l'industrie permettra d'améliorer les protocoles de travail pour ces travailleurs. On a fait appel à des travailleurs de la restauration pour étudier les méthodes pouvant servir à colliger des données sur la station debout prolongée. Les données recueillies avant et après l'étude n'ont révélé aucune différence significative quant aux paramètres choisis dans cette étude, qui visait une période de travail de 4 heures. D'autres recherches seront effectuées pour tenter de déterminer les paramètres pouvant être mesurés afin de déceler les effets de la fatigue en station debout.

ABSTACT
Many occupations require workers to be on their feet for prolonged work periods. Understanding the impact of prolonged standing on industrial workers will help to improve work protocols for these workers. This is particularly relevant in the food service industry. While over 2.2 million individuals are employed as wait staff in the US and experience a considerable number of musculoskeletal disorders (MSD's) each year, little is known about how their occupation impacts the risk factors associated with MSD's (Wills, Davis, & Kotowski, 2013). In assembly line positions and other occupations, employees experience pain and discomfort associated with long periods of standing (King, 2002). Modifications must be made to the work place or worker's equipment to prevent these injuries from occurring. The majority

of studies examining MSDs in workers involved in prolonged standing have been qualitative implementing ergonomic tools such as interviews and/or checklists. A few studies have simulated work conditions and examined prolonged standing in laboratory settings. This research study used wireless sensor technology to measure biomechanical and physiological data during prolonged standing in food service workers during actual work operations. Previously, wireless wearable insoles have been used to analyze pressure parameters such as peak plantar pressure, shift in the center of pressure (COP) and the effect of heel wedges in distribution of plantar pressure and reaction force (Rose et al. 1992). While insole sensors have been used to study standing and walking (Orlin and McPoil, 2004 Shu et al. 2010), there is little literature regarding prolonged standing during work and the impact of fatigue on pressure parameters. The ability to collect pressure data from the foot during actual work operations may provide insight into the risks faced by food service workers and will help employers and workers better understand and manage those risks.

PROBLEM STATEMENT

The impact of prolonged standing, particularly in occupations requiring long work shifts, has been shown to cause significant musculoskeletal discomfort and disorder (King, 2002). While various methods have been used to measure fatigue during work, the ability to measure data from the foot during actual work operations could provide significant information to better understand the human factors and ergonomic risk factors of this job. Recent advances in technology, including insole wearable sensors, have allowed researchers to better study the impact of standing on posture and fatigue. This study used insole wearable sensors to investigate foot pressure and the impact of prolonged standing in food service workers during a typical shift. Muscle fatigue was assessed using a standardized questionnaire and energy expenditure was assessed using wireless physiological sensors.

RESEARCH OBJECTIVE/QUESTION

The purpose of this research was to examine the impact of prolonged standing on food service workers on musculoskeletal health.

METHODOLOGY

Participants Twenty food service workers (12 females and 8 males) with a minimum of two years' experience from Sodexo Canada Ltd were recruited to participate in this study (Table 1). The study protocol was approved by the University of New Brunswick Ethics Board. Of the 20 participants, 1 had incomplete data from the insole sensors and was not included in the data analysis.

Table 1 Mean participant anthropometric and grip strength (standard deviation)

	Males	Females	Both
Height (cm)	170.5 (11.9)	162.1 (6.9)	165.5 (9.9)
Weight (kg)	77.0 (16.4)	74.9 (17.7)	75.7 (16.8)
Age (years)	51 (8.9)	48.8 (11.8)	49.7 (10.5)
Grip Strength (KgW)	36.3 (9.8)	25.1 (5.0)	26.9 (9.3)

Instrumentation

A fatigue survey, Nordic questionnaire, activity tracker, and wearable insole sensor were the instruments used to observe fatigue in the food service workers. A modified fatigue survey (Chalder et al., 1993) consisting of 14 questions was used to measure the severity of fatigue. The scale rating used a binary scale to categorize fatigue and has been shown to be reliable and valid (Chalder et al., 1993). The Nordic Questionnaire (Kuorinka et al., 1997) was used to determine the musculoskeletal issues that a participant has experienced.

A smart watch activity tracker (Fitbit®Surge™, CA), was used to monitor heart rate, step count, blood pressure as well as other physiological markers including the number of sleep hours, stress level and athletic performance assessments. The chosen activity tracker was capable of providing continuous and automatic heart rate from the wrist and thus was appropriate for recording continuous physiological data during the work shift.

The workers were instrumented with insole wearable sensors in their footwear (LOGR™ RX, Orpyx®, Calgary, AB). The LOGR™ RX system is a mobile plantar pressure-monitoring platform that tracks and alerts pressure-induced damages such as neuropathic foot ulceration. The system collects pressure data at a sampling frequency of 100 Hz from the foot through a 1 mm thin specialized shoe insert and wirelessly send the information to the user via a smartwatch, IPhone, IPod, or IPad. Each insole has 8 pressure sensors that have a measurement range of 0 -75 PSI. The 8 pressure sensors are evenly distributed across the insole with two sensors located at the forefoot, three sensors at the metatarsal region, two sensors at the mid foot and one sensor at the heel.

A handgrip dynamometer (Takei Hand Grip Dynamometer, Japan) was used to measure whole body muscle strength.

Procedures.
Prior to data collection, the researchers presented an overview of the study to the food service workers at two different meal service locations on the university campus. Data collection took place during the participant's regular shift times at the meal halls from January to the end of March, 2017.

Prior to data collection participants were provided with an information letter, consent form and Nordic Questionnaire. Participants were asked to complete a fourteen-question survey regarding fatigue. Once the questionnaires were completed, participants were asked to perform a grip strength test using a handgrip dynamometer, both pre- and post-shift. The hand grip dynamometer measured grip strength in kilograms (kg) to the nearest 0.5 result. When possible, the results of the grip strength test were read by the same researcher to increase consistency in the measurements. The grip strength of each participant was recorded and a paired t-test was used to examine differences pre and post shift with an alpha level set to 0.05.

Upon completion of the handgrip strength test, participants were instrumented with the insole sensors and activity tracker. Each participant was provided insole sensors for both feet according to their anthropometrics. They were then asked to wear the activity tracker. Participants were asked to keep the activity tracker on their non-dominant hand and above the wrist at all times. The participants were asked to carry the IPod in their pockets so that it maintained the Bluetooth connection. An IPod was chosen as it supported the Orpyx logR application and was lighter than a phone or tablet. The researchers started and stopped the data recording on the application, so that the participants were simply required to carry it on them.

Once the participant was instrumented with the sensors, they were asked to begin their shift as usual. Each worker completed four hours of work with a 15-minute break. The activity tracker monitored heart rate while the insole sensors monitored some foot pressure parameters throughout the work shift. Data was collected pre and post shift (approximately 4 hours).
Due to individual variation in rest times, the insole sensor data was trimmed to eliminate the rest period during the four hour shift. The reduced data was analyzed for significant changes in the peak plantar pressure, center of pressure (COP) and ground reaction force over the four-hour shift. Three time points, each of 15 minutes interval was selected from the trimmed data: start, mid and end. The values were calculated in each interval and tabulated for all the participants. This provided an indication of the pressure changes over time. Repeated measures ANOVA was used to analyze the differences in the peak plantar pressure, COP and

ground reaction force between the three time points, beginning of shift, mid-shift and at the end of the shift with the alpha level set to 0.05.
Energy expenditure was estimated in kJ/min from the data collected with the physical activity tracker similar to Keytel et al. (2005) as follows:

> *EE = gender × (−55.09069 + (0.6309 × HR) + (0.1988 × weight kg) + (0.2017 × age)) + (1 − gender) × (−20.4022 + (0.4472 × HR) − (0.1263 × weight kg) + (0.074 × age)). Where gender =1 for males and 0 for females.*

RESULTS

The questionnaire data showed mixed results. The modified fatigue survey found that all participants indicated no fatigue in response to the 14 questions. The results of the Nordic Questionnaire showed that two of the 20 participants had a record of lower back pain.
Paired t-test showed that there was no significant difference between the pre grip strength (M=29.5 kg, SD= 8.8 kg) and post grip strength (M=30 kg, SD=10.5 kg) for the right hand. Similar results were obtained for the left hand with a pre grip strength (M=29.4 kg, SD= 8.9 kg) and post grip strength (M=29.5 kg, SD=9 kg).
The average energy expenditure for the 4 hours period was 20.7 ± 7.6 KJ/min. The average energy expenditures of the male and female workers are 27.7 ± 6.3 KJ/min and 15.7 ± 3.6 KJ/min respectively.
No significant change in the peak plantar pressure in the start, mid and end time-points of the prolonged standing duration (see Figure 1). Seven of the eight sensors on the left foot and five of eight on the right foot showed a slight increase in the mean peak plantar pressure (averaged across all participants). Upon analyzing the COP values, 12 participants showed a COP shift towards the posterior-anterior direction in the left and right foot. 10 participants showed a COP shift in the left foot and 11 participants showed a COP shift in the right foot in the lateral aspect with the magnitude of change being very less. Also, there was no significant change in the ground reaction forces in either of the feet.

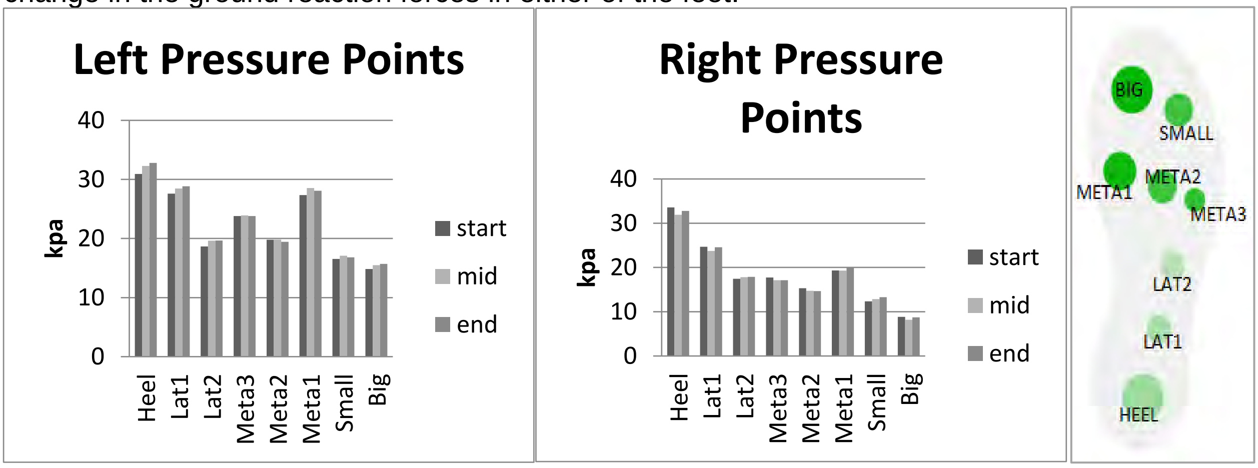

Figure 1 Mean values of peak plantar pressure (kilopascals) for all eight sensors in the left and right feet averaged across all participants. The picture on the right shows the sensors locations: big, small, metatarsal region 1, 2, and 3 (Meta1, Meta2, Meta3 resp.) lateral region 1 and 2 (Lat1, Lat2 resp.) and heel.

DISCUSSION

None of the participants reported fatigue in the questionnaire data. This is surprising given the nature of the work. It is possible that the participants underreported their symptoms.
The hand grip strength data showed no significant difference between the pre and post time-points, which indicated that prolonged standing didn't have a considerable fatigue effect on the upper body. Some significant changes might be expected had the working shifts being studied longer (8 hrs.).

For an 8-hour continuous work period, a physical work capacity limit of 5.2 Kcal/min (21.8 KJ/min) is recommended by (Garg, Chaffin& Herrin, 1978) for a young healthy male. The male workers' capacity is within the recommended capacity. The average energy expenditure was also found to be less than the recommended capacity limit but 4 participants individually exceeded the recommended capacity and are susceptible to fatigue before the end of their shift. As expected, the step counts of the general helps were seen higher than the cooks. It was also expected that the energy expenditure of the general helps to be higher than the cooks because more activities were performed by the general help. But that is not the case; the average metabolic rate of the cooks is 22.7 ± 9.9 KJ/min while the general help 20.1 ± 7.3 KJ/min. The continuous exposure to heat during cooking may have increased the metabolic rates of the cooks. The difference between the average energy expenditure of the first and last hours of the 4-hour data collection duration were determined. The result showed an increase in the energy expenditure of the workers in the morning session and a decrease in the energy expenditure of the workers in the afternoon session. This shows that time of the day may have a significant effect on work capacity. From the result obtained, if the two work session were combined to make an 8-hour shift, there is high chance of accumulating fatigue as the shift becomes longer.

The random shifts in the center of pressure show that the participants change their postures to adjust their center of Pressure (COP) possibly due to the presence of fatigue. Prolonged standing causes fatigue in the gastrocnemius and peroneus muscles which results in this shifting effect (Gefen et al 2002). The abnormality in the results shows that there is no fixed direction in shifting of COP; people shift their pressure on the feet in a direction of their convenience which might be a general indication of fatigue.
No significant changes were found across the time points in the peak plantar pressure data or in the ground reaction force. This was surprising given that the workers were standing for long periods of time. One of the limitations with the insole sensors used was the number of sensors. The insoles were limited to eight sensors distributed around the foot and therefore accuracy may be limited. In addition, the data was reduced to less than 4 hours in order to remove rest breaks. A longer data collection may provide more information regarding the foot kinematics. The lack of significant findings with the questionnaire and handgrip data with respect to fatigue may also be due to the instruments used. This study did not employ the use of surface electromyography (EMG), which has been used extensively to monitor muscle fatigue. Gefen et al. (2002) assessed muscular fatigue in the gastrocnemius and peroneus muscles in high-heeled walking trials using EMG sensors as well as plantar pressure sensors and correlated fatigue in these muscles to the medial/lateral instability of COP. As discussed earlier, a longer working shift (8 hrs.) might result in significant changes.

Four of the twenty participants showed energy expenditure levels higher than the recommended values. It is surprising that this was not reflected in the questionnaire data. It has recently been shown that the use of body maps can be helpful as indicators of physical pain for workers (Messing et al., 2008). Future work could employ the use of body maps to help workers identify pain. In addition, having focus groups with workers in this industry may help to provide a more conducive environment to share concerns regarding this workplace.

CONCLUSION

Prolonged standing work is common in many industries. It is important to understand the extent of the discomfort and fatigue to provide the employer with improved guidelines regarding work protocols as well as to consider how to best prepare workers. This study investigated the pre and post foot plantar pressure, energy expenditure, and hand grip strength of 20 food service workers to determine the presence of fatigue over a 4-hour work period. The questionnaire produced inconclusive information regarding the mental and physical fatigue of the participants. The results obtained showed that the workers worked within the recommended work capacity but may accumulate fatigue with a longer shift. The selected pressure parameters and force parameters showed no significant change at the pre and post shifts that could estimate the period when the participants experienced fatigue. There was no coordinated direction of the COP movement. These preliminary data with an addition of EMG data in a future study will provide valuable information regarding fatigue on workers with prolonged standing duties.

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MUSCULOSKELETAL DISCOMFORT AND RISK EXPOSURE IN BARISTAS

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KEYWORDS
Backpain, shoulder, wrist, strain, coffee-making, café.

SUMMATIVE STATEMENT
In the service industry worldwide, many thousands of small and medium enterprise cafes employ baristas to make espresso-style coffees. Musculoskeletal discomfort (MSD) risk exposures for the work activity of espresso style coffee-making and the job of baristaring in cafes were found to be moderate. MSD prevalences in baristas were highest for neck, shoulder and wrists.

Malaises musculosquelettiques et exposition aux risques chez les baristas

MOTS-CLÉS
Douleur au dos, épaules, poignets, tension, préparation de café, café

SOMMAIRE
Dans le secteur des services à l'échelle mondiale, il existe de nombreux cafés de petite ou moyenne taille qui embauchent des baristas pour préparer les espressos. Les risques d'exposition aux troubles musculosquelettiques (TMS) pour la préparation de ces types de café et les tâches des baristas se sont révélés modérés. La prévalence des TMS chez les baristas était plus élevée au niveau du cou, des épaules et des poignets.

PROBLEM STATEMENT
In the service industry worldwide, many thousands of small and medium enterprise cafes employ baristas to make even more thousands of espresso-style coffees. A barista’s work involves long periods of standing and quasi-static repetitive upper extremity actions, often at a fast pace with a high pressure to deliver promptly to customers. Anecdotally, baristas complain of musculoskeletal discomfort (MSD) for low back, shoulder and wrist associated with their work. These complaints fit with the expected consequences of the biomechanical strain and high speed of service provision associated with café style coffee-making. Apart from a single published study (Dainty et al., 2014), the extent (prevalence) of MSD and level of risk exposure associated coffee-making by baristas are unknown.

RESEARCH OBJECTIVE/QUESTION
This study examined the prevalence of musculoskeletal discomfort and of musculoskeletal risk exposure in baristas.

METHODOLOGY
The prevalence of MSD for the previous 12 months for neck, shoulders, arms, elbows, wrists/hands, upper back, lower back, hips/thighs/buttocks, knees, ankles/feet body regions was assessed using a modified Nordic musculoskeletal questionnaire (developed by the UK Health and safety Executive (2000) based on Dickinson et al., 1992) in 43 baristas within

one major café franchise of 30 coffee shops in New Zealand. The work task of coffee-making was evaluated with the Strain Index (SI) (Moore & Garg, 1995), with SI scores of <3 classified as ‘probably safe’, 3 -7 as ‘may place individual at increased risk of distal upper extremity disorders’, and >7 as ‘probably hazardous’. The job of ‘baristaring’ was evaluated using the Quick Exposure Check (QEC) (Li & Buckle, 1999), with total risk of exposure scores classified as low (<40%), moderate (40-49%), high (50-69%) or very high (>70%) (Brown & Li, 2003).

RESULTS

Body region MSD prevalences were 68% (neck), 70% (shoulders), 40% (arms), 28% (elbows), 73% (wrists/hands), 48% (upper back), 58% (lower back), 33% (hips/ thighs/ buttocks), 38% (knees) and 40% (ankles/feet). The mean SI score for coffee-making was 3.8. 40% of the baristas had a moderate QEC total risk of exposure score. 33% had a low score, 28% had a high score and 0% had very high score.

DISCUSSION

This study is the first to use the internationally accepted Nordic musculoskeletal questionnaire to examine MSD in baristas. High MSD prevalences for neck (68%), shoulders (70%) and wrists/hands (73%) fit well with the known work actions performed by baristas and differ from those reported previously by Dainty et al (2014) (44%, 68% and 41% respectively for lifetime MSD prevalences). The prevalence of MSD for the lower back (58%) was lower than previously reported by Dainty et al (2014) (73%). The SI and QEC MSD risk scores indicate that coffee-making and baristaring are work activities and jobs with a moderate risk of MSD.

CONCLUSIONS

MSD risk exposures for the work activity of espresso style coffee-making and the job of baristaring in cafes are moderate. MSD prevalences in baristas were highest for neck, shoulder and wrists.

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RAMP – A NEW TOOL FOR MSD RISK MANAGEMENT IN MANUAL HANDLING

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KEYWORDS
Risk assessment, method, dissemination, MOOC, training

SUMMATIVE STATEMENT
In this paper, the development of a new research-based risk management tool for manual handling, RAMP (*Risk Assessment and Management tool for Manual Handling Proactively*), is described, as well as the development of flexible online training on how to use and implement the tool.

RAMP : Un nouvel outil pour gérer les risques de tms liés à la manutention manuelle

MOTS-CLÉS
Évaluation des risques, méthode, diffusion, cours en ligne ouverts à tous (CLOT), formation

SOMMAIRE
La présente communication décrit comment un nouvel outil de gestion des risques fondé sur la recherche (RAMP : *Risk Assessment and Management tool for Manual Handling)* a été développé de même que la conception d'une formation en ligne souple pour utiliser l'outil et le mettre en application.

PROBLEM STATEMENT

Musculoskeletal disorders (MSDs) are still the most common occupational injuries in the European Union (Schneider & Irastorza, 2010). Manual handling work is regarded as one of the main causes of work related MSDs. Further, the prevalence of MSDs in industries with a large amount of manual handling, such as the manufacturing industry, is high (SWEA, 2016). Several MSD risk assessment tools have been developed, but they have been found to have insufficiencies in managing MSD risks for manual handling. The insufficiencies include that tools only assess certain body parts or certain types of work, are not freely accessible, assess exposure but not risks, and do not support the whole risk management process (Nordander, 2006, Palm et al., 2014).

In 2009, a call from a global company identified a need for a research-based, freely accessible, risk assessment and risk management tool. The tool should support systematic risk management of MSD risks in manual handling and to be used by companies themselves. To meet this call the development of the RAMP tool (*Risk Assessment and Management tool for Manual Handling Proactively)* was started. In addition, the development of relevant competence for users of the tool was discussed.

RESEARCH OBJECTIVE

The main objective of the research and development project was to develop a freely available computer-based MSD risk management tool for manual handling operations (RAMP). It should be possible for companies to use the RAMP tool themselves and it should support the whole systematic MSD risk management process, from identifying risks to managing them. Two additional aims were to find strategies for dissemination of the tool and ways to provide adequate training on how to use RAMP, preferably free of charge. In a wider perspective the aim of the project was to contribute to the decrease of work related MSDs.

METHODOLOGY

Throughout the project a participative methodology was used and the tool was iteratively developed in close co-operation between researchers and practitioners at companies. First a needs analysis was carried out (Rose et al., 2011), followed by a literature study (Lind et al., submitted manuscript; Lind et al., manuscript). Prototypes of the RAMP tool were developed and tested iteratively, taking into account the feed-back from the users involved in the project.

The development of the tool was based mainly on research publications, e.g. Snook & Ciriello (1991), Takala et al. (2010), Sluiter et al. (2001) and Potvin (2012), standards e.g. ISO 11228-3 (ISO, 2007), legislation, such as AFS 1998:1 (SWEA, 1998), and to some extent other risk assessment methods, e.g. the NIOSH lifting equation (Waters et al., 1993) and expert assessments by the project´s expert group (consisting of researchers and ergonomists), but also on user testing and feed-back from practitioners and experts in industry and a reference group (including representatives from the parties on the labour market, the Swedish Work Environment Authority and from some of the participating companies). In all, over 250 research publications were used as a base for the tool and over 80 practitioners participated in the development process. In addition, evaluations of prototypes/early versions of parts of the tool have been carried out, mainly regarding usability and reliability (e.g. Sandahl, 2013; Lind & Rose, 2016).

The digitalized version of the tool, as well as a user's manual were also developed iteratively, considering feed-back from test users, who applied the RAMP tool on real cases.

Dissemination of the tool was discussed with several stakeholders. e.g. the main funder of the project, AFA Insurance, and within the project´s reference group. Here questions such as how to find a stable platform and a reliable organisation to secure long-term availability of the tool were in focus.

As a separate project the development of RAMP-courses was initiated, to provide users with adequate training on how to use and implement RAMP in practice. To enable flexible scalable learning suitable for professional development across companies and nations the Massive Open Online Course (MOOC) format was chosen. The MOOC-format supports the idea of free and available learning resources regarding RAMP, as well as offering exams and professional certificates to validate and assure adequate use of RAMP. To utilize the MOOC potential, the courses are developed using a multi-disciplinary collaborative-model for instructional design in online learning; including content experts, media producers and educationalists (McGrath et al, 2017). Following the collaborative MOOC-design model, the training material will be pre-tested before course launch. The instructional design of the MOOCs is based on learning theories stressing the importance of continuous assessment and feedback as important drivers for motivation and learning, as well as authenticity and meaningful learning (e.g. Manninen, 2014; Lee et. al., 2016).

RESULTS

The development has resulted in a new risk assessment and risk management tool, RAMP. It consists of four modules: The checklist-based RAMP I for screening of MSD risks, the

RAMP II module which enables a more in depth risk assessment, the Results module for visualisation and communication of the results, and the Action module, supporting the development of risk reducing measures and systematic risk management. Several evaluations of the different modules and on different versions of prototypes of the RAMP tool were performed. For example in an evaluation among 20 ergonomists 90 % or more agreed that the tool shows clear results and over 80 % agreed that the tool is usable as a decision base (Lind & Rose, 2016).

The development also resulted in a digitalized version of the RAMP tool, which is available via a homepage from KTH Royal Institute of Technology (ramp.proj.kth.se). It can be downloaded free of charge, which enables free dissemination.

In addition, a series of three Massive Open Online Courses (MOOCs) about the RAMP tool are being developed. The courses are built around authentic situations of manual handling at different workplaces to facilitate learning of various risk assessments. All four RAMP modules will be included in the courses that will be accessible via the edX platform from the fall 2017 and run for several months, which makes it possible for individuals to learn about RAMP in their own pace. At the same time, the courses enable companies to enhance knowledge among groups of employees who can study together. Offering RAMP training via MOOCs also provides learning analytics for formative feedback and further course improvements.

At the ACE-ODAM 2017 conference the RAMP tool use will be demonstrated and user experiences from applying RAMP will be shared. In addition to the presentation described in this conference paper, a workshop on RAMP will be held at the ACE-ODAM 2017 conference.

DISCUSSION

In this conference paper the development of the new risk assessment and risk management tool RAMP has been described, as well as the training offered via accessible online courses; MOOCs, providing automated assessments and feedback.

Compared to several other risk assessment tools, e.g. RULA (McAtamney & Corlett, 1993) and the NIOSH lifting equation (Waters et al., 1993) the RAMP tool enables assessment of a wide range of risk factors, considered relevant for developing MSDs.

Four user groups for the RAMP tool have been identified in the project: People at functions who *i*) carry out physical ergonomics risk assessments today, *ii*) are responsible for production and are dependent on good working environments and *iii*) are responsible for the work environment and *iv*) are decision makers in companies.

The digitalized RAMP tool including all four modules (RAMP I, RAMP II, the Results module and the Action module) was made officially available in May 2017 and users have just started using it. Therefore, evaluations of its relevance to industrial companies, implementation effects, et cetera will take some time. Results from several evaluations are in the publication process for the time being e.g. on the tools reliability and usability. We encourage others to perform evaluations of the tool as well. One sign of the RAMP tool´s relevance is that one of the participating companies, Scania, a global automotive industrial company, has decided to and started to use RAMP as their global standard for managing MSD risks in manual handling jobs.

Several studies on the RAMP tool are planned, e.g. a longitudinal study including validity aspects, and another regarding the package of Massive Open Online Courses (accessible with the start during the autumn 2017) on disseminating knowledge and training.

At the conference, it will be discussed how freely accessible methods such as RAMP, can be spread after the research and development project is finished. Another question is how to secure updates in the future for methods which do not bring any profit for the developers/owners.

CONCLUSIONS

It is concluded that the research and development project briefly described here resulted in RAMP, a research-based new tool for risk assessment and risk management of MSD risks in manual handling. It is freely available via KTH's homepage (ramp.proj.kth.se). Evaluations of some aspects of the RAMP tool are in the publication process. Published evaluations support that the tool is usable for risk assessment of manual handling.

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PRELIMINARY RESULTS ON THE EFFECTS OF SEAT PARAMETERS ON SEAT CONTACT FORCE AND DISCOMFORT

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KEYWORDS
Seat design, Discomfort, Contact force, Shear force, Pressure distribution

SUMMATIVE STATEMENT
Current sitting discomfort research has predominantly examined existing manufactured seats: limiting the ability to fully evaluate the effects of seat parameters on seat contact force and sitting discomfort.

Résultats préliminaires de l’incidence des paramètres du siège sur la force de contact et l’inconfort

MOTS-CLÉS
Conception de siège, inconfort, force de contact, force de cisaillement, répartition de la pression

SOMMAIRE
La présente recherche sur l'inconfort des sièges a principalement examiné des sièges déjà fabriqués, ce qui limite la possibilité de bien évaluer l'incidence des paramètres du siège sur la force de contact et l'inconfort.

PROBLEM STATEMENT

Pressure and shear force on the seat contact surface has been suggested to have an effect on sitting discomfort (Reed et al. 2000). More specifically, the higher peak pressure found on the seat pan, the more prevalence the sitter will report discomfort. The surface area between the ischii and the skin surface is only a few centimeters when in a seated position, as the gluteal muscles are pulled to the side of the ischial tuberosities (ITs) (Reed et al. 2000). Pressure caused by the ITs on the seat surface contact has been linked with: 1) distortion of microcirculation under the ITs (Zhang, 1994); 2) deep tissue deformation/stress adjacent to the ITs (Linder-Ganz and Gefen, 2008); and 3) potential neuropathy due to sciatic nerve proximity (Güvençer et al, 2008). Literature investigating pressure distribution has predominantly reported normal force on the contact surface since pressure pads are the primary means of measurement. Shear force and its distribution are more challenging to measure, hence the limited literature on shear force related to sitting. The combination of shear forces and normal pressure leads to a reduction in blood flow and oxygen to the tissue (Goossens et al., 2000). To our knowledge, few researchers (Bush and Hubbard, 2007 and Hirao et al., 2006) have successfully measured shear force during a sitting task. These studies were limited to only investigating males, simulated vehicle seats and the experimental seats had limited range of adjustability. The effects of seat contact force on sitting discomfort are still not very well understood.

RESEARCH OBJECTIVE

The research objective was to investigate the association between contact forces, including shear force on the seat pan and sitting discomfort.

METHODOLOGY

Experimental seat

The experimental seat (Figure 1) used in this study was composed of four main structural components: the supporting frame (A), seat back frame (B), seat pan frame (C) and foot support (D). The backrest frame (B) articulated with the supporting frame (A) around a lateral axis (y-axis) passing through the reference point of the experimental seat, named PRC ('Point de Référence du Conformateur'). There were three movable panels fixed on the seat back frame (B), providing support on the lumbar, thoracic and neck region. Each panel could rotate freely and its position was controlled by two electric actuators. A uni-axial force sensor was mounted on the axis of each actuator, allowing force measurement on each panel in the xz plane. The position and orientation of the seat pan frame (C) in xz plane was controlled by three electric actuators attached to the main structure (A). The seat pan had a surface formed by a matrix of 52 cylinders (Figure 2); each cylinder had a disk head of 60mm in diameter and could freely rotate around its center. The vertical position of each cylinder (controlled by an electric actuator) had a stroke length of 40 mm. The contour of the seat pan was customized by imposing a coupling law that controlled the height of each cylinder. A force sensor was also mounted on the seat pan allowing the measurement of the global force in the xz plane. The foot support (D) had a rectangular surface with a width of 500 mm and a length of 600 mm. The foot support could move in both the x and z direction, controlled by two electric actuators. A uni-axial force sensor was mounted on the axis of each actuator, allowing the measurement of the force applied on the foot support in the xz plane. Two armrests (E) were fixed on the main structure (A) and their position and orientation was adjusted manually. A bi-axial force sensor was mounted on each armrest, allowing the measurement of force in the xz plane. A more detailed description can be found in Beurier et al (2017).

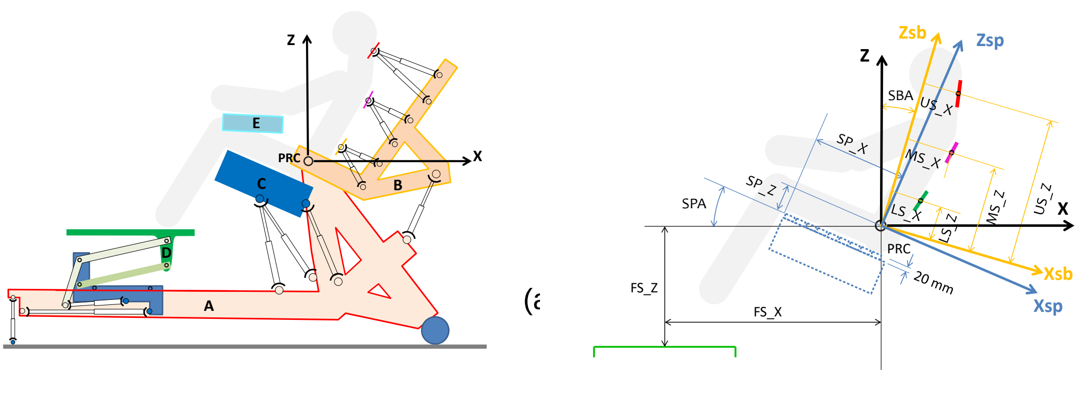
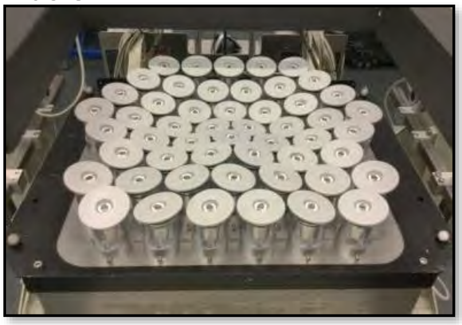


Figure 1. Main structure of the experimental seat (a) and definition of thirteen adjustable parameters and different coordinate systems (b). The global coordinate system (GCS) is defined with X being directed rearward parallel to the foot support surface, Z directed upward perpendicular to the foot support surfaceas follows. Its origin is located at the mid of the lateral axis Y (experimental reference point named PRC) which articulates the backrest frame (B) with the main supporting frame (A). Two local systems of coordinate (LCS) are defined from the global coordinate system (GCS), one attached to the seat back frame (B) after a rotation of seat back angle (SBA), another attached to the seat pan frame (C) after a rotation of seat pan angle (SPA).

Pressure distribution on the seat pan surface was controlled using a uniform coupling law relating normal force and position for each cylinder. The coupling law enabled us to distribute normal contact force as uniformly as possible among the 52 cylinders (given the maximum displacement of the cylinders). For a given normal contact force on the seat surface (F_n^{SP}), a target mean force ($\bar{F}_n^{SP}$) was estimated as F_n^{SP}/(0.75*52) considering that approximately ¼ of the seat surface was not in contact with the buttock or thighs. Each cylinder lowered its height once its contact force (F_n^i) was higher than $\bar{F}_n^{SP}$, while it maintains its position when $F_n^i \leq \bar{F}_n^{SP}$. The movement of the cylinders had a limitation of 40 mm in stroke length, therefore the force distribution depended on the initial height of the cylinders.

(a)



(b)

Figure 2. A participant sitting on the experimental seat (a) and the matrix of 52 cylinders (b)

Data Collection

Participants: Two groups of 18 participants (29.55+/-9.42yrs) were recruited for this study: The first group (A) were composed of 18 females, divided into 3 equal groups based on height: short [5 to 15%ile female (154-157cm)], average [50%ile female (164+/-2cm)] and tall [80 to 95%ile female (170-175cm)]. The second group (B) was composed of 18 males, divided into 3 equal groups based on height: short [5 to 15%ile male (168-171cm)]; average [50%ile male (178+/-2cm)]; and tall [80-95%ile male (185-190cm)]. Within each sub-group there were three participants with BMI's ranging between 18.5 and 25 and three participants with BMI's over 30, this was part of the selection criteria. Prior to commencing, participants were screened using a health screening form and those who experienced any back injury or pain in the previous 3-months were excluded from this study. This study was reviewed and approved by the ethics research committee at IFSTTAR ("Institut francais des sciences et technologies des transports, de l'aménagement et des réseaux"), and informed consent was obtained prior to experiment.

Discomfort rating: To monitor the participants' global perceived discomfort, the Category Partitioning Scale CP-50 (Shen and Parsons, 1997) was administered after each seated position. The discomfort rating categories included: No discomfort ("imperceptible"), very low discomfort ("inconfort tres faible"), very low discomfort ("inconfort faible"), Medium discomfort ("inconfort moyen"), high discomfort ("inconfort fort"), very high discomfort ("inconfort tres fort") and extreme discomfort ("inconfort extremement fort"). Once participants chose the category that represented their level of discomfort, they were instructed to choose a scale ranging between 1 and 10, with exception of "no discomfort" which equaled 0 and "extreme discomfort" which equaled the maximum score possible which could be higher than 10. Scores were then compiled to equal a score of 50, score higher than 50 means extreme discomfort.

Test conditions and procedure: Participants were instructed to sit in a total of 40 seat positions that simulated an economic airplane seat. The H-point location of an existing airplane seat was used to define the x position of the middle support with MS_X being fixed at 135mm, and the z position of the seat pan support with SP_Z=98 mm (Fig.1b). Two seat backrest angles (SBA) from the horizontal (SBA=100°, 110°) and three seat pan angles (SPA=0°, 5°, preferred) were used to define 6 different SPA/SBA combinations. For each combination, 5 conditions were tested in the following order:

1. *Reference position with the initial cylinder height of 20 mm (CH=20mm).* The reference position was used to determine seat pan length, foot support height and armrests position for each participant. The three backrest panels were positioned at specific anatomical points (occipital bone, T9 and L3). Panel position in the x-direction (protrusion) was fixed at 135 mm in the seat back LCS. The seat pan length (SP_X, Figure 1b) was fixed until there was approximately 70mm (hand width) of space between the popliteal (behind the knee) and the front of the seat pan. Participants were asked to keep their back in contact with the lower and middle supports. The foot support was adjusted (FS_Z, Figure 1b) until the knees were set at approximately 90 degrees. Participants were also asked to place a rectangular foam of 100 mm (in thickness) between the knees to reduce postural variation. The armrests were self-positioned by subjects. Once participants were fitted to the seat, they were instructed to step off the experimental seat to zero all the force sensors. Participants were then asked to reposition themselves back on the experimental seat and look forward without use of the upper support. Measurements were recorded at a rate of 20 Hz for 1.25 seconds. Subjects were then asked to rate their perceived discomfort using the CP50 questionnaire; CP50 scores were recorded for each tested conditions (N=40).
2. *Watching a movie with CH=20mm.* Participants were asked to re-place the 100mm foam between their knees and maintain a comfortable sitting position while looking forward. The uniform law was applied to distribute the seat contact force to the 52 cylinders. Once the pressure was distributed, the middle (T9) and lower (L3) supports needed to be repositioned. The level of lumbar protrusion (LS_X) was self-selected. Participants were required to remain in contact with the middle (thoracic) panel. Once the middle and lower back supports were appropriately positioned, participants were then instructed to step off the experimental seat to perform a complete zero of all the force sensors. Participants were then asked to reposition themselves back on the experimental seat and look forward without use of the upper support. Seat parameter and contact forces were then recorded.
3. *Relaxing with CH=20 mm.* Step 2 was repeated with the addition of the upper support. The upper support was positioned at the occipital bone and its protrusion was self-selected.
4. *Relaxing with CH=40mm.* Step 3 was repeated with now the cylinders set at a stroke height at 40mm.
5. *Watching a movie with CH=40mm*. Step 2 was repeated with now the cylinders set at a stroke height at 40mm.

The preferred SPA was self-selected by participants for the reference position and kept unchanged for the 4 other test conditions with a fixed backrest angle. The five test conditions of the combination with SPA=5° and BA=110° were repeated three times to measure intra individual variability. In total, 40 sitting positions were measured for each participant. The test order of six SPA/BA combinations was randomized.

Data Processing. The first step of data processing was to calculate the medians of the measurements of each trial. After eliminating all inconsistent trials, 1383 over 1440 (36 participants x 40 conditions) trials remained. The sum of the external forces applied to the body had to equal zero. Therefore, an inclusion criterion was set as the total sum of forces in the horizontal (X) and vertical (Z) had to be smaller than 11 and 25N. Also, all forces were normalized by body weight (F/weight*1000). To reduce the individual effects for discomfort scores (CP50), the average score was calculated for each participant, then the scores of the participants were centered relative to his/her average (CP50_C). The normal force distribution on the seat pan was characterized by the cylinder peak force (Fzmax) and the mean cylinder force (Fzm) over the cylinders in contact with the sitter.

This paper focuses only on the data from the specific task "Relaxed Position". Dependent variables included: discomfort (CP50_C), normal and shear force for each seat support surface (3 backrest panels, seat pan and foot support). Independent variables included: seat pan angle (SPA), seat back angle (SBA), and cylinder height (CH). A Univariate ANOVA with a Bonferroni correction was run on discomfort scores and a Multivariate ANOVA (alpha level set at 0.05) with a Bonferroni correction was run on all contact forces. Alpha level was set at 0.05. A Pearson correlation was also run to understand the relationships between the independent and dependent variables. All statistical analyses were done using IBM SPSS Statistics for Windows (Version 22.0. Armonk, NY).

RESULTS

Discomfort scores were significantly lower when SBA was set at 110° (-3.39(Mean)±0.43(SE)) versus 100° (-0.13±0.49) (*p*=.000*). Identical trends were found for CH (*p*=.000*) with discomfort scores lower at 40mm (-2.69±0.46) versus 20mm (-.82±0.46). No effect was found for SPA.

According to the correlation matrix, seat back angle (SBA) had the strongest correlation coefficient associated with discomfort (Table 2). A higher SBA led to lower discomfort scores. Note that significant coefficients with CP50_C were also found for cylinder height (CH), cylinder normal force distribution (Fzm, Fzmax), normal force on the middle support (Fn_MS) and tangential force on the lower support (Ft_LS).

Table 2. Correlation Matrix. Significant correlations are bolted and starred. Abbreviations are as followed: Seat Pan Angle (A_SP); Seat Back Angle (A_SB); Cylinder Height (CH); Normal Force applied on the lumbar support (Fn_LS) and middle support (Fn_MS); tangential force applied on the lumbar support (Ft_LS) and middle support (Ft_MS); Average (Fzm) and peak (Fzmax) normal force applied on the cylinders, and centered discomfort (CP50) scores. Fx_SP_L is the global seat pan force component parallel to the non-compressed flat seat pan surface in the symmetric plane (XZ).

	A_SP	A_SB	CH	Fn_LS	Fx_SP_L	Fn_MS	Ft_LS	CP50_C	Ft_MS	Fzm	Fzmax
A_SP	1	***0.116**	-0.007	***0.241**	*****0.682**	***0.186**	0.023	-0.058	-0.008	0.061	0.058
A_SB	***0.116**	1	0.004	0.078	***-0.190**	****0.407**	***-0.180**	***-0.263**	-0.074	***0.182**	0.095
CH	-0.007	0.004	1	0.040	-0.092	0.072	-0.071	***-0.123**	-0.022	*****0.548**	****0.436**
Fn_LS	***0.241**	0.078	0.040	1	***-0.190**	*****-0.502**	***-0.272**	-0.004	***0.264**	-0.024	0.043
Fx_SP_L	*****0.682**	***-0.190**	-0.092	***-0.190**	1	-0.093	0.022	0.099	-0.091	0.059	0.061
Fn_MS	***0.186**	****0.407**	0.072	*****-0.502**	-0.093	1	***0.264**	***-0.179**	***-0.295**	0.096	-0.002
Ft_LS	0.023	***-0.180**	-0.071	***-0.272**	0.022	***0.264**	1	***0.100**	-0.063	****-0.341**	****-0.408**
CP50_C	-0.058	***-0.263**	***-0.123**	-0.004	0.099	***-0.179**	***0.100**	1	-0.042	***-0.131**	***-0.168**
Ft_MS	-0.008	-0.074	-0.022	***0.264**	-0.091	***-0.295**	-0.063	-0.042	1	***-0.121**	-0.070
Fzm	0.061	***0.182**	*****0.548**	-0.024	0.059	0.096	****-0.341**	***-0.131**	***-0.121**	1	*****0.791**
Fzmax	0.058	0.095	****0.436**	0.043	0.061	-0.002	****-0.408**	***-0.168**	-0.070	*****0.791**	1

Determinant = .001

* Small Correlation Coefficient
** Medium Correlation Coefficient
***Large Correlation Coefficient

An increase in SBA led to an increase in shear force production on the seat pan (Fx_SP_L) (Table 3). When participants chose their own SPA, Fx_SP_L significantly decreased for both fixed SBA of 100° and 110°. Preferred SPAs were respectively 5.88 and 6.68° on average for SBA of 100° and 110°. An imposed SPA of 5° versus 0° significantly lowered Fx_SP_L.

By using the uniform control law of the cylinders' displacement, the normal force on the seat pan should be more evenly distributed on the cylinders with a higher stroke length. This was confirmed by the observation that both peak and mean cylinder forces significantly lowered with a stroke height of 40mm versus 20mm (Table 3). Also, changes in CH induced a small change in Fx_SP_L.

Table 3. Multivariate analysis of seat contact forces. Significant effects are bolted and starred. Alpha level was set at 0.05. The term “Pref” found in the table is an abbreviation for “preferred”, meaning participants had the freedom to choose their own SPA. All forces were normalized by body weight and multiplied by 1000.

	Fn_LS			Fx_SP_L			Fn_MS			Ft_LS			Ft_MS			Fzm			Fzmax		
SPA	**0°**	**5°**	**Pref**	**0°**	**5°**	**Pref**	**0°**	**5°**	**Pref**	**0°**	**5°**	**Pref**	**0°**	**5°**	**Pref**	**0°**	**5°**	**Pref**	**0°**	**5°**	**Pref**
Mean	37.2	44.3	49.9	-114.0	-68.5	-64.1	114.3	125.6	125.4	-13.7	-13.4	-12.8	-17.4	-17.4	-18.2	-18.5	-17.9	-18.0	-49.2	-47.2	-47.0
Std. Err	2.6	2.1	2.5	2.2	1.8	2.1	2.6	2.1	2.5	1.0	0.8	1.0	1.0	0.8	1.0	0.2	0.2	0.2	1.3	1.1	1.3
p-values Vs 0°		.096	***.001**		***.000**	***.000**		***.002**	***.008**		1.00	1.00		1.00	1.00		.084	.353		.754	.780
p-values 5° vs Pref			.273			.341			1.00			1.00			1.00			1.00			1.00
SBA	**100°**	**110°**		**100°**	**110°**		**100°**	**110°**		**100°**	**110°**		**100°**	**110°**		**100°**	**110°**		**100°**	**110°**	
Mean	41.9	45.7		-74.1	-90.4		108.4	135.1		-11.0	-15.7		-16.3	-19.0		-18.6	-17.6		-49.1	-46.5	
Std. Err	2.1	1.8		1.8	1.6		2.1	1.8		0.8	0.7		0.8	0.7		0.2	0.2		1.1	1.0	
p-values		.166			***.000**			***.000**			***.000**			***.018**			***.000**			.065	
CH	**20°**	**40°**		**20°**	**40°**		**20°**	**40°**		**20°**	**40°**		**20°**	**40°**		**20°**	**40°**		**20°**	**40°**	
Mean	42.9	44.7		-79.5	-84.9		119.2	124.3		-12.5	-14.1		-17.5	-17.9		-19.7	-16.5		-55.2	-40.4	
Std. Err	2.0	2.0		1.7	1.7		2.0	2.0		0.8	0.8		0.8	0.8		0.2	0.2		1.0	1.0	
p-values		.541			***.023**			.065			.122			.717			***.000**			***.000**	

DISCUSSION

The main observations can be summarized as follows:

- Discomfort was strongly associated with seat back angle (SBA). Discomfort scores significantly lowered when SBA increased to 110°. However, shear force on the seat pan significantly increased with a greater backrest angle.
- Participants preferred a greater inclination for seat pan for both seat back angles (BA=100°, 110°). Shear force applied on the seat pan was at its lowest when participants had the freedom to choose their own SPA compared to the two imposed seat pan angles (SPA=0° and 5°).
- Discomfort was also significantly affected by initial cylinder height (CH). An increase in cylinder stroke length led to lower normal peak and average force applied on the cylinders suggesting that normal contact force on the seat pan was more evenly distributed.

Our results support that pressure distribution on the seat pan is a viable objective measure for quantifying discomfort. A lower peak force on the cylinders was associated with a lower discomfort score. Discomfort scores were significantly lower when participants used a greater backrest angle. This supports the recommendation by Harrison et al’s (2000) that the backrest angle should be set at a position so that thigh-trunk angle is at least 105°. However, a greater backrest angle leads to higher shear force production on the seat pan. Significantly, it was found that the lowest shear force on the seat pan was obtained when participants self-selected their own seat pan angle; seat pan shear force is also an objective measure for quantifying discomfort.

CONCLUSIONS

Relationship patterns were found between seat parameters, contact force and discomfort. These findings provide preliminary results on the relationship patterns found between perceived discomfort and seat contact forces while performing a specific sitting task. Future research will determine how contact force should be distributed throughout the seat to improve passenger comfort while performing different tasks.

ACKNOWLEDGEMENTS
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THE EFFECT OF BIT WEAR ON HANDLE VIBRATION AND PRODUCTIVITY DURING CONCRETE DRILLING

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KEYWORDS
Hand arm vibration syndrome; tool design; construction; musculoskeletal disorders

SUMMATIVE STATEMENT
This hammer drill test bench study showed a small but significant increase in z-axis handle vibration and exposure time with worn concrete bits when compared to a new bit. Drill bit manufactures may consider advising contractors that worn bits will increase the exposure of workers to hand vibration and will reduce worker productivity. Construction contractors should consider adopting bit replacement programs based on bit wear patterns or cumulative bit usage.

Les conséquences de l’usure de la mèche sur les vibrations de la poignée et la productivité au cours de tâches de perçage du béton

MOTS-CLÉS
Syndrome vibratoire main-bras, conception d'outil, construction, troubles musculosquelettiques

SOMMAIRE
Cette étude portant sur des essais de perceuse a démontré une augmentation légère, mais non négligeable, de la vibration de la poignée au niveau de l’axe z et du temps d'exposition lorsqu’on utilisait une mèche à pierre usée comparativement à une mèche neuve. Les fabricants de mèches pourraient ainsi informer les entrepreneurs que les mèches usées augmentent l'exposition aux vibrations des mains chez les travailleurs et réduisent leur productivité. Les entrepreneurs en construction devraient envisager d'adopter des programmes de remplacement de mèches en fonction des caractéristiques d'usure ou de l'usage cumulatif..

PROBLEM STATEMENT
The use of large electric hammer drills and pneumatic drills exposes construction workers to high levels of hand vibration that may lead to hand arm vibration syndrome and other musculoskeletal disorders.

RESEARCH OBJECTIVE/QUESTION
The aim of this study was to investigate the effect of bit wear on drill handle vibration and drilling productivity (e.g., drilling time per hole).

METHODOLOGY
A laboratory test bench system was used with an 8.3 kg electric hammer drill and 1.9 cm diameter concrete bit (a typical drill and bit used in commercial construction) (Figure 1). The system automatically advanced the active drill into aged concrete block under feed force control to a depth of 7.5 cm while handle vibration was measured according to ISO

standards (ISO 5349 and 28927). Bits were worn to 4 levels by consecutive hole drilling to 4 cumulative drilling depths: 0, 1900, 5700 and 7600 cm (Figure 2) [Antonucci et al. in press].

FIGURE 1. Test bench system with hammer drill secured to 6-axis load cell with grips on the handle. This assembly is pushed on a lathe bed by the linear actuator under the mannequin. The concrete blocks are advanced automatically and secured with a linear actuator during drilling.

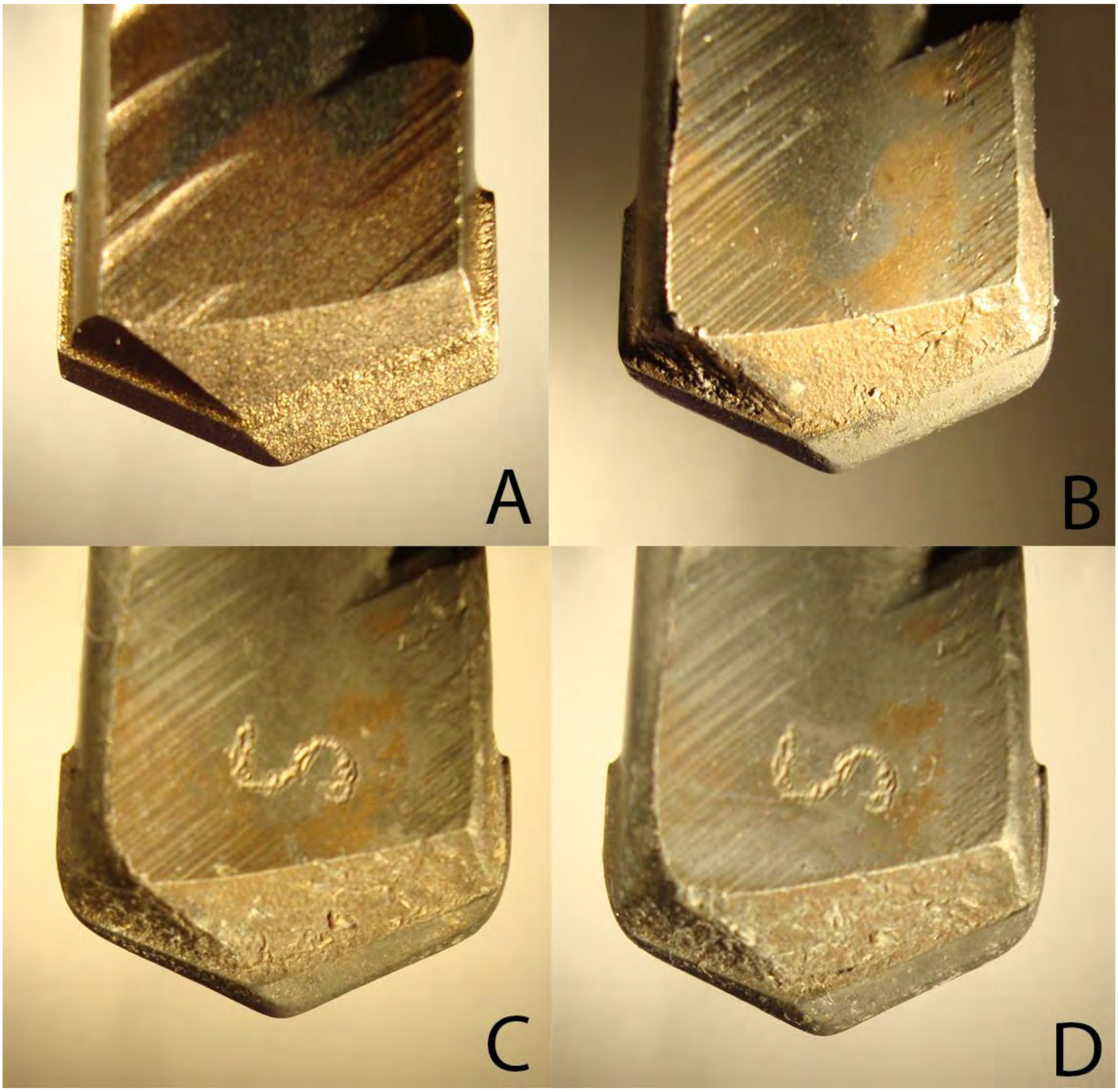

FIGURE 2. The four levels of bit wear were (A) new bit, (B) 1900 cm, (C) 5700 cm, and (D) 7600 cm of cumulative depth drilled.

RESULTS

Z-axis handle vibration increased significantly ($p<0.05$) from 4.8 to 5.1 m/s^2 (ISO weighted) and from 42.7 to 47.6 m/s^2 (unweighted) when comparing a new bit to a bit worn to 1900 cm of cumulative drilling depth. Handle vibration did not increase further with bits worn more than 1900 cm of cumulative drilling depth. Neither x- nor y- axis handle vibration was affected by bit wear. The time to drill a hole increased by 58% for the bit with 5700 cm of cumulative drilling depth compared to a new bit.

DISCUSSION

Bit wear led to a small but significant increase in both ISO weighted and unweighted z-axis handle vibration. Perhaps more important, bit wear had a large effect on productivity. The effect on productivity will influence a worker's allowable daily drilling time if exposure to drill handle vibration is near the ACGIH Threshold Limit Value for Hand-Arm Vibration.

CONCLUSIONS

Construction contractors should implement a bit replacement program based on these findings. The decision about bit replacement should be guided by the condition of the bit tip (e.g., width and wear of cutting blades [Botti et al., in press]. Construction workers who use hammer drills should be trained on the hazards of drill handle vibration, noise, and dust exposure and methods of reducing exposures to these hazards (e.g., work methods, exposure time, personal protective equipment) [Carty et al., in press]. Bit replacement programs and other safety interventions should be promoted by unions, trade associations and drill and bit manufacturers.

ACKNOWLEDGEMENTS

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Technical Session 3: Physical Ergonomics 2

Séance technique 3: Ergonomie physique 2

REACH ENVELOPE AND RANGE OF MOTION DIFFERENCES WITH TOTAL ROTATOR CUFF TEARS

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SUMMATIVE STATEMENT: Persons with total rotator cuff tears have reduced range of motion and reach envelope capabilities, particularly with respect to horizontal and vertical motions at the periphery of the reach envelope. Ergonomic accommodations for an individual can be made to allow for potential return to work and assistance with activities of daily living if the limitations are known.

Les différences sur le plan de la sphère d'atteinte et de l'amplitude du mouvement dans les déchirures complètes de la coiffe des rotateurs

SOMMAIRE : Les personnes manifestant une déchirure complète de la coiffe des rotateurs ont une moins grande amplitute de mouvement et une moins grande sphère d'atteinte, notamment sur le plan des mouvements horizontaux et verticaux à la péripherie de l'enveloppe articulaire. Des adaptations ergonomiques peuvent être effectuées pour ces personnes pour favoriser un retour au travail éventuel et faciliter les activités quotidiennes lorsque les restrictions sont connues.

PROBLEM STATEMENT: To quantify the differences in reach envelope and range of motion (ROM) between asymptomatic age-matched participants and participants with full rotator cuff tears (RCT) under 3 load conditions.

RESEARCH OBJECTIVE / QUESTION: Quantify the difference between ROM measures extracted from reach envelope measures and clinical ROM values. To develop simple tools to translate clinical and research measures to end users.

INTRODUCTION: Human reach envelope, as defined by Konz (Konz, Goel 1969) is the area (volume) in which a seated or standing human can reach while performing a task. Execution of the maximum reach is performed with the trunk stable and the upper limb fully extended, thus shoulder mobility and function are key determinates of the motion. Typically reach and the reach envelope have been examined by collecting empirical data or by creating mathematical models. Researchers know there are many intrinsic (body shape, segment length and range of motion) and extrinsic (clothing, body position and types of restraints) factors that can impact reach (Stoudt 1973, Sengupta, Das 1998). The shape and volume of the reach envelope also depends on the shoulder and elbow range of motion which may be impacted with the presence of an injury or disease. However, there is little empirical evidence of the impact of shoulder injuries on the reach envelope and if the reach may be regained following a surgical intervention. Similarly, there has been very few studies that attempt to relate the MRE to clinical measures of shoulder ROM.

A crossover between ergonomics and health research occurs when creating work accommodations for injured persons. Rotator cuff tears are the most prevalent shoulder injury accounting for 40% of all shoulder injuries, (Jaeger, Izadpanah et al. 2014) and prevalence increases with age. Rotator cuff injuries, particularly full tears or ruptures of one or more of the 4 SITS muscles (Supraspinatus, Infraspinatus, Teres minor and Subscapularis) lead to severe pain, decreased mobility and loss of strength.

The objective for this paper is to quantify differences in range of motion and reach envelope (ROM) between asymptomatic, age-matched to participants with participants with full rotator cuff tears (RCT) while performing the MRE measures under 3 load conditions. In addition, methods for data reduction and knowledge translation of these data will begin to be explored.

METHODOLOGY: Reach envelope data has been collected from 8 seated, asymptomatic participants and 6 participants with total RCT using the Computerised Potentiometric System for Anthropometric Measures (CPSAM) (Das, Kozey et al. 1994). Each participant completed 2 side and 2 front facing trials for each of 3 handheld load conditions; no load, 0.5kg and 1.0kg. Trials were 45 seconds at a collection rate of 20Hz, yielding 3800 data points following the protocol described by Johnston et al (Johnston, Dewis et al. 2016). Due to the effect of the shoulder injury, in some cases the data collection methods were varied for the symptomatic participants. Typically this was accommodated by providing more, shorter duration trials with longer rest periods between trials.

Raw voltage data was processed using custom designed Matlab code to translate to 3-D Cartesian coordinates, and to combine front and side facing trials. The 3-D Cartesian values were translated to an origin at the acromion and expressed in both cylindrical and spherical coordinates. This volume space was then panelled into 54 reach panels in cylindrical coordinates (6 z levels and 9 θ bands), and spherical coordinates with (6 φ bands and 9 θ bands, see Figure 1). All data points within each panel were used to calculate a median reach vector. In addition the total counts (occurrences of reach) and the standard deviation of these were calculated.

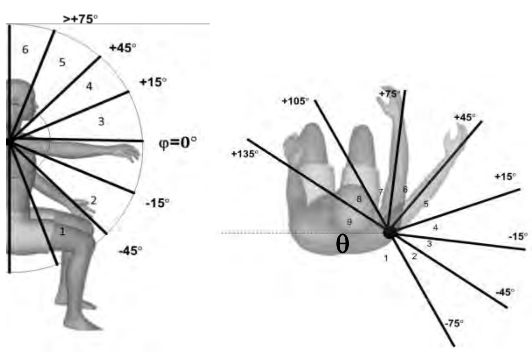

Figure 2a: Cylindrical Coordinate (Theta and Z-Level)

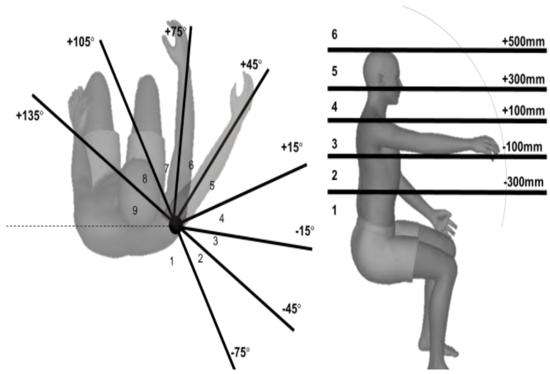

Figure 1b: Spherical Coordinates (Phi and Theta)

Clinical ROM values (flexion/ extension, internal/external rotation, ad/abduction) were collected using a goniometer (Lafayette Instrument Co. Model 01135), utilizing standard clinical assessment methods. Active ROM values for ab/adduction, flexion/ extension and horizontal flexion/ extension were calculated using the Cartesian coordinate values from the reach envelope data. These were calculated using the maximal and minimal points +/- 100mm of either direction of the acromion in each plane, then using tangents to find arm angles. These values were imported into Minitab for statistical comparisons including descriptive statistics and because the values were not normally distributed, a Mood's Median test was used for all comparisons.

A method of dissemination of the reaching results both for individual participants as well as groups was developed using a novel mapping process. Using the maximal reach vectors, a mapping system was developed to compare the reach profiles. In this case, a score of 1 was given to the case where a participant reached into the associated panel limited by Z and theta. The panel counts were then tallied within each group to create gray scaled maps useful for the dissemination to participants and clinicians.

RESULTS: ROM values for asymptomatic participants are consistently greater than their symptomatic cohort (Table 1). These differences were significantly different[1] between the asymptomatic and symptomatic groups for active flexion (p=0.048), CPSAM flexion (p=0.048), active abduction (p=0.048), passive abduction (p=0.002), and passive external rotation (p=0.048).

Table 2: Range of Motion Means (Standard Deviation)

Angular Measures (degrees)	Asymptomatic	Symptomatic
Active Flexion [1,2]	174 (7)	140 (36)
CPSAM Flexion[1]	140 (36)	89 (30)
Passive Flexion	176 (5)	158 (6)
Active Abduction[1, 2]	170 (16)	111 (37)
CPSAM Abduction	138 (25)	112 (22)
Passive Abduction[1]	168 (12)	130 (13)
Passive External Rotation[1]	83 (15)	57 (12)
Passive Internal Rotation	55 (17)	50 (15)
CPSAM Horizontal Flexion	196 (20)	165 (21)

Comparing between the methods of collecting ROM values, there are significant differences[2] between the active flexion and CSPAM flexion values (p=.006) but not between active and CPSAM abduction values (p=0.239).

Figure 2 presents an example of the colour maps developed for simple dissemination of the results. In this case a darker panel means more subjects were able to reach to the panel. It can be seen that RCT participants have trouble reaching to the panels which form the outer borders of the reach envelope, specifically when reaching across their body, and above shoulder height. As load increases (as shown for the 0.5kg and 1.0Kg conditions in Figures 3 and 4) extension capabilities diminish as does the ability to reach across the body. This effect is more pronounced in the symptomatic group.

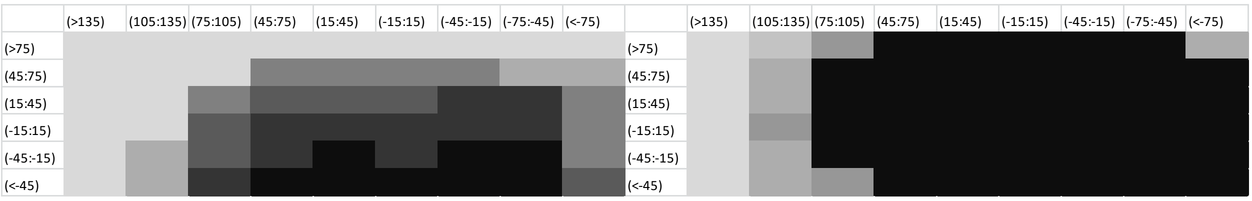

Figure 3: Colour Maps of Symptomatic Participants (Left) versus Asymptomatic Participants (Right) in Cylindrical Coordinates with 0.0kg load

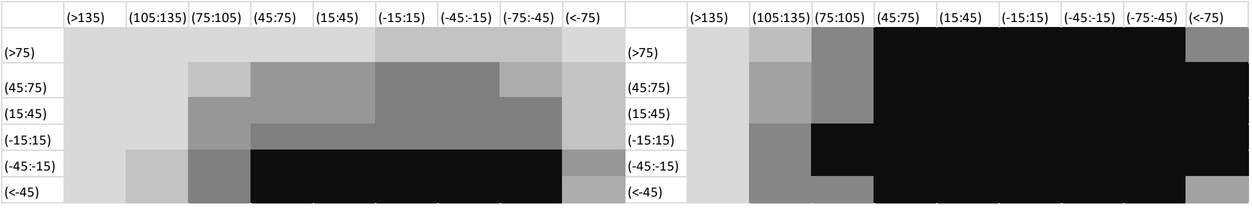

Figure 4: Colour Maps of Symptomatic Participants (Left) versus Asymptomatic Participants (Right) in Cylindrical Coordinates with 0.5kg load

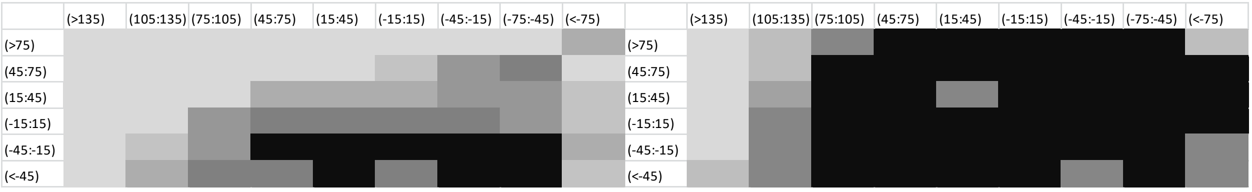

Figure 5: Colour Maps of Symptomatic Participants (Left) versus Asymptomatic Participants (Right) in Cylindrical Coordinates with 1.0kg load

DISCUSSION: The symptomatic group can be seen to have a smaller reach envelope than the asymptomatic group, and these differences become amplified as handheld weight is added. Participants were encouraged to paint the outer boundaries of their reach for the first portion of each trial to maximize volume collected, as well as monitoring to ensure full internal coverage, and researchers monitored the movement to help ensure all areas were filled, however symptomatic participants may guard themselves against pain during prolonged dynamic movement, by not pushing themselves to a place they expect to hurt (Hall, Duncan et al. 2014, Podlog, Eklund 2005, Johnston, Carroll 1998).

Statistical differences between the 2 groups were found in several ROM measures with active/passive flexion and CPSAM abduction bordering on significance. It is hypothesised that with more participants, differences between the 2 groups will become more pronounced and increase significance.

Some of the differences between the active/passive ROM values and values pulled from the MRE may be explained by participants guarding, from the participant directed movement that is captured while using CPSAM leaving gaps, or be an indicator that dynamic range of motion varies from static. With respect to ergonomics, knowing a person with RCT cannot perform extension with handheld load allows for accommodations to be made.

These differences in MRE and ROM between RCT and asymptomatic participants highlight the need for creating accommodations for persons with RCT, particularly as this will impact activities of daily living.

Colour maps are an initial method to reduce the data, and create a visual tool for comparisons of reach volume of groups. These could be expanded to having maps for the comparison of individuals to the group means to track MRE improvement over time

Future work will continue looking at meaningful data reduction methods, ways to display the change in arm length throughout the reach volume, as well as methods to predict where a particular subject would be able to reach. Additionally, potential ergonomic accommodations for both activities of daily living and workplace will be explored.

CONCLUSIONS: There are differences between reach and ROM capabilities of persons with RCT and asymptomatic, with a reduction in range of motion capabilities being reflected in a reduced reach envelope. Accommodations for both workplace and ADL may be required to allow an injured person to maintain functionality, particularly when reaching in across the body and above the head.

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DESIGNING A PRACTICAL ASSESSMENT TOOL BASED ON A DUTY CYCLE EQUATION CALCULATING MAXIMUM ACCEPTABLE EFFORTS ACROSS MULTIPLE SUBTASKS

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KEYWORDS
Assessment, duty cycle, equation, maximum acceptable effort, ergonomics

MAIN MESSAGE
A duty cycle-based equation, for predicting maximum acceptable efforts (MAE) for repetitive tasks, was transformed into a practical tool to assess multiple tasks and used across a multinational manufacturing company. The tool's ability to evaluate the cumulative effect of subtasks has empowered operations teams to effectively confirm standard work instructions, ergonomics job mapping, job rotation planning, equipment design and continuous improvement efforts that collaboratively support the company's drive for world class operations.

Conception d'un outil d'évaluation pratique reposant sur une Équation de cycle de travail en vue de calculer les efforts acceptables de tâches multiples

MOTS-CLÉS
Évaluation, cycle de travail, équation, effort maximal acceptable, ergonomie

MESSAGE PRINCIPAL
Une équation basée sur le cycle de travail, visant à prédire l'effort maximal acceptable (MAE) pour les tâches répétitives, a été transformée en outil pratique pour évaluer des tâches multiples dans l'ensemble d'une multinationale du secteur de la fabrication. La capacité de l'outil à évaluer l'effet cumulatif des sous-tâches a permis aux équipes chargées des opérations de confirmer efficacement les consignes de travail courantes, la cartographie ergonomique des emplois, la planification de la rotation des tâches, la conception de l'équipement et les efforts d'amélioration continue qui appuient collectivement la volonté de l'entreprise à détenir des opérations de calibre mondial.

PROBLEM

Cooper Standard was in need of a quantitative method to practically evaluate the cumulative effect of discrete job tasks performed repeatedly over the course of a work shift. Moreover, this method needed to be sensitive to small job improvements so the company's operations leadership could measure improvement to ergonomics acceptability across thousands of industrial job tasks.

CONTEXT

The majority of ergonomics assessment tools available to industry either evaluate jobs against defined threshold limit values and/or evaluate single static or dynamic tasks. Such tools, although reasonably practical, are limited in ability to compute the cumulative effect of combined individual efforts across multiple job tasks, for multiple body segments, especially when attempting to include frequency and effort duration factors.

ACTIONS

The Potvin MAE equation was modified to calculate a time-weighted average of efforts to the fourth exponent, to better account for fatigue effects of each effort from multiple subtasks. The total duration of efforts was used to determine the duty cycle of this composite effort, and compared to the MAE for that duty cycle. This cumulative MAE was combined with biomechanical modeling of working posture scenarios and computer programmed into a user friendly electronic system.

Table 1: Computing a body segment score

Score	cMVC/cMAE	Comparison of cMVC to cMAE
cMAE	*1-(Overall Duty cycle- [1/28800]$^{0.24}$*	Composite Maximum Acceptable Effort
Overall duty cycle	$\frac{\sum Effort\ Duration}{Cycle\ Time}$	Sum of effort exertion duration over cycle time
Effort duration	∑Task Duration	Time of effort application
Cycle time	Unit of time	Time to complete one unit or piece. Constant defined by production schedule.
cMVC	$\left(\frac{\sum Effort\ Impulse}{Effort\ Duration}\right)^{1/4.167}$	Composite effort %MVC (maximum voluntary contraction)
Effort Impulse	($MVC^{4.167}$)(Task Duration)	Result of each joint effort action
MVC	Percent value from lookup table of function given based on joint, posture, force/load	Maximum voluntary contraction (strength requirement of effort for task)
Task Duration	Unit of time	Exposure time to effort for task (MVC)

OUTCOMES

The tool computes cumulative acceptable effort scores for eight body segments based on each job task effort requirements. A user friendly interface enables simple data input entry removing complex, manually intensive computations from the user. Job scores can be generated providing objective ergonomics job assessment data for operations, safety and management teams.

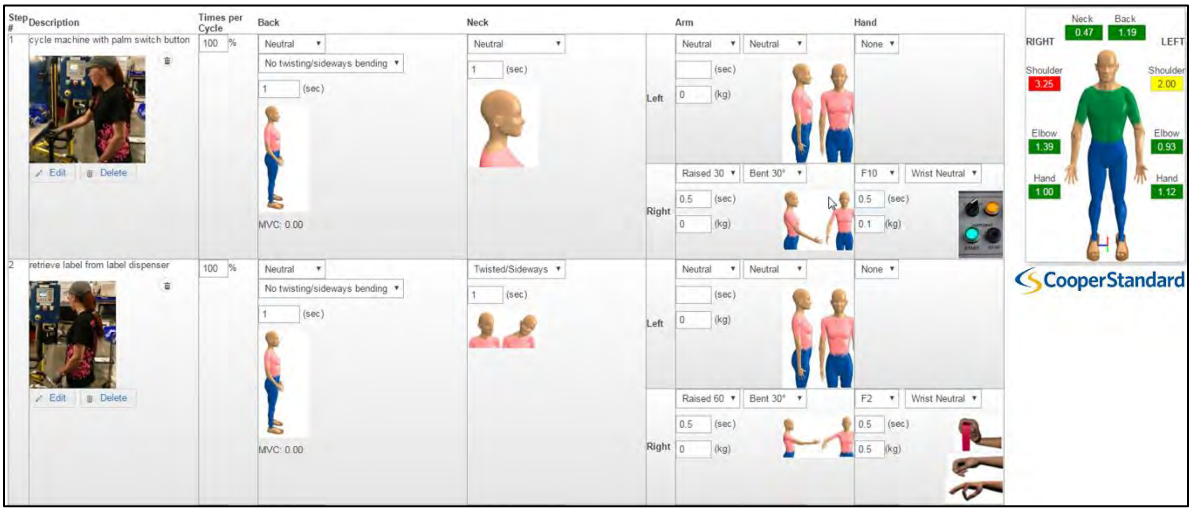

Figure 1: Assessment tool user interface

DISCUSSION
The assessment tool acts as the primary indicator of ergonomics acceptability of job design and human performance capability. Manufacturing operations adoption was possible because of its universally designed, user friendly interface and is based on emerging leading peer reviewed scientific research.

CONCLUSION
Practitioners seeking to bring emerging ergonomics research into workplace application should: (a) partner with researchers to fully understand the scientific models and (b) apply both macro and micro ergonomics approaches to the design of the desired outcome, while maintaining intent on optimal practicality and usability.

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IS THERE A RELATIONSHIP BETWEEN LOW BACK PAIN AND SIT-TO-STAND WORKSTATION USAGE?

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KEYWORDS
Sit-stand; Low Back Pain; Standing; Workstation;

SUMMATIVE STATEMENT
The Active Hip Abduction Test (AHABD) can determine if an individual is likely or unlikely to generate low back pain (LBP) during prolonged standing. In a field study, the AHABD test was performed on a group of adults involved in a longitudinal study designed to assess the influence of pain status and education program on usage of sit-stand workstations (SSW). Results from the current study show a relationship between susceptibility of generating LBP while prolonged standing and the use of SSWs.

Existe-t-il un lien entre la lombalgie et l'utilisation d'un poste de travail assis-debout

MOTS CLÉS
Assis-debout, lombalgie, station debout, poste de travail

SOMMAIRE
Le test d'abduction active de la hanche (AHABD) peut déterminer s’il est probable ou peu probable qu’une personne manifeste de la lombalgie en station debout prolongée. Dans le cadre d’une étude sur le terrain, le test AHABD a été effectué auprès d’un groupe d'adultes participant à une étude longitudinale qui vise à évaluer l'influence du niveau de douleur et des programmes d'éducation sur l'utilisation des postes de travail assis-debout. Les résultats de l'étude actuelle montrent un lien entre la possibilité d'avoir mal au bas du dos en demeurant debout pendant une longue période et l’utilisation d’un poste de travail assis-debout.

PROBLEM STATEMENT
Generally, over time some people who have SSWs use the functionality of their workstation less often over time or not very frequently when they first receive it. There is little research to explain this behaviour or the role that low back pain may play.

RESEARCH OBJECTIVE/QUESTION
Does likelihood of developing low back pain while standing influence an individual’s sit-stand behaviour with a height adjustable workstation?

METHODOLOGY
Thirty-five adults between the ages of 23 and 64 were recruited from a research centre to assess the influence of education/training program on the long-term usage of SSWs. Participants were divided into 1 of 2 groups based on their job tasks, age and sex. A Baseline period was collected as participants worked at their original non-height adjustable workstations before they participated in an educational program and received their SSWs. Both groups received an initial training program that was an example of what is currently

taught in industry. The one group then received an additional session that focused on transitioning between sitting and standing, and proper sitting and standing techniques. These two groups participated in the remainder of the of the study: only industry example (IE) and current best practice (RE). The first four weeks after the training sessions represented the Intervention phase of the study. During this time, those in the group who received the additional training program also received weekly meetings from the experimenter to answer any questions that the participants had regarding their workstation as well as daily reminders to rotate between sitting and standing in a 1:1 ratio. These meetings were stopped for the subsequent four weeks as this time acted as the Post-Intervention phase.

Prior to the beginning of the study, all participants completed the AHABD test. The AHABD test was designed by Nelson-Wong and colleagues (2009) as a tool to aid in the identification of low back pain developers in response to occupational tasks that require standing for prolonged periods of time (Nelson-Wong, Flynn, & Callaghan 2009). During this test, participants are instructed to “Keep your knee straight and raise your top thigh and leg towards the ceiling, keeping them in line with your body, and try not to let your pelvis tip forwards or backwards” (Nelson-Wong, Flynn, & Callaghan 2009, pg 650). After the completion of the test on both legs, participants were scored based on the AHABD scoring criteria (*Table 3: Scoring cues for the examiner to assign a score to each leg of a participant who completes the Active Hip Abduction Test.*Table 3). A score of two or higher, was used to classify participants as likely to develop LBP while standing for prolonged periods of time and will therefore classify participants as a positive “P” test (Nelson-Wong, Flynn, & Callaghan, 2009). A score of 0 or 1 categorized participants as a having a negative test “N”. These participants were deemed “unlikely” to develop LBP while standing.

Table 3: Scoring cues for the examiner to assign a score to each leg of a participant who completes the Active Hip Abduction Test.

Test score assigned to each lower limb	Cues for Examiner (M. Riddell)
0 = No loss of pelvis frontal plane	- Participant smoothly and easily performs the movement. - Lower extremities, pelvis, trunk and shoulders remain aligned in the frontal plane.
1 = Minimal loss of pelvis frontal plane	- Participant may demonstrate a slight wobble at initiation of the movement, but quickly regains control. - Movement may be performed with noticeable effort or with a slight ratcheting of the moving limb.
2 = Moderate loss of pelvis frontal plane	- Participant has a noticeable wobble, tipping of the pelvis, rotation of the shoulders or trunk, hip flexion, and/or internal rotation of the abducting limb. - Movement may be performed too rapidly, and participant may or may not be able to regain control of the movement once it has been lost.
3 = Severe loss of pelvis frontal plane	- Participant demonstrates the same patterns as in a test score of 2, with greater severity. - Participant is unable to regain control of the movement and may have to use a

	hand or arm on the table to maintain balance.

Desk transitions from sitting to standing were tracked using tri-axial data logging accelerometers that were securely mounted to each participants' desk (Gulf coast solutions, Waveland, Mississippi). Differences between the number of positive scorers on the AHABD test in each group (RE and IE) at the beginning and as study progressed were analyzed using McNemar and Fisher's Exact tests. Data were analyzed using a three-way general linear model with between factors of education group and AHABD status and a within factor of time.

RESULTS

At the beginning of the study, there was no difference in the number of positive scores on the AHABD test between the IE (10) and RE (12) groups (*p*=0.4578). At the end of the three-month period, there was a difference in the number of positive scorers for those in the RE group (4) (*p*=0.0215) but not the IE (5) group (*p*=0.2188).

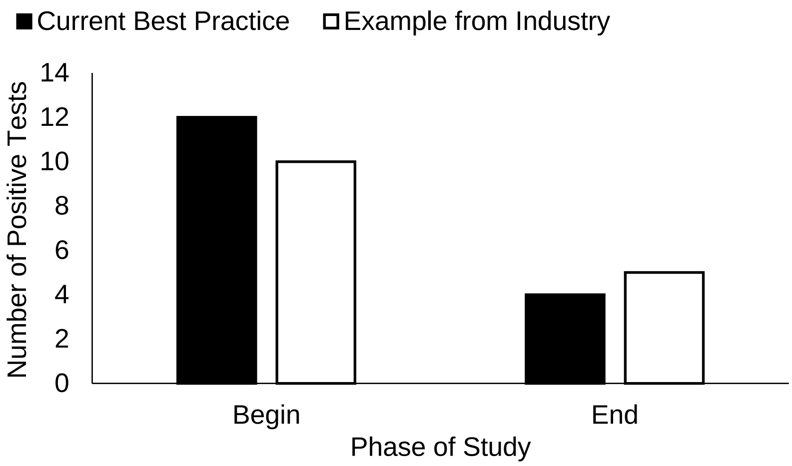

Figure 6: Number of positive AHABD tests at the beginning and end of the study.

There was a three-way interaction between group, time, and AHABD status (*p*=0.0262). In the initial four-week period after receiving their SSW workstation (Intervention phase), those in the RE group who scored positive on the AHABD test transitioned between sitting and standing more frequently (6.8) than those who scored negatively on the AHABD test (6.1). The opposite was true for those trained only with the example from industry training with positive scorers moving 2.6 times and negative moving 3.6 times a day. In the Post-Intervention phase, those who scored negative consistently moved more frequently (6.3 (RE) and 3.3 (IE)) than those who scored positive (5.1 (RE) and 2.2 (IE)) on the AHABD test.

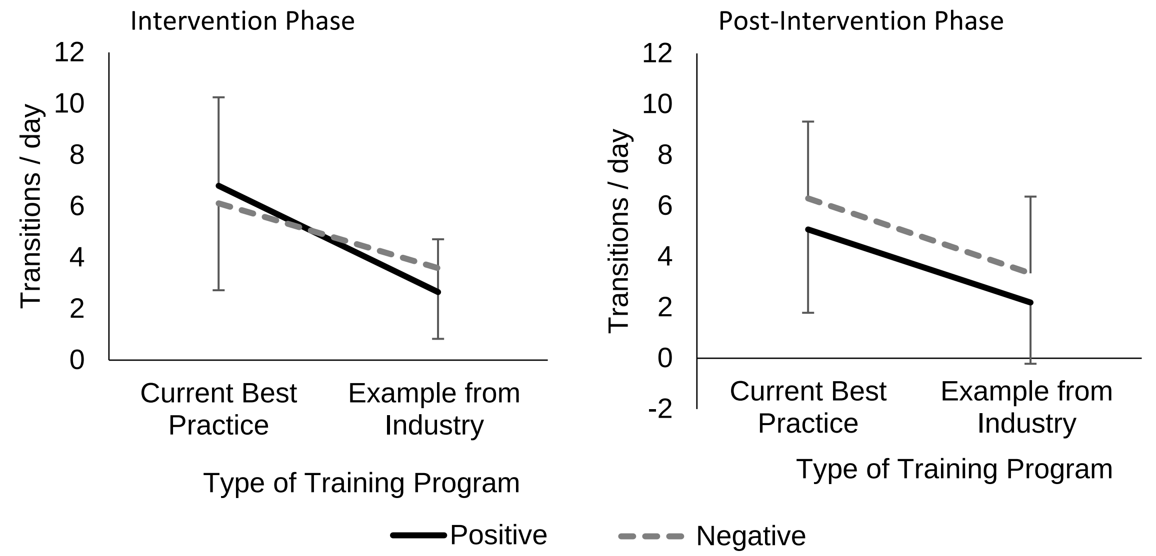

Figure 7: Frequency of sit-stand transitions in the Intervention and Post-Intervention phase of the study.

DISCUSSION

Although participants were not randomized into groups by the outcome of their AHABD test, there was not a significant difference in the number of positive scorers in each group. It was expected that the number of participants who would score positive on the AHABD test would be roughly equal between groups. This aligns with previous work that states approximately 40-70% of the population will develop low back pain as a result of prolonged standing (Marshall, Patel, & Callaghan, 2011; Nelson-Wong & Callaghan, 2010; Raftry & Marshall, 2012).

A study conducted by Nelson-Wong and Callaghan (2010a) showed improvements in pain scores in response to a four-week long intervention program which focused on strengthening trunk musculature. Participants in the RE group of the current study showed improvements in the AHABD scores at the end of the study whereas those in the IE group did not. This change may have been brought about by increased standing and frequent postural breaks from sitting and standing. Previous work has shown that erect standing postures are more active than slumped sitting (Sullivan et al., 2002). Assuming participants sit in a “slumped” seated posture for the majority of the day, standing may have allowed for greater use of trunk musculature. Over a period of two months this may have allowed participants to increase trunk musculature control which could have resulted in a change in AHABD scores.

The number of sit-stand transitions per day made by participants of the current study, may have been influenced by the susceptibility of generating LBP as categorized by score on the AHABD test. Both positive and negative scorers on the AHABD test in the RE group transitioned at a higher frequency than those in the IE group. In the RE group, positive scorers dropped from 6.8 (±3.5) transitions a day in Intervention to 5.1 (±3.3) times in Post-Intervention. Those in the RE group in the Intervention phase of the study would have been receiving weekly meetings with M. Riddell which may have prompted those who would have otherwise avoided standing (due to the risk of pain development) to stand. When these weekly meetings stopped in the Post-Intervention phase individuals did not transition between sitting and standing as much. This may be because they are actively avoiding the amount of their day that they spend in standing (their “pain developing posture”). For those in the group who only received the industry example of training, those who scored positive on the AHABD test transitioned approximately one time fewer/day in both the Intervention and Post-Intervention phases. Overall, those who scored negative on the AHABD test (and categorized as unlikely to generate LBP during a prolonged bout of standing) transitioned more frequently each day than those who scored positive. This is true for both groups.

CONCLUSIONS

There is an influence of individual's score on the AHABD test and their usage of SSWs and reports of LBP. Future steps should be taken to ensure that the relationship between LBP and the use of SSWs is understood and considered when implementing height adjustable workstations for individuals with potential LBP in response to prolonged standing.

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SENSITIVITY ANALYSIS OF BRAKING DECELERATIONS ACROSS DIFFERENT SPEEDS AND BRAKING STRATEGIES

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KEYWORDS
Braking, deceleration, whole-body vibration, shock

MAIN MESSAGE
Braking strategy has the greatest effect on deceleration exposures when driving (maximum vs normal). Speed from which braking begins has a substantially lesser effect (20 MPH vs 5 MPH). Both effects are significant across vehicle types (sedan and truck).

Analyse de sensibilité de décélérations de freinage à diverses vitesses et au moyen de différentes stratégies de freinage

MOTS-CLÉS
Freinage, décélération, vibration globale du corps, choc

MESSAGE PRINCIPAL
Une stratégie de freinage a le plus d'effet sur les expositions de décélération lors de la conduite (maximum versus normal). La vitesse à partir de laquelle le freinage commence a un effet considérablement moindre (20 mi/h versus 5 mi/h). Les deux effets sont significatifs sur les types de véhicules (berline et camion).

PROBLEM
Deceleration exposures can now be quantified, recorded, and stored in on-vehicle devices, which do so on an on-going basis—as a function of time. This can provide the user of such technology with information regarding traffic incidents that may occur with the vehicle and the vehicle's driver and passenger(s). This technology also includes video of the driver and road conditions, an example of which is the DriveCam® event recorder technology, shown in Figure 1. Figure 1 also shows how the DriveCam® technology records and displays for/aft and lateral accelerations/decelerations in real time.

We undertook this study to provide common-life exposure information with which comparisons can be made to better understand the significance of deceleration exposures measured and recorded by devices like the DriveCam® video and event recorder.

Figure1: An example of the DriveCam® technology with for/aft and lateral acceleration/deceleration data and video of the operator and road conditions

CONTEXT
Page Engineering is an industrial engineering and ergonomics consulting firm. We performed the testing at a local community college's parking lot where are test conditions could best be controlled.

ACTIONS
We measured the peak and average decelerations under four driving speeds, two vehicles and two braking strategies in a complete factorial design—general linear model. We tested braking from 5, 10, 15, and 20 mph to a complete stop; two different vehicles, a Chevy Tahoe and an Acura RSX; and two braking strategies, a hard or maximum braking strategy and a common-sense, "normal" braking strategy. Each test condition was repeated three times. The test conditions were performed by a single test driver.

Average and peak accelerations were measured in the fore/aft direction following generally accepted standards for measuring shock and whole-body vibration. (ISO 2631-1, 1997), (ANSI S3.18, 2002).

The acceleration/deceleration data was collected using a Biometrics DataLog® data acquisition device. The DataLog® system uses a multimedia card to store data as it is collected in real time. Two 10G tri-axial accelerometers were used with the DataLog®. One of the 10G triaxial accelerometers was placed inside a seat pad and positioned directly below the test subject's ischial tuberosities. The seat pad was affixed to the seat pan using duct tape. The other 10G triaxial accelerometer was affixed to the frame of the vehicle directly beneath the occupant's seat using a magnetic mounting plate. The 10G tri-axial accelerometers were set to record vibration data in the range of 0-100Hz. The sampling rate was set to 500 Hz.

Software developed by Biometrics Ltd. was used to collect and interpret the acceleration raw data. Seat pad accelerations were compared to acceleration results on the frame. Significant variations in the acceleration recorded by the two accelerometers could indicate the presence of occupant-induced motion, which is known as an artifact. (Cooperrider & Gordon, 2008), (DiFore et al., 2011). Video observation was used to confirm that the event was the result of an artifact or due to the motion of the vehicle. Some examples of artifact include seat ingress/egress or other significant movements such as repositioning one's self on the seat. The acceleration data was processed using Vibration Analysis Tool Set (VATS)™ software, developed by NexGen Ergonomics, Inc. Statistical analyses were conducted using DataDesk.

OUTCOMES

Braking method had a statistically significant effect on, both, average and peak acceleration, with maximum braking effort generating higher Gs. Speed also had a significant effect on, both, average and peak accelerations, with the slowest speed (5 mph) being significantly lower than the other three speed conditions tested. However, the effect was not as large as the effect of braking strategy. See Figures 2 and 3, below. Vehicle type had a statistically significant effect on, both average and peak accelerations with the Acura RSX being significantly higher than the Chevy Tahoe across test conditions.

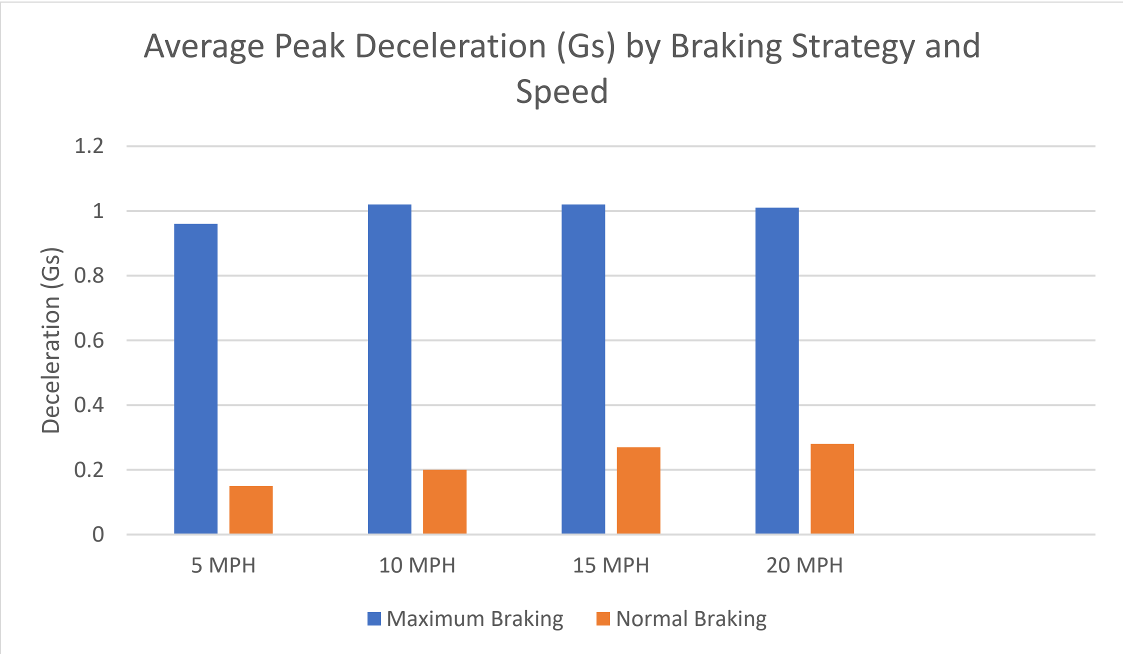

Figure 2: G-forces by braking speed and braking strategy for the Chevy Tahoe

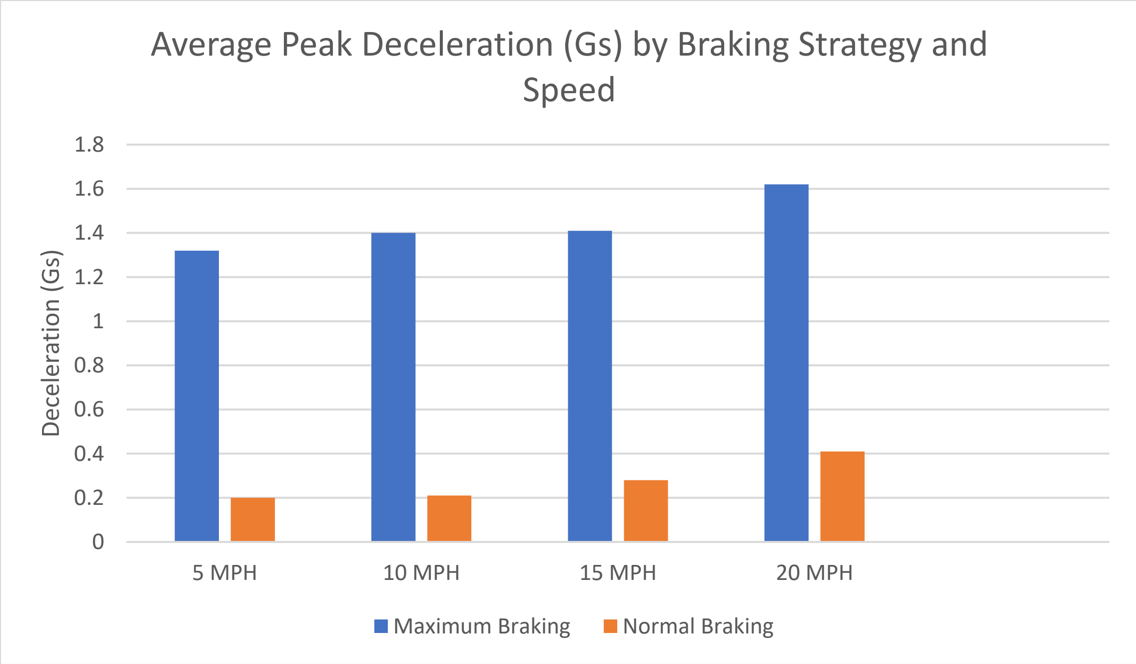

Figure 3: G-forces by braking speed and braking strategy for the Acura RSX

DISCUSSION

Braking method or strategy had a noticeable effect on deceleration. Compared to the effect of speed, braking method had a substantially larger effect, independent of the effect of speed. This suggests that the driver has significant control over deceleration during a braking event by the way in which the brakes are applied, independent of the speed of travel (within the range tested: 5 MPH to 20 MPH).

CONCLUSION

Our results can be compared with the findings of on-board vehicle video event recorders, such as the DriveCam® to provide context. Moreover, our results can also be compared with for/aft braking deceleration studies performed in laboratory environments that provide an understanding of injury risk. (Szabo, et al., (1994).

Future studies could investigate the effects of specific vehicle suspensions and possible interactions between vehicle size (e.g., weight) and suspension types. Further studies could also assess a higher range of speeds.

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RISK OF DEVELOPING MUSCULOSKELETAL DISORDERS IN A CHICKEN SLAUGHTERHOUSE

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KEYWORDS
UL-WMSDs, Poultry slaughterhouse, Risk assessment, Ergonomics, OCRA

SUMMATIVE STATEMENT
Poultry processing tasks predispose workers to a greater probability of developing upper limb work-related musculoskeletal disorders. Simulations of reducing the working pace demonstrate the effectiveness of this organizational measure to reduce the risk of UL-WMSDs.

Les risques d’apparition de troubles musculosquelettiques dans un abattoir de poulets

MOTS-CLÉS
TMS des membres supérieurs, abattoir de poulets, évaluation des risques, ergonomie, OCRA

SOMMAIRE
Les tâches de transformation de la volaille prédisposent les travailleurs à une plus grande probabilité de manifester des TMS des membres supérieurs. Des simulations de réduction du rythme de travail démontrent l'efficacité de cette mesure organisationnelle afin de réduire les risques de TMS des membres supérieurs.

PROBLEM STATEMENT
Brazil is the largest exporter of chicken meat since 2004 (ABPA, 2016). Most Brazilian chicken meat exported is in the form of cuts (57.7%), and the remainder consists of processed meat (5.5%), salted meat (4.2%), and whole chicken (32.6%) (ABPA, 2016). Thus, most of the chicken meat produced in Brazil is processed by means of hand tools (knives) or specific machines (chainsaws). However, improvements in the working conditions in this sector have not grown at the same rate as production growth (Sardá et al., 2009). The slaughterhouse workers are exposed to biomechanical risk factors for development of work-related musculoskeletal disorders of the upper limbs (UL-WMSDs) such as repetitiveness, high-frequency of technical actions, excessive force, awkward postures, insufficient time for recovery, use of tools and exposure to cold (OSHA, 2013). Thus, it is necessary to monitor the risks associated with repetitive movements of the upper limbs in meat processing tasks.

RESEARCH OBJECTIVE/QUESTION
The aim of this study was to evaluate the risks associated with repetitive movements of the upper limbs in different meat processing tasks in a poultry slaughterhouse, using the checklist OCRA.

METHODOLOGY
The local Ethics Committee in Research with Human Beings, in accordance with the Helsinki Declaration, approved this study. The study was conducted in a poultry slaughterhouse with

3,500 workers in which 350,000 chickens were hovered daily, divided into two shifts. In order to evaluate the risks associated with repetitive movements of the upper limbs, 10 % of the workforce was evaluated while carrying out their work tasks, using the checklist proposed by OCRA method (Colombini & Occhipinti, 2006; Occhipinti et al., 2000). Descriptive statistics was used, as well the Student t-test (SPSS 17.0) was used to compare the risk between the sides of the workers' body ($p \leq 0.05$).

RESULTS

The 15 work activities analyzed were the following sectors: cutting (7); packing (3); freezing tunnels (2); reception (1) and scalding (2). The average of occupational repetitive actions performed by poultry workers was 64.7±13.3 per minute, representing 9 points in the OCRA's scale (0 to 10 points scale). The average score of OCRA's checklist was 19.5±2.5 (moderate risk). The scores for the right upper limb (20.0±3.0 -moderate risk) were significantly higher ($p=0.024$) than the contralateral limb (17.7±2.8 -moderate risk). Considering the five risk categories proposed by the OCRA method, one work task was considered high risk (7%) and 14 were within a moderate risk (93%).

DISCUSSION

Due to predominant highly repeatable movements of the upper limbs in poultry slaughterhouses (Sundstrup et al., 2014), and previous studies suggesting the reduction in working pace to prevent UL-WMSDs (Reis, Reis & Moro, 2015; Reis et al., 2015, 2016), simulations of reduced working pace to achieve very low risk levels utilizing the OCRA checklist were performed. Through simulations, in all activities it was possible to reduce the risk of UL-WMSDs to very low levels, only reducing the working pace (-48.5±11.8%). Reis et al. (2015, 2016) also carried out simulations aiming to lower the risk for UL-WMSDs in poultry slaughterhouses. When the pace was reduced to -42.1±14.5% and -38.8±13.3%, very low risk levels were achieved for most of the activities analyzed (24/26 and 20/22, respectively), with the exception of those activities requiring significant force exertion.

CONCLUSIONS

From these results, it is possible to suggest that poultry processing tasks classified as high (7%) and moderate risk (93%) predispose workers to a greater probability of developing upper limb work-related musculoskeletal disorders (>21.5% probability for high risk and 10.8 to 21.5% for moderate risk). Simulations of reducing the working pace showed the effectiveness of this organizational measure to reduce the risk of UL-WMSDs.

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Technical Session 4: Macroergonomics & Management

Séance technique 4: Macroergonomie et gestion

ORGANIZATIONAL FACTORS IN FAILURE TO FOLLOW PROCEDURES EVENTS

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KEYWORDS
Keyword 1 to 5 go here

SUMMATIVE STATEMENT
The incidence of Failure to Follow Procedures (FFP) events continues to be a major issue. This project used literature and incident databases to show that many of the problems arise from organizational issues.

Les facteurs organisationnels dans les activités liées au non-respect des procédures

SOMMAIRE
La fréquence des activités liées au non-respect des procédures demeure un problème majeur. Le présent projet repose sur la documentation et les bases de données d'incidents consultées afin de démontrer que bon nombre de ces problèmes découlent de problèmes organisationnels.

PROBLEM STATEMENT
The objective was to provide industry with effective good practices to ensure that where procedures are meant to be used, they are indeed followed correctly. This research also addresses whether existing data bases and the technical literature on FFP incidents can provide useable patterns of FFP incidents, potential contributing factors and potential good practices for industry. The aspect reported here is how organizational factors contribute to FFP events, and which organizational good practices are likely to be effective in prevention.

RESEARCH OBJECTIVE/QUESTION
Procedures, and specifically maintenance procedures, occur in many enterprises, from nuclear power plants through offshore oil rigs to biological laboratories. In aviation maintenance, written procedures control essentially all activities, specifically by adhering to the Code of Federal Regulations (CFRs) Part 14, Section 43.13(a). The industry and regulators have placed great faith in these procedures to ensure that steps do not get missed and users (mechanics, inspectors) have a clear indication of what has to be done to complete each maintenance task. Mostly, this faith is justified: tasks are typically completed successfully by following the procedures. However, as Drury and Johnson (2013) noted, “Procedure not followed re-occurs with depressing regularity in incident and accident reports in aviation”. The current project was undertaken to get beneath the use of “Failure to Follow Procedures” (FFP) as a cause of incidents, to find the deeper causes of FFP events.

While much of the Human Factors literature on aviation concentrates on the flight deck crew and the air traffic controllers (Wise, Garland and Hopkins, 2010), there has been considerable study of the Human Factors/Ergonomics (HFE) aspects of the maintenance domain, largely starting with the Aloha Flight 243 incident in 1988 (e.g. Drury, 2010). Maintenance tasks can be routine, where they are expected and planned for, or non-routine, where the condition of the aircraft at the time forces a maintenance event. In either case, the Maintenance Planning group issues a procedure called a Task Card to cover the work required, usually a self-contained short document where the steps are enumerated, required data (e.g. tire pressures) given and a sign-off is demanded for each step. In the early years of HFE involvement, these procedures were particularly poorly written (Patel, Drury and Lofgren, 1994), but there have been some advances since that time, including the use of laptop computers, tablets and smartphones to present the procedure to the user. Good HFE design of procedures has been found to reduce or eliminate errors (Drury, 1998). When the aircraft mechanic (Aircraft Maintenance Technician, or AMT) completes the procedure, the work is often examined by an independent Inspector in what is known as a Buy-Back inspection before the aircraft can be returned to service. The task steps of all concerned are quite rigidly controlled by the maintenance organization and the regulatory authority (e.g. Federal Aviation Administration), particularly for their certification and training, as well as to ensure completeness of all required sign-offs.

The process of writing procedure documents starts from the aircraft or component manufacturer, who uses drawings and specification to devise the set of steps required, then (most of the time) validates the procedure before publishing it. This procedure becomes the basis for the actual maintenance procedure when it has been modified by the maintenance organization to suit their way of working. The procedure may then be further modified in use from user feedback or planned optimization, as shown in Figure 1.

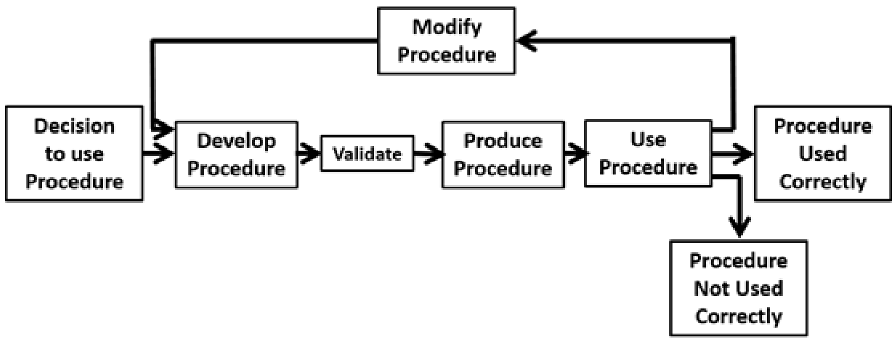

Figure 1: How procedures are designed and used.

METHODOLOGY

To devise good practices, it was necessary to examine the published literature from aviation maintenance and other domains to determine what cause FFP events, and what practices have been advocated (or even shown) to reduce or eliminate them. The range of industries using procedures provides a wide literature on both proper design of procedures and analysis of incidents where procedures were not followed. The literature may be wide, but it is not particularly deep. Findings of the prevalence of FFP events include Rankin (2008) who found FFP as the primary cause of maintenance errors reported in Boeing’s MEDA database, and Johnson and Watson (2001) for aviation maintenance malfunctions. Landry, Jacko and Coulter (2006) for pilots, and Walker (2005) for offshore oil rig incidents found comparable results. Results for design of procedures documents are well-documented, e.g. Drury (1998) where all the errors arising from one document occurred in steps where human factors design guidelines were violated. There are also many sets of procedures guidelines in the literature where adherence is advocated, but no data or analysis are presented, e.g. Center for Process Safety (1996).

In the current project, over 100 books, reports, published papers, conference proceedings papers and URL’s relevant to the issues and/or contributing conditions to FFPs were located an analyzed, although few comprehensive mitigation approaches were in evidence: Many

sources were trade papers or URL's advocating either improved design of procedures or increased responsibility and vigilance on the part of the ultimate user of the procedure. Typical of the latter approaches are the USA's National Transportation Safety Board (NTSB) 2013 Safety Alert encouraging mechanics to manage risks to ensure safety (NTSB, 2013) e.g. "Carefully follow manufacturers' instructions" or "Be thorough when performing routine inspections". These, along with advocated FAA training programs, represent good advice, but put the onus on the person "at the sharp end" of a complex event. Under the same heading are the FAA's Personal Minimums Checklists for before and after a maintenance task:
(https://www.faasafety.gov/files/gslac/library/documents/2013/Mar/75457/PMCBizCard.pdf). Again, this emphasizes personal behavior and responsibility: extremely important and necessary, but not a sufficient condition for safety improvement. As Wenner and Drury (2000) noted for aircraft ground damage incidents "…ground damage incidents are often caused, at least partly, by latent failures in the system. These latent failures cannot be eliminated without making changes in the system further upstream than the mechanics, or even the first line supervisors." In the current project, the explicit aim was to cast a net more broadly to examine a range of such latent failures, termed here as Contributing Factors, and industry Good Practices so that future interventions can be more comprehensive in nature.

The literature was summarized using a classification scheme that worked well for FFP data, and was based on the SHELL model (ICAO, 1989) with a separation of Procedure Document as a specific factor. This was labelled the TAPES scheme, shown in Table 1.

TAPES	**Definition**
Task	The actual task performed by the actor
Actor	Those involved in conducting aviation maintenance tasks, including the Aviation Maintenance Technician (AMT), maintenance supervisor, job inspector.
Procedure Document	The paper or electronic document used by the actor to perform the task
Environment	The conditions surrounding the task to be performed. Includes physical layout, thermal / visual environment etc. excludes the documents used.
Social	The interactions between people in the broader organization beyond the immediate actor.

Table 1: TAPES classification definitions.

Using this scheme, each reference was examined and Contributing Factors and Good Practices tabulated using a tree-level hierarchical system so that collapsing was possible where data were insufficient. To check on whether this classification could be supported by other data, two different databases were analyzed. The Aviation Safety Reporting System (ASRS) has been used for over 20 years to self-report and analyze events or incidents in aviation. Although mainly a database for flight operations, it does contain many maintenance incidents. A sample of 154 cases selected by prior FAA investigators for maintenance from 1999 through 2012 was used here. It is important to note that this sample's search criteria focused on Chart or publications, logbook entries, manuals, and procedures. In contrast, the 94 cases from the National Transportation Safety Board (NTSB) used accident data investigated by professionals. The accidents used were all maintenance-related and occurred from 2005 through 2014. To extract contributing factors from these data bases, two of the authors coded a sample of 20 cases independently and resolved any discrepancies. Then, the coders worked together on 30 new cases to ensure that their criteria for factors were consistent. The remaining cases were divided equally between the coders. Table 3 shows one of the classifications, for Social.

TAPES Class	Number from Literature	Number from ASRS	Number from NTSB
Task	26	34	32
Actor	93	22	4
Procedure	163	141	7
Environment	16	16	1
Social	113	29	18
Unexplained		3	59
Total	411	245	121

Table 3: Counts of each TAPES Class for each data source.

Top Level	Second Level	Lowest Level
500 Social Contributing Factors	510 Organizational policy	511 Were alternatives to Procedures considered?
		512 Written rules to control maintenance activities
		513 Interface between MRO and operator
		514 Training Users for Procedure awareness
		515 Fair enforcement policy implemented locally
	520 Organizational Effectiveness	521 Ineffective Procedure Policy enforcement locally
		522 Ineffective guidance / coaching
		523 Unresponsive to employee suggestions
		524 Lack of resources for task performance
		525 Lack of resources for procedures design/revision process
		526 Negative organizational culture
		527 Changes to procedures condoned without task updating procedures
		528 Supervisors turn a blind eye to non-compliance
		529 Inadequate supervision
	530 Local Norms	531 No procedures provided
		532 User did not know current practice was wrong
		533 It has been done that way for years
		534 Violations ignored when they interfere with production
		535 User believes procedure better if modified
		536 User believes procedure not needed by experienced people
		537 Users believe they know what they are doing
		538 Users believe that deviation demonstrates their job knowledge
	540 Organizational Pressures	541 Time / production Pressure
		542 Task interruptions tolerated
		543 Task distractions tolerated

Table 2: Final classification scheme for one class of Contributing Factors, Social.

The first finding of Table 3 is the considerable number of Unexplained Contributing Factors for the NTSB reports. This was because many did not provide in-depth data on maintenance incidents. The second finding is the quite divergent results between the three data sources. A Chi-square test omitting the "unexplained" category gave highly significant results (Ch-square (8) = 157, $p < 0.001$). Both the literature and the ASRS reports find the largest number of issues in the Procedure class. In the literature, this was to be expected as much of it came from studies of document design. For the ASRS data, the respondents were typically AMTs, inspectors and perhaps their supervisors, who see changes to the procedure, and to the user training, as a relatively straightforward way to prevent specific errors from recurring. For the NTSB analysis, much of the emphasis as on effectivity, i.e. should this specific part be on this particular aircraft. It appears that the concerns of the person or group investigation/reporting an incident play at least some part in the contributing factors reported. However, all sources did agree that a substantial fraction of the contributing factors came from the Social category which includes organizational as well as personnel interactions.

RESULTS
With such diverse results, perhaps due to sampling or reporting biases, the safest way to proceed was to find the most frequent Contributing Factors in each data set, then to derive Good Practices from the merged set. Obviously Contributing Factors to FFP events are negative: they increase the likelihood of an event. Good Practices were typically found only in the literature so that both Contributing Factors, expressed by their converse and Good Practices were collected together. When this was done (see Drury et al, 2017 in Press for details), a set of 15 potential Good Practices that received wide support from one or more of the data sets analyzed. These are classified using the TAPES scheme in Table 4.

TAPES class	**Good Practices for each TAPES class**
Task	1. There is a known policy to deal with incorrect or incorrectly installed parts on the aircraft.
Actor	2. Users are trained appropriately, experienced and knowledgeable.
Procedure Document	3. Procedures are technically accurate. 4. Procedures are designed to conform to Human Factors guidelines for content, organization, readability and graphics. 5. Procedures are used only as needed, and at a suitable level for professional users. 6. Procedures are in a medium suitable for use at the working point. 7. Procedures are kept up-to-date. 8. Procedures have been validated by observing their use in detail. 9. Procedures incorporate explicit input from users, i.e. AMT's and inspectors with direct knowledge of the tasks.
Environment	10. A high-quality visual environment is provided, including aids for seeing inaccessible work points.
Social	11. Organizational policy on use of procedures is in place, 12. Organizational policy is enforced by all levels of management as well as by peers. 13. Procedures are available when needed and users can always find the correct procedure. 14. Users are insulated from time / production pressures. 15. Users have an appropriate and known plan to improve or optimize procedures

Table 4: Good Practices classified by TAPES.

DISCUSSION
As expected from Table 2, most of the Good Practices concern either the Procedure itself or the Social/Organizational environment in which it is used. However, two of the Procedure Good Practices (8, 9) concern the system for validating procedures and for modifying them after use so imply an organizational component. A second observation from our knowledge of the domain is that many of these Good Practices are being implemented quite effectively at present e.g. incorrect parts (1), technical accuracy (3), good visual environment (10), and a policy for procedure use (11). In addition, the advent of electronic production, distribution

and display of procedures has greatly improved their suitability for use at the working point (6), the updating process (7), and their ubiquitous availability (13). These have all been problems with procedures in the past (e.g. Drury, 2010), but can now be largely solved, albeit at some capital expense. Direct electronic communication has also been found helpful for maintenance organizations to communicate with manufacturers about procedures, a prior concern in the industry (e.g. CAST, 2013).

To address the FFP issue in a comprehensive manner requires at least two approaches. First is a better way to ensure that HFE findings are incorporated into the procedure document itself. Second is more attention to the demands of the organization placed on the end-users of the procedures. Most maintenance organizations have been introduced to HFE through Human Factors training and prominent posters at work. However, the issues covered are largely personal (cutting corners, complacency, lack of teamwork, lack of assertiveness), which are important but do not cover how to build better tools or procedures for human use. Guidelines have been made available since the 1990's, but the writers of procedure documents typically use industry standards that have no HFE content. An exception is the use of Simplified Technical English by manufacturers and some maintenance organizations. This have proven effective, e.g. Chervak, Drury and Oulette (1996). Tackling the second set of issues is likely to be more difficult as they get to the heart of the business model of an organization, with enforcement of policies that may detract from the workflow (12) and the time pressures that are linked to all organizations. These findings should not be particularly surprising to the HFE community, since they were derived partly from the literature that contained many HFE sources. For example, Bates and Holroyd (2012) noted for biological laboratory procedures that: "The reasons for cutting corners and the situations where cutting corners could be more likely were mainly found to be due to situational and organizational factors. For example, time pressure, workload, staffing levels, training, supervision, and availability of resources." Any steps towards a comprehensive solution to the problem of Failure to Follow Procedures needs to maintain those practices that are currently being done well, incorporate more HFE findings into the design of the procedures themselves, and address what may prove to be difficult organizational issues. From the literature analyzed, this is true beyond the narrow domain of aviation maintenance.

CONCLUSIONS

This paper concentrates on organizational findings with the aim of providing industry with effective good practices to ensure that where procedures are meant to be used, they are indeed followed correctly. A set of 14 good practices was developed with support from the analyses performed. Of these, almost half were organizational in origin.

DISCLAIMER

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SEPSIS: A WORK SYSTEMS ANALYSIS OF 30 SURVIVOR AND TRIBUTE STORIES

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KEYWORDS
Sepsis, SEIPS, Patient Safety, Systems approach, Healthcare

SUMMATIVE STATEMENT
Often reported incidents involving sepsis state opportunities were missed. This raises the question of where in the system these opportunities are present. Through a qualitative document analysis of tribute and survivor stories, work system elements that may provide an opportunity for the successful treatment or those that may hinder effective treatment of sepsis were identified.

La sepsie : une analyse des systèmes de travail au moyen de 30 récits de survivants et d'hommages

MOTS-CLÉS
Sepsie, modèle SEIPS, sécurité du patient, approche systémique, soins de santé

SOMMAIRE
Souvent, les rapports d'incident touchant la sepsie indiquent que des occasions ont été ratées. Cela soulève la question de savoir où se trouvent ces occasions dans le système. Grâce à une analyse qualitative de récits de survivants et d'hommages, on a pu déterminer des éléments des systèmes de travail qui pourraient fournir une possibilité de traitement efficace ou compromettre l'efficacité du traitement de la sepsie.

INTRODUCTION

Sepsis is a complex clinical syndrome (Kent and Fields, 2012) that is a major healthcare issue worldwide (Angus et al., 2001; Lang and Tasker, 2017; Namas et al., 2012; Vincent et al., 2006). The most recent view of this syndrome is that it is characterized by multiple systems within the body responding to a microbial pathogen including biochemical, cellular and organ-organ interactions and involves a complex chain of events involving numerous systems within the human body (Namas et al., 2012).

Due to the complexity of sepsis and despite individual mechanisms of this syndrome having been extensively studied, challenges in diagnosing and treating it successfully remain (Kent and Fields, 2012; Namas et al., 2012). And despite medication available to treat sepsis, mortality rates are as high of 25% to 50% (Chege and Cronin, 2007; Wolf, 2012). One effective approach for the treatment of sepsis that has been identified includes receiving aggressive treatment early, particularly within the first hour, and can influence severity, survival, morbidity and mortality (Chege and Cronin, 2007; Jones et al., 2007).

Despite evidence of the time critical nature of this syndrome, often delays in diagnosing and treating of sepsis occur. Aspects that cause delays in the identification and treatment of sepsis that have been identified include delays in diagnosis, lack of availability of beds and delays in nursing care (Burney et al., 2012). Current interventions aimed at identifying and treating sepsis include clinical guidelines for the treatment and management of sepsis (Chege and Cronin, 2007; Kent and Fields, 2012) as well as increasing awareness regarding the signs and symptoms of sepsis through campaigns (e.g. Surviving sepsis campaign) (Chege and Cronin, 2007).

To better understand and develop treatments for sepsis, recently a systems approach has been adopted to expand the biological understanding of the mechanisms of sepsis (Namas et al., 2012). Furthermore, it has been suggested that to bring about successful change with regards to the treatment of sepsis, a system-wide approach needs to be developed that includes all the healthcare staff, and even family and carers that come in contact with the patient (Lang and Tasker, 2017). Examples of current system approaches for the identification and triage of sepsis in young children include at the level of public health and prehospital public awareness generated by the UK Sepsis Trust, at the primary healthcare level support materials for professionals, and at the hospital or emergency department level the Manchester Triage system or 'NICE Red Traffic Lights' in acutely ill children (Lang and Tasker, 2017).

From a human factors and ergonomics perspective, a systems approach has not only been used to understand healthcare processes better to improve patient safety (Rivera et al., 2008; Gurses et al., 2012) but also to understand infection outbreaks within acute care settings to identify the larger system contributing factors of the outbreaks (Waterson, 2009). This raises the question if a systems approach, from a human factors and ergonomics perspective, could not be adopted to better understand the influencing system factors regarding the current identification and treatment protocols for sepsis as this is such a time sensitive syndrome whereby the patient will come in contact with numerous healthcare subsystems.

This research aimed to identify potential system elements that may assist or hinder the identification and treatment of sepsis. The research objective was to analyse documents relating both to tribute as well as survivor stories to identify possible opportunities, that were either missed or utilised, in the treatment and diagnosis of sepsis from a human factors systems approach.

METHODOLOGY

A sample of 30 survivor and tribute stories were qualitatively analysed from the perspective of system ergonomics to identify opportunities and system elements that aid or hinder in the identification and treatment of sepsis. The survivor and tribute stories were downloaded from the UK Sepsis Trust website (www.sepsistrust.org) on the 8th of February 2017.

Of the 30 stories analysed, 15 were tribute stories and 15 were survivor stories. The stories were selected so that an equal number of stories per age group were analysed. A total of four stories, two survivor and two tribute for analysed for the age groups 0-10, 11-20, 31-40, 41-50, 51-60, 61-70. A total of six stories, three survivor and three tribute stories for analysed for the age group 21-30. The distribution of the stories per age group and per type is graphically represented in Figure 1.

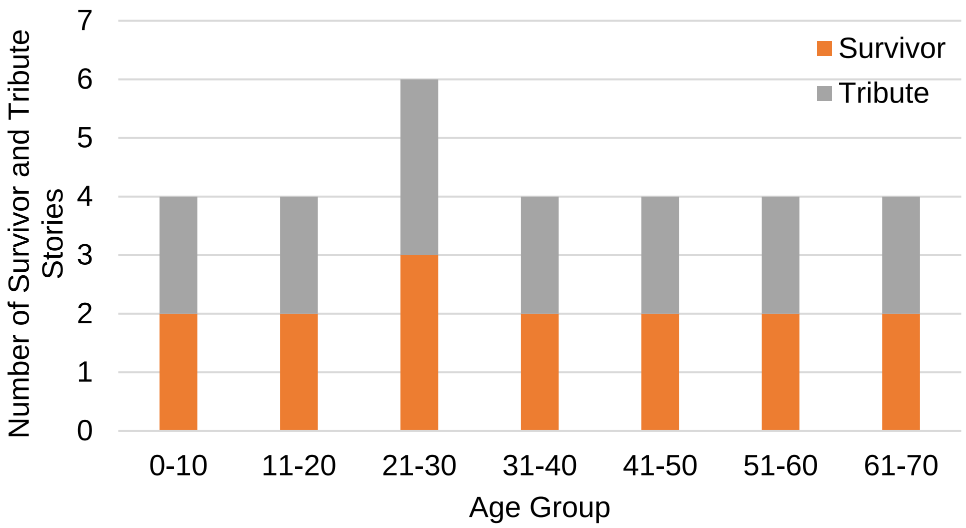

Figure 1: The number of stories analysed per age group for the survivor and tribute stories in the sample.

All data were analysed using NVivo 10 (QSR International, 2014) using thematic analysis (Braun & Clarke, 2006). The analysis was based on the SEIPS 2.0 model (Holden et al., 2013) as this model incorporates a systems approach, is healthcare-specific yet still general enough to be applicable to various healthcare scenarios (Carayon et al., 2006, 2014). Initial data reduction was done by using pre-set codes, and all data was categorised according to the sociotechnical work system components and the outcomes as described in the SEIPS 2.0 model. The sociotechnical work system components included the person, task, tools and technology, organization, internal and external environment components. The person component consisted of the elements family, patient and staff. The outcomes included of the patient, professional and organization outcomes. Finally, emergent codes were developed for the SEIPS 2.0 elements using focused coding. Common themes across the examples were collated and mapped onto the SEIPS 2.0 model. Additionally, examples of aspects where the system worked well were identified.

RESULTS

Contributing factors were found to originate from four of the six work system components. These included person, task, organisation and external environment components. With some of the identified examples, it was possible to classify the contributing factor as positive or negative. A summary of the results for the work system aspects has been graphically represented in Figure 2. No elements were identified for the tool and technology or internal environment components in the 30 stories analysed. Example excerpts from the stories for each work system aspect have been included in the results below.

The person component of the work system influencing the treatment of sepsis included patient-related, family-related and staff-related elements. Majority of the patient-related elements identified in the stories were found in both the survivor and tribute stories. The patient-related elements identified as influencing the treatment of sepsis included the patient’s history, general health, their behaviour (e.g. refusing help), the underlying infection, and the physical and physiological signs and symptoms they experience (e.g. pain, fever, breathing problems, confusion, feeling unwell). Additional patient-related elements identified in only the survivor stories included the patient recognising the symptoms of sepsis themselves due to previous experience and the patient pleading for treatment, which is highlighted in the following excerpt: *“It was there that I collapsed after trying to convince the GP that there was something terribly, terribly wrong with me”*.

The family-related elements identified in both survivor and tribute stories included either rationalising away the symptoms (e.g. *"all… girls caught chickenpox consecutively"*) or intercepting and seeking medical attention on behalf of the patient (e.g. *"…my wife wanted to call 999"*). A family-related element identified in the survivor stories included advocating for the patient. This is highlighted in the following excerpt: *"my fiancé turned and said to the doctor – 'but he can't even walk, this can't be right'"*. Another example of this is highlighted in the following quote from one of the survivor stories: *"Her Mum's insistence on the attendance of a senior doctor probably saved her life"*.

Similarly, to the family-related element, a staff-related element identified in both survivor and tribute stories included medical staff advocating for the patient. This is highlighted in the following excerpt: *"I was so fortunate that the Junior Doctor pushed and pushed for me to be taken to the ICU in spite of others who wanted me to stay put"*. Unfortunately, as this element was identified in both stories, this alone is not enough to ensure the successful treatment of sepsis and the timing of this in the development of sepsis appears to be crucial. An additional staff-related element that has a negative effect identified in the tribute stories included not recognising the urgency of the patient's situation. Positive elements identified from the survivor stories included staff trying to ensure shorter waiting times at the emergency department as they knew the severity of the patient's condition, staff being aware of sepsis, and quick reactions of staff (e.g. immediate surgery, antibiotics being administered by paramedics).

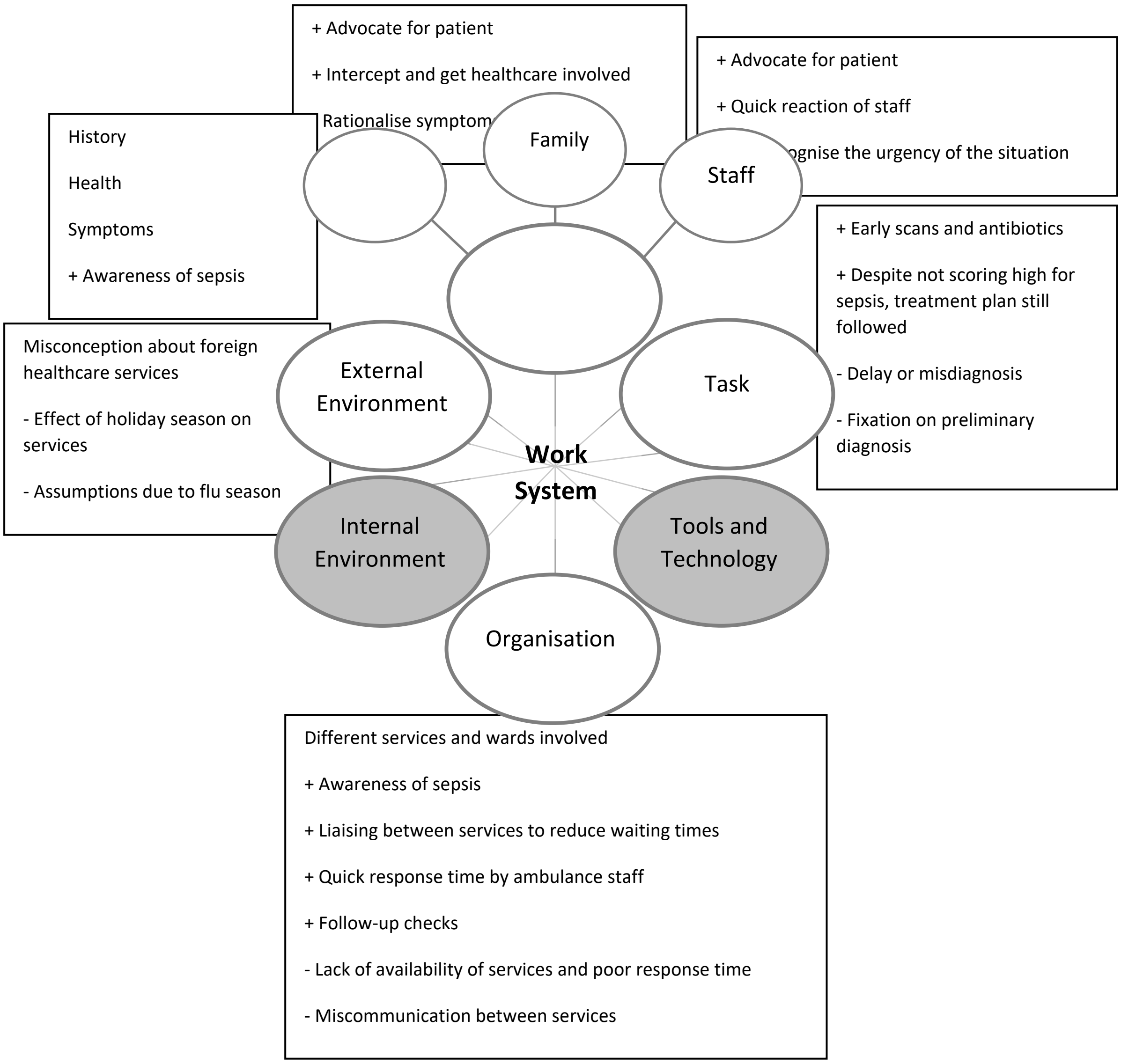

Figure 2: A Summary of the key contributing factors, negative factors (-) and positive factors (+) identified for each of the work system aspects. No elements were identified for the tool and technology or internal environment components in the 30 stories analysed.

In both story types, the task components identified as hindering the treatment of sepsis included an incomplete diagnosis with a fixation on the preliminary diagnosis. This is highlighted in the following excerpt from one of the survivor stories *"the GP put down to being muscular. I kept returning with the pain and was just given stronger painkillers and told to rest"*. The negative task components identified in the tribute stories included delays in receiving scans, administration of antibiotics, services (e.g. GP) and being diagnosed. Additional negative task components identified included being misdiagnosed (e.g. Viral versus bacterial infection), antibiotics not being prescribed and being inappropriately triaged either by A&E or by the GP. The positive task components identified in the survivor stories included receiving scans early and in a timely manner, early administration of antibiotics specifically IV antibiotics, and immediate medical treatment such as surgery. This is highlighted in the following excerpt: *"whilst I apparently didn't initially score too high for sepsis they treated me with IV fluids and antibiotics, painkillers and various X-rays and scans"*. The negative task components identified in the survivor stories included not monitoring the patient's vital signs and despite the need for antibiotics being identified early, they were not administered for several hours.

Majority of the stories analysed highlighted that numerous services and wards were involved in the treatment as well as in the diagnosis of sepsis (e.g. GP, Emergency medics, NHS helpline, emergency numbers such as 111 and 999). Negative organisational work system components identified across both the survivor and tribute stories included a lack of availability of services, and poor response times (e.g. GP appointments). Organisational elements identified in the tribute stories included miscommunication between services due to a lack of understanding of the severity of the condition. In the survivor stories, quick response time by ambulance staff, liaising between systems to reduce waiting times for the patient to receive medical care, and an organisational awareness were the organisational elements identified that aided the treatment of sepsis. An example of the different systems liaising with each other to reduce waiting times is highlighted in the following excerpt: *"The nurse liaised with … Hospital and arranged for me to … get to A&E – armed with a letter saying I wasn't to wait in reception to be seen, and had to go straight through"*. A negative organisational element identified in one of the survivor stories included the patient leaving the hospital early due to a bad experience.

External environment elements identified in the tribute stories included assigning the symptoms to flu due to flu season. This and the resulting effect is highlighted in the following quote: "*This was the height of the flu epidemic of 2010/2011 and her symptoms were quickly assessed to be another case of seasonal flu. She was immediately dismissed, receiving no treatment, and with the standard advice to rest and take plenty of fluids".* The external environment elements identified in the survivor stories included the negative effects of the holiday season on access and availability to healthcare services and the misconceptions and concern regarding seeking healthcare treatment whilst in a foreign country.

The outcomes identified across the 30 stories could be categorised as organisational outcomes or patient outcomes. No examples of professional outcomes were described in the texts. The patient outcomes described in all 15 tribute stories was death, the patient outcomes described in the survivor stories included the negative side effects of suffering from sepsis such as both physical and mental health complications as well as emotional distress. The organisational outcomes identified in both survivor and tribute stories included a lack of trust in the healthcare systems due to negative experiences and negative effects on the healthcare system's reputation. An additional organisational outcome identified in the survivor stories included the increased costs of additional hospital stays.

DISCUSSION AND CONCLUSION

All the stories highlighted that a patient suffering from sepsis will come into contact with numerous sub-systems such as the emergency paramedics, GP's and telephone helplines as well as numerous wards within one hospital stay. The delays identified both in survivor and tribute stories could be categorised as predominantly originating from either the patient or the healthcare system. Patient delays included rationalization of the severity of the symptoms away, whereas delays as a result of the healthcare system included delays in diagnosis, prescription and administration of antibiotics, as well as delays in diagnostic scans. Positive system elements identified, which occurred predominantly in the survivor stories include either family members or specific members of staff advocating the seriousness of the condition of the patient, department awareness of sepsis and quick reactions of medical staff with regards to treatment.

From the results, the prompt administration of antibiotics was identified as a key factor, which has been highlighted in the literature regarding current treatment plans (Chege and Cronin, 2007; Kent and Fields, 2012). Additionally, the results highlighted that the early administration of antibiotics was often due to specific individuals advocating for the patient. This raises several questions relating to antibiotic prescription and use. What causes the delay in prescription and administration of antibiotics? Specifically, which system elements need to be addressed to ensure timely administration of antibiotics? Is the culture associated with the overprescription of antibiotics negatively affecting sepsis treatment plans? Adopting a system's approach, from a human factors perspective, to the analysis of sepsis treatment and diagnosis can aid in the identification of potential bottlenecks, specifically those related to work structure and organisational factors, that may have detrimental effects for this time-sensitive condition.

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NEW LEGISLATION ON ORGANIZATIONAL AND SOCIAL WORK ENVIRONMENT: A CASE STUDY

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KEYWORDS
road and construction industry, unhealthy workload, working hours, victimization, leadership

SUMMATIVE STATEMENT

This case study shows how a revised work environment legislation on organizational and social work environment influenced operations in a large road construction and maintenance company.

Nouvelle réglementation sur l'environnement organisationnel et social du travail : un étude de cas

MOTS-CLÉS
Industrie de la construction routière, charge de travail malsaine, heures de travail, victimisation, leadership

SOMMAIRE
La présente étude de cas démontre comment la révision d'une loi portant sur les conditions organisationnelles et sociales du milieu de travail avait influencée les activités d'une grande entreprise de construction et d'entretien des routes.

PROBLEM STATEMENT

In Sweden, a number of people are suffering from unhealthy workload andcosts every year estimated to $8 billion. In order to counteract this development, the Swedish Work Environment Authority released new provisions (Arbetsmiljöverket, 2015) on the 31st of March 2016 which clarify and emphasize the responsibility for employers to offer a sound organizational work environment. The main purpose of the provisions was formulated: 'to promote a good work environment and prevent risks of ill health due to organizational and social conditions in the work environment'. The release has gained a lot of attention and numerous educations and activities were started regarding how to manage the situation. The release has gained a lot of attention and numerous educations and activities were started regarding how to manage the situation. The release has gained a lot of attention and numerous educations and activities were started regarding how to manage the situation.

Job demands have shown to have significant physiological and psychosocial costs (Crawford et al., 2010). The quality of relationships amongst employees at a workplace has also a big impact on both job satisfaction and the level of stress perceived (Einarsen et al., 1994). However, a health promoting leadership is of utmost importance to the health of employees. Being in the formal leader role you possess a strong ability to affect occupational health. By possessing certain amount of formal organizational power to assign tasks and punish or promote other employees, the leader-follower interaction is vital for the wellbeing of followers (Kelloway & Barling, 2010).

When approaching the work environment management, one must first understand that the work environment is ever-changing and complicated in nature (Lennér-Axelsson & Thylefors, 1991). Individual personalities, needs and ambitions result in different experiences on the same working situation. What one person perceives as stressful and tearing could be perceived as a stimulating challenging by others. This put requirements on regular and systematic assessments of the demands in the work, resources required and potential conflicts.

The construction industry is by nature a tough and hazardous workplace that requires heavy lifting, awkward postures and other forceful exertions (Schneider & Susi, 1994). Further, the construction industry work environment is characterized by risky outdoor environments, high workload, constant changing of site conditions and less formally defined processes (Reese & Eidson, 2006). Work is often performed close to ongoing traffic which adds stress and risk to the work. This environment is largely caused by the nature of the work, poor work practices of the individual and pressure from budgets and time (Holmes et al., 1999). Ill health or musculoskeletal disorders are major problems that force workers to leave the industry early (Ardnt et al., 2005).

Organizational resources such as rewards, fair treatment, appropriate equipment and training is essential for the safety of the workers within this industry (Tam et. al., 2004). To approach the risks of the construction industry, organizational, psychological and social aspects must be considered (Törner & Pousette, 2009). Djebarni (1996) and Leung et. al (2008) link stress amongst managers in construction projects with lower levels of performance. The construction industry is also a man dominated industry were men make up 90% of total employed within the business (SCB, 2013). Women only make up for 10% of the total employees which can be explained by different career choices but also, in some cases, due to a dominating male culture and victimization (Nandorf, 2015).

RESEARCH OBJECTIVE/QUESTION

The objectives of this paper are to contribute to the understanding of how current work practices in construction industry can be improved regarding organizational and social conditions in the work environment. The aim is more specifically to explore a) what measures needs to be taken in the case study company to implement the new provision and b) how the organization can support managers and other employees in fulfilling the provisions.

METHODOLOGY

A case study (Yin, 2009) was undertaken in three sites of a large Swedish road construction and maintenance company that operates throughout Sweden with a dispersed organization including many small sites and a few larger. Data were collected through document analysis, interviews and questionnaires. Nine people were interviewed based on different roles (managers, first line managers and operators) within the organization. A questionnaire was conducted at the three sites based on the interview findings. 21 respondents answered the questionnaire which represented a response rate of 53 percent. Interviews were analyzed by content analysis and questionnaires with descriptive analysis and combined with document analysis from the studied company.
Interviews and questionnaires were developed in line with the new provisions' (AFS 2015:4) content comprising the following six aspects: 1) systematic work environment management, 2) knowledge requirements, 3) social and organizational objectives, 4) workload, 5) working hours and 5) victimization.

RESULTS

The results are presented according to the six parts in the (AFS 2015:4) elaborated below:

1) Systematic work environment management

The provisions on systematic work environment management state rules regarding work environment policy, knowledge and directions on how employers should investigate and assess operational risks on a regular basis. The employers should in accordance take action in order to manage risks detected. (§5 AFS 2015:4)

According to interviews, questionnaire as well as the document analysis, the studied company had a well-functioning work process regarding the way they managed the work environment. Findings from interviews and questionnaire further showed that employees could participate, voice their opinions and provide suggestions most of the time. However, one exception was the setting of organizational and social objectives, which is developed in subsection 3 below. The organizational and social work environment had not received as much focus compared to the physical work environment in the past.

2) Knowledge requirements

The employers have a responsibility to make sure managers and supervisors have the right knowledge to be able to 1) Prevent and deal with unhealthy workload, 2) Prevent and handle victimization. The employer shall implement prerequisites for putting the knowledge into practice. (§6 AFS 2015:4)

The knowledge among managers and supervisors in the construction company, within this area was considered good in general by respondents. Education had been provided though a course called BAM (Better Work Environment), which aimed to develop their ability and knowledge of occupational health and safety by providing a holistic perspective on the work environment. Front-line workers who requested it were also able to attend this course. However, BAM did not include any education of e.g. handling victimization.

To prevent victimization there is a need to understand the social work place setting in order to detect problems and indications early. In order to handle these problems, knowledge of appropriate actions and prerequisites to take these actions are required.

Leadership in relation to the organizational and social work environment was considered an important success factor by the respondents and something that worked well in the construction company. It was commented by the respondents that when e.g. a new manager with well-developed leadership skills entered an operation, both the work environment and the result improved.

3) Social and organizational objectives

The employer shall have objectives for the organizational and social work environment. Employees should be able to take part in producing these objectives and it is the responsibility of the employer to give them the opportunity. If there are ten or more employees in the operations, the objectives should be in written form. (§ 6, 7 AFS 2015:4)

The company had social and organizational objectives set at a top management level, but the informants didn't perceive that they had opportunity to participate in affecting the drafting of these objectives. It was discussed that setting objectives for the organizational and social work environment at a level closer to the managers, supervisors and front-line workers would be a way to allow more employees to participate. Respondents suggested that these could be discussed as a permanent item in weekly meetings and ultimately lead to local objectives which they could identify with. This could also be a way to create interest in and lift the organizational and social work environment as an important part of the everyday work.

4) Workload

In order to make sure unhealthy workloads do not arise, the demands in the work should be met by appropriate and adapted resources. It is the responsibility of the employer to make sure employees have the knowledge of: 1) tasks they are to perform, 2) results to be achieved with the work, 3) particular methods with which the work is to be performed, and if so how, 4) which work tasks are to be prioritized when available time is not enough for all work tasks to be performed, 5) whom they can turn to in order to receive help and support in carrying out the work. To counteract work tasks and situations that are mentally stressful, the employer should take measures necessary to prevent illness caused by mental stress amongst employees. (§ 9, 10 AFS 2015:4)

The data collected on workload indicated a high workload especially for managers but also supervisors and front-line workers. The demands in the work could include the amount of workload, time limitations, degree of difficulty and physical and social conditions. The demands could be cognitive, physical and emotional in nature. The resources attained at the construction company were generally considered good but they could have been better. Even if some respondents felt it was manageable other found it challenging. However, there should be routines to make sure no one suffers ill due to a high workload. One thing which worked very well was the employer to employee communication where an open dialogue was enabled.

5) Working hours

The employer shall take all steps necessary to counteract illness amongst employees caused by the scheduling of working hours. Some examples of scheduling of working hours that could result in illness are: 1) shift work, 2) night work, 3) split shifts, 4) large extent of overtime work, 5) long work shifts, 6) far-reaching probabilities of having to work at different times and places, with expectations of being constantly reachable. (12 § (AFS 2015:4)

The empirical findings indicated three main extensions of the regular working hours: overtime work, long work shifts and expectations of being constantly reachable. The most frequent occurring was the last mentioned. In addition, some respondents had on-call services at times which then occurred every 5th night. The findings suggest that extending the regular working hours happened quite frequently in in the company. Furthermore, one manager had been working almost 60 hours every week on a regular basis which may work for a limited time but is not sustainable in the long run.

6) Victimization

It shall be made clear by the employer that victimization is not acceptable. The employer shall take actions to counteract conditions that could give rise to victimization in the work environment. The employer shall make sure that there are procedures for handling victimization. The procedures should indicate: 1) who receives information that victimization is occurring, 2) what happens with the information, what the recipient is to do, and 3) how and where those who are subjected to it can quickly find help. It is the employers' responsibility that the procedures of handling victimization are known to all employees. (13, 14 § AFS 2015:4)

There was a variation of knowledge among employees regarding procedures to prevent victimization. This could be explained by that the company introduced new procedures only a few months earlier. However, in practice, actions to prevent victimization was generally perceived as well functioning among the respondents which most likely was related to the few perceived cases of victimization within the organization.

DISCUSSION

The findings indicated that the organization had made major efforts in systematic work environment management. Typically for the business, risks related to accidents and physical workload were considered to be most important. However, it was found that the company would benefit from making organizational and social work environment a permanent item on the agenda. In the studied company, such issues showed to have a potentially large influence on the work environment and likely affect also the physical work environment. To meet the new provisions, further education was requested to improve knowledge and implementation into practice. Additional development demanded was to create a plan to address high mental workload and working hours through discussions involving both managers and employees. It was found that the company also would gain from including a perspective on ethical leadership and emphasize the importance of leadership for a good work environment. A follow-up one year later indicated that the company started several of the suggested activities to improve the situation like specific education on the subject, workshops regarding diversity, new routines to handle victimization and using a new cell phone application for safety during solitary work.

Moreover, the introduction of new provisions regarding organizational work environment issues did have effects on the company's focus regarding work environment. Clarifications on responsibilities and how to handle the different aspects of organizational issues were brought into the agenda in a much clearer way than earlier. The requested training regarding these issues is a sign of this. Another sign is the request for more participation in setting goals for organizational work environment and a third sign is the unawareness of how to handle victimization issues.

It must however also be concluded that the studied company was well organized regarding work environment management and that it had extensive, standardized ongoing educational activities. The company also had national experts regarding work environment that continuously worked with improving management work and educational activities.

CONCLUSIONS

It is apparent that the new provisions affected the company to revise their work environment regarding organizational and social issues, which provided some noteworthy improvements. By that, the Work Environment Authority has reached some intended outcomes in the studied company. However, this study suggests that the following measures are further developed to implement the new provision.

- Make the organizational and social work environment a standing item on the agenda of weekly frontline meetings.
- Set objectives for the organizational and social work environment allowing everyone to participate in the process.
- Provide training to raise the competence and knowledge of managers, supervisors and safety representatives through e.g. education and case- exercises, preferably coupled together.
- Enable and encourage objectives for the organizational and social work environment to be set starting at a work place level.
- Make clear where employees shall turn if experiencing ill health.
- Spread and make clear the procedures for handling victimization throughout the organization.
- Include a perspective on organizational and social work environment and ethical leadership when educating leaders.

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NATIONAL ECONOMIC INCENTIVE SCHEMES BASED ON AUDITED OHS MANAGEMENT SYSTEMS AND WORK ENVIRONMENT PRACTITIONERS' STRATEGIES

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KEYWORDS
Intervention, change management, strategy, OHS practitioner, health and safety management system, audit.

SUMMATIVE STATEMENT
Work environment practitioners have a central role in implementing externally audited health and safety management systems. Their strategies depend on their background and the organisational context. Many identify stakeholders' needs and interests for the basis of their interaction and support. They develop participatory practices with stakeholders who are neutral or positive towards implementation, work around or ignore stakeholders who are against changes.

Projets d'incitatifs économiques nationaux fondés sur les systèmes de gestion de sst vérifiés et les stratégies de praticiens en sst

MOTS-CLÉS
Intervention, gestion du changement, stratégie, praticien en SST, système de gestion de la santé et de la sécurité, vérification

SOMMAIRE
Les praticiens en SST jouent un rôle important dans la mise en œuvre de systèmes de gestion de la santé et de la sécurité qui feront l'objet d'une vérification externe. Leurs stratégies dépendent de leur expérience et du contexte organisationnel. Bon nombre d'entre eux déterminent les besoins et les intérêts des intervenants sur la base de leur interaction et de leur soutien. Ils élaborent des mesures participatives avec les intervenants qui démontrent une attitude neutre ou positive à l'égard de la mise en œuvre, et contournent ou ignorent les intervenants qui s'opposent aux changements.

PROBLEM STATEMENT

National economic incentive schemes based on audited occupational health and safety management (OHSM) systems are a specific type of OHS interventions. Many countries have launched national incentive programmes to motivate organisations to implement OHSM systems either by giving economic incentives or other advantages (Elsler et al., 2010).The programme theory (Pawson & Tilley, 1997) behind these schemes is that the economic incentive will encourage organisations to implement OHSM systems, the audit will ensure that they function and that a functioning OHSM system will create and maintain good work environment and prevent injuries and ill-health. These schemes are often only evaluated on outcome e.g. reduced injury claims from which it is difficult to see if the programme theory works because claims are influenced by many other factors.

We know little about how these incentive schemes works in organisations, or what different stakeholders do to implement them and make them work. It has been suggested that internal work environment practitioners like health and safety managers, coordinator or advisors have a central role in managing OHS and implementing OHSM system. Olsen (2012) found that some work environment practitioners used audited OHSM systems as support when they tried to get middle managers to fulfil their role in relation to e.g. risk management.

Previous research have identified that work environment practitioners have various roles e.g. change agents or political reflective navigator (Broberg & Hermund, 2004) and use a variety of strategies e.g. regulatory strategy and knowledge strategy (Hasle & Sørensen, 2011; Olsen, 2012). Further it has been identified that they have to do organisational work before they can start implementing changes (Theberge & Neumann, 2010). These strategies and roles have mainly been identified in relation to improving the work environment but not in relation to establishing OHSM systems. We know very little about the role of work environment practitioners and their strategies to implement externally audited OHSM systems connected to incentive schemes or how they use these schemes to improve OHSM systems, practices and the work environment.

Olsen (2014) surveyed 203 work environment practitioners in New Zealand involved in implementation and/or maintenance of a national economic incentive schemes based on audited OHSM systems. She found practitioners focused on activities related to establish the system and particularly influencing management. There were differences between practitioners that had suggested implementing the scheme and practitioners that just supported the implementation of the scheme. The practitioners that suggested implementing the scheme focused on influencing senior management and engaged more stakeholders. She also found that the main drivers for joining the scheme were the economic incentive and arguments that could support the practitioners' job role. Arguments that the scheme would help identify areas for improvements of OHSM systems and give the organisation an audited national framework to work to. The survey also tested the practitioners' perception of how well the programme theory behind the scheme worked and found that 83% perceived the scheme to have improved the OHSM system, 77% that it had improved OHS practiced but only around half of them perceived that it had reduced risks and injuries (K. B. Olsen, 2014). The survey identified the practitioners' tasks and stakeholders they interacted with as well as reasons for joining, but it did not look into the organisational processes or the practitioners' strategies.

RESEARCH OBJECTIVE/QUESTION

The aim of this paper is to identify the roles and change strategies of work environment practitioners in implementation of national economic incentive schemes which build on audited OHS management systems and how they use the scheme in their change strategies.

METHODOLOGY

Ten work environment practitioners took part in semi-structured face-to-face interviews to explore their roles and strategies. They were selected from a pool of 79 practitioners that answered that they would be willing to participate in further research in the questionnaire survey mentioned above (K. Olsen, 2014; K. B. Olsen, 2014).The practitioners were selected to maximise the chance that they had various roles. They should cover some that suggested joining, some that supported joining and some that did not have a role or another role in joining the scheme (see Table 1, column 3). Practitioners were also selected in relation to when the organisation joined the scheme (Table 1, column 2,). The practitioners were also selected so that there was a spread over who they sought support from when preparing to join the scheme (Table 1 column 4-6).

Table 4. Selection criteria for selecting work environment practitioners for interview

Work environment practitioner	Time of joining scheme	Role in deciding to join	sought support from		
			HS reps or committee	Senior management	middle management
OHSP_02	after employment	supported joining	Unassigned	Yes	Yes
OHSP_03	after employment	no role	N/A	N/A	N/A
OHSP_04	after employment	suggested joining	No	Yes	Yes
OHSP_05	after employment	suggested joining	No	No	No
OHSP_06	after employment	suggested joining	Yes	Yes	Yes
OHSP_07	planning to join	suggested joining	Yes	Yes	No
OHSP_08	planning to join	supported joining	No	No	No
OHSP_10	after employment	another role	N/A	N/A	N/A
OHSP_11	before employment	N/A	N/A	N/A	N/A
OHSP_12	after employment	no role	No	No	No

The interviews covered the practitioners' work role, drivers for joining the scheme, process of preparing the organisation to join, the practitioners' activity related to implementation processes, and how the practitioners engage with different stakeholders. The interviews took on average two hours and took the onset in how the practitioner had answered the questionnaire. The interviews were verbatim transcribed, entered into an analysis software QSR NVivo 10. The interviews were analysed thematically, first to identify strategies explicitly or implicitly described. Looking at the practitioners as actors that aims to create change the practitioners' strategy sections were reanalysed to identify if and how the practitioners covered the elements Kotter (2007) had identified were needed to successfully create change in organisations:

1. Establishing a sense of urgency
2. Forming a powerful guiding coalition
3. Creating a vision to help direct changes and develop strategies
4. Communicating the vision (including teaching new behaviours through example by the guiding coalition)
5. Empowering others to act on the vision (removing obstacles to change and changing systems that may undermine the achievement of the vision)
6. Planning for and creating short-term wins (planning visible performance improvements and recognising and rewarding people's involvement in the change process)
7. Consolidating improvements and producing still more change changes (promoting and developing people who can implement the vision and constantly improve and reassess)
8. Institutionalising new approaches (reinforcement of the changes to date, to ensure they become imbedded in the company culture. Including induction of new staff and acknowledging the link between the new (learned) behaviours and company success)(Kotter, 2007, p. 99).

Assuming that the practitioners strategies differs in relation to the practitioners experience and background and the contextual factors in the organisation the practitioners were divided into three groups:

The first group consisted of four practitioners (OHSP_02, OHSP_03, OHSP_05 and OHSP_06) who became involved in implementing and maintaining the scheme from a position within the organisation. They were employed in the organisation in other job roles before becoming involved in OHS and implementing OHSM systems or joining the scheme. Two of the practitioners came from management and administration (OHSP_02, OHSP_05), one were employed to supply clients with OHS training (OHSP_06) and one had been a trade union and health and safety representative (OHSP_03).

The second group consisted of three practitioners (OHSP_07, OHSP_10 and OHSP_12) who were employed to implement an OHS system. One of them was specifically employed to implement the scheme (OHSP_10). The three practitioners did not have a degree in OHS. Two had a background in human resources management (OHSP_07 and OHSP_12) and one was educated as a teacher and had developed and implemented courses that followed assessment standards (OHSP_10).

The third group consisted of three practitioners who had diplomas or graduate diplomas in OHS (OHSP_04, OHSP_11 and OHSP_12). They were all relatively new to the organisation and spend considerable time on the shopflor or in departments familiarising themselves with the organisation. They all appeared more confident in their role as OHS practitioners. They all worked on establishing trust between themselves and first line managers and workers.

RESULTS

The results will be presented in relation to the three groupings. The characteristics of the practitioners are presented in column 1. The organisations they were employed in are presented in column 2 and their strategies are presented in relation to Kotter's eight elements in column 3 (see tables 2-4).

Table 5. Characteristics of practitioners becoming involved with implementation from a non OHS position in the company. Characteristics of the organisation and the practitioner's strategy.

Work environment practitioner	Characteristic of the organisation	Strategy to implement and maintain the scheme
OHSP_02 (**others suggested to join the scheme)** 12 years in the organisation. Worked in an administrative role close to the CEO. No prior experience in OHS.	Food storage (Coolstor) and transport. 55 fulltime permanent employee. Employs seasonal casual employees. Several locations in New Zealand. New Zealand owned. Commitment to OHS from new CEO. Member of Zero Harm. Resistance from middle management.	**Vision:** The company's goal to join the scheme (getting tertiary). **Create urgency:** Use of accidents from other organisations and references to legislation. Later the audit was used to create urgency. **Powerful coalitions:** Used top management commitment. Involved middle management in developing procedures and tools. **Empowering others:** Giving management and workers tools that were easy to use. **Communication:** Persistent in giving justification and explanations. Build on understanding.
OHSP_05 (Suggested to join the scheme) 11 years in the organisation. Was service centre manager. Worried they would kill somebody, asked overseas owner if they had safety procedures they could implement. Was then asked to implement OHS systems.	Equipment pooling. Hire, wash, repair and maintain. 330 employees distributed over several locations in NZ. Part of international business. Some top managers were against implementing OHSM systems. New CEO committed to OHS. Member of Zero Harm.	**Vision:** Used the scheme as a vision that could facilitate development of OHS standards. **Create urgency:** Established OHS committee, contacted managers weekly and used accidents to show problems. Introduced OHS key performance indicators. **Powerful coalitions:** Worked with senior manager that were positive hoping the others would follow (they came on board when new CEO came in), sought help from overseas OHS department. Worked from the bottom up. **Empowering:** Used training and feedback from Health and safety representative training to give them tools.
OHSP_06 (Suggested to join the scheme) 18 years in organisation. Designed and delivered safety training to clients. Part time auditor of the incentive scheme.	Manufacture, distribute and sell safety equipment and training. 700 employees distributed on several locations in NZ. Internationally owned. Top manager committed to OHS. Middle managers were difficult to get on board.	**Create urgency:** Used court cases and audit. **Powerful coalitions:** Used Senior management to enforce the system. **Communication, empowering others:** Worked with departments to come to understand them (communities of practice). Used training and meetings (Garbage cane). **Planning and short term wins:** Divided tasks into small steps placed in a calendar. Implemented awards to reward effort. **Consolidated** improvements by having yearly evaluations. **Institutionalising:** The scheme was in itself an institutionalisation

OHSP_03 (Had no role in joining the scheme) 20 years in the organisation. Has been a trade union delegate and Health and safety rep. Progressed to laboratory safety role and a field safety role	Crown research institute, 850 employees, highly qualified. Several locations in NZ. Member of Zero Harm	**Create urgency:** Used a mine disaster. **Established community of practice** by listening and building trust. Focused on field staff. **Empowering:** On the operational level giving management several options (solutions) to choose from

Table 6 Characteristics of practitioners employed to implementation OHSM systems. Characteristics of the organisation and the practitioner's strategy.

Work environment practitioner	Characteristic of the organisation	Strategy to implement and maintain the scheme
OHSP_07 (Suggested to join the scheme) Has a Bachelor degree in HR management. Started but did not finish GDipOHS. This was the first real job in OHS. Was employed to coordinate OHS for the whole company. Feels on her own in relation to OHS in the organisation)	Manufacture natural health products. Export. 450 employees distributed over several places in NZ, 130 on main production site. New Zealand owned. Few overseas sites.	**Vision:** The scheme would show how good they were. Reputation. **G**et in to the scheme at the lowest level and progress. **Create urgency**: Made management understand their responsibilities (legal requirements). **Powerful coalition:** Established support from management by promoting the vision. Established communities of practices around risk management. Used rewards to engage workers (cakes at meetings, vouchers for reporting incidents). **Communication**: Used every opportunity to talk about the Scheme, kept explaining elements so that people understood. Made sure managers and workers felt they were cared for. **Empower sort-term wins:** Made the 8 elements of the OHSM system simple. **Institutionalising:** Created OHS questions for HR they could use during job interviews.
OHSP_12 (Had no role in suggesting to join the scheme) No training in OHS has a diploma in HR management. Was first employed to establish OHS systems. Now General manager HR.	Crown research institute. 390 employees (280 scientists). Several sites in NZ. Part of top management not committed to OHS.	**Vision:** Getting in to the scheme was the vision when creating the OHS system. **Create urgency:** Used the scheme as an outside force to make things happen. Difficulties establishing urgency. A fatality created urgency. Used people from outside to increase pressure. **Powerful coalitions:** Worked with the positive managers (they were also the ones having staff in high risk areas) Worked around the top manager that was negative. Got middle management on board. **Empowering:** Side-lined people that did not want to participate and hope they would come on board later. **Planning and creating short term wins:** The scheme created structure and a time frame to work to. **Institutionalising:** Got OHS requirements into employment agreements.
OHSP_10 (another role) Was employed to implement the OHS system that would give them access to the scheme and levy reduction. No training in OHS. Educated as a teacher, experience in developing courses to educational standards.	Lock trucking company. 120 employees (100 truck drivers). Two sites in NZ. New Zealand owned. Owners are also employed in senior management positions. General manager wanted to join the scheme. Some owner/senior managers were opposed to implementation of OHS procedures.	**Vision:** Joining the scheme and receiving levy reduction. Used financial arguments to show that some of the systems were important. **Create urgency:** Using outside factors to create a common "enemy" that require things done (Insurance and forestry company). **Powerful coalition**: The general manager wanted to join the scheme. Worked around the difficult top manager. Used the others and hoped that he would follow. Created communities of practice with workers by meeting them on their terms. Established trust by only asking for things that were necessary and by caring for staff. **Communication**: She used the scheme to make managers and workers understand the OHS tasks needed to be carried out. **Institutionalising**: The scheme with the audit was an institutionalization of practice.

Table 7 Characteristics of practitioners with diploma in OHS and new to the organisation. Characteristics of the organisation and the practitioner's strategy.

Work environment practitioner	Characteristic of the organisation	Strategy to implement and maintain the scheme
OHSP_04 (Suggested to join the scheme) Parents were OHS consultants. Became involved with OHS as HS representative. Has a GDipOHS, Has had previous jobs as OHS coordinator. This organisation had not had an OHS manager before she was employed. New CEO demanded an OHS manager.	Food and Beveridge. Import/export, production, and distribution. 520 employees. Several locations in NZ. Owned by overseas company. Managing director committed to OHS (opens all OHS courses)	**Vision:** The levy discount in relation to senior management. Also to consolidate the different systems in to one OHSM system by using the scheme. **Creating urgency:** Used deadlines. **Powerful coalitions:** Relied on full support from top management. **Commentating:** Visited each site four times a year. Took all opportunities to communicate the OHS message (Garbage cane). Implemented OHS induction e-learning. **Empowering:** Gave people confidence by pointing out what they were good at. **Planning, creating short-term wins**: Formed community of practices with middle management and workers. Recognising what they were good at. Involved people in changes. Identified people’s problems and helped solve them. Implemented the system bit by bit making sure all departments could identify a bit of them self in procedures (taking the best from different departments).
OHSP_08 (Decided to leave the scheme, to re-enter) Diploma in OHS, worked in OHS for other large companies.	Pack house, Receive sort, pack and distribute fruit to market. 250 permanent employees, up to 3000 employees during packing season (3 month). Permanent staff skilled, casual unskilled. Several sites in NZ. Generally committed to OHS.	**Vision:** Discount and reputation for management. Used the aim of re-entering the scheme to improve practices and procedures. For the practitioner the scheme was the vehicle. Best practice was the vision. **Creating urgency:** Used a mine disaster to highlight management obligations. Informed top-management about injuries and injury causation. Used the outcome of the audit to show senior management that they needed to improve. **Powerful coalitions:** Established close relation with the person managing food safety (core to the business). Based relations to managers and workers on trust. Spend many hours in the production. **Communication:** Used accidents as opportunity for communication. **Empowering:** Provided good simple tools. **Planning:** Created plans for change (5 year plan for implementing machine guarding). **Institutionalise:** Integrating OHS and food safety audit. The scheme consolidates the OHS system.
OHSP_11 (Was employed to re-enter the scheme). GdipOHS. Worked in OHS and quality management in other organisations. 10 years’ experience in OHS.	Fabricate and assemble hydraulic machines, 90 employees (½ on salary, ½ on wages). One site in New Zealand, Overseas owned. Produce to export. Committed to OHS.	**Create urgency:** Used injuries and injury management; highlighted the consequences of incidents. **Powerful coalitions:** Spend considerable time finding out how the organisation functioned. Focused on building trust by solving small, often technical problems; entering community of practice. Identified advocates for OHS on the shopflor. Involved managers to do inspections. **Communication:** Communicated by asking questions, letting managers and workers come up with answers/solutions. **Empowering:** Creating tools that were simple and fast to use (e.g. incident reporting forms that took 30 seconds to fill in). **Planning and short-term wins:** by implementing and improving the OHSM system element by element and solving “small” problems on the shopflor.

DISCUSSION

The practitioners' strategies are summarised below in relation to Kotter's elements. The variations in strategies are highlighted in relation to the practitioners' different situation in the organisation and in relation to some of the contextual factors emphasised by the practitioners during the interview.

Vision:

Two practitioners coming from management position and administrative position described a clear vision. Both described the vision as joining the scheme, but for the practitioner that came from the management position the aim was also to create OHS procedures because there were no procedures in place. For the three practitioners employed to implement OHSM systems and two newly employed the vision was to enter the scheme and receive the levy discount. This was particularly used to get buy in from top management. Some of the practitioners pointed out that their personal vision was to improve the practices and the scheme was just a vehicle.

Urgency:

Practitioner that experienced resistance from part of senior management used different strategies to establish urgency compared to practitioners that had support from top management. One relied on a bottom-up strategy; implementing OHS key performance indicators for middle management and established OHS committees. Two that were employed to establish OHSM systems tried to create urgency by using external requirements from the client or the insurance company. A fatality created urgency for one of them. Several practitioners across the three groups used internal or external accidents or court cases. Some referred to management legal obligation. This indicates that they both rely on ethical and legal arguments to establish urgency.

Power full coalitions:

Two practitioners with support from senior management experienced resistance from middle management which they tried to overcome by working with them and create tools that were simple to use. One practitioner that experienced resistance from some senior managers sought support from overseas OHS department and the OHS committee and worked around the negative top managers. The two practitioners employed to implement OHSM systems that also experienced resistance from senior management worked with the senior managers and middle managers who were positive towards OHS and hoped to get the negative managers on board later. One practitioner formed a coalition with the person managing food safety which was a core business for the organisation and managed to integrate OHS audit with food safety audit. This indicates that there is a need for the OHS practitioners to do organisational work as Theberge and Neumann (2010) found but it seems like some practitioners avoid it when it comes to try and convert non-committed senior managers to engage in implementation of OHSM systems.

Empowering people to act:

Practitioners across the three groups worked with middle management to help them establish practices and to create or become members of communities of practice, to create trust. Many developed tools that were easy for managers and workers to use. Particularly the practitioners with education in OHS who were newly employed in the organisation focused on establish trust by working with middle management. One focused particularly on finding things they were good at to establish a positive relationship and give people confidence. This practitioner also made a point of creating systems that every department identify a piece that came from their department. Again this shows that the practitioners need to do organisational work to establish trust and to be able to implement part of OHSM systems.

Planning and short-term wins:
Many of the practitioners divided the implementation into bits (one part of the OHSM system at a time). One established awards to reward the effort people put in. One used the scheme to create structure and time frames for management of OHS.

Consolidating and institutionalising:
One practitioner established a yearly evaluation and a calendar with specific tasks for each month. Two stated that the scheme was an institutionalisation of the OHSM system and practices. Two practitioners with human resource management background implemented OHS requirements into the employment agreement and created OHS questions to be included in job interviews. One integrated the OHS audit with food safety audit which was essential to be able to sell their products.

The description above indicate that the practitioners shape and create their strategies in relation to the situation in the organisation and that they have a personal political agenda to improve the work environment, which indicate that they act as political reflective navigators as Broberg and Hermund (2004) have found was necessary for external consultants. Further it indicates that practitioners use a combination of knowledge strategies and regulation strategies (Hasle & Sørensen, 2011) and finally they have to do organisational work before being able to implement OHSM systems (Theberge & Neumann, 2010).

CONCLUSIONS
Work environment practitioners used economic incentive to get senior management committed to implement the national economic incentive scheme based on audited OHSM systems. Practitioners who experienced resistance from part of the senior management team used pressure from external stakeholders like clients and insurance company and used examples of accidents and court cases to create urgency to implement the scheme. They created coalitions with committed senior and middle managers to implement the scheme. Practitioners with support from senior management can pay their attention to create communities of practice with middle management to make them committed to implement the system and practices in the departments. All practitioners seem to rely on a strategy where they enter a community of practice with middle managers and workers to create trust and succeed in implementing procedures. Some establish awards and rewards for participating. A few practitioners manage to consolidate and institutionalise parts of the system by integrating OHS in key performance indicators, employment agreements, job interviews and audits related to the core business (food safety audit). The practitioners' strategies are both formed by their previous experience and by the commitment and resistance by senior managers and middle managers.

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A STRATEGY TO ADDRESS THE NEEDS OF SMALL BUSINESSES IN PREVENTION OF MUSCULOSKELETAL DISORDERS

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KEYWORDS
Musculoskeletal Disorders, Ergonomics, Small Businesses, Prevention

SUMMATIVE STATEMENT
A message based upon mitigating a major risk factor for development of low back pain, lifting with the hands close to the floor - was developed: Store-it-off-the-Floor. The message was well received by the small business. Such an approach has the potential to reduce a major hazard for developing or aggravating low back pain in large numbers of people.

Une stratégie pour répondre aux besoins des petites entreprises quant à la prévention des troubles musculosquelettiques

MOTS-CLÉS
Troubles musculosquelettiques, ergonomie, petites entreprises, prévention

SOMMAIRE
Un message servant à atténuer un important facteur de risque lié à la manifestation de douleurs lombaires (c.-à-d. soulever une charge à partir du plancher) a été conçu : « Store-it-off-the-Floor ». Ce message a été bien accueilli par la petite entreprise. Une telle démarche a la possibilité de réduire un risque majeur de présenter des douleurs lombaires ou de les aggraver chez un grand nombre de personnes.

PROBLEM STATEMENT
The lifting of objects is a common hazard for low back pain and injury, both inside and outside of the workplace. Recognition of situations where lifting could increase the risk of low back pain is needed in order to intervene to reduce risk. Although there are many such methods available to experts and ergonomists, they are too complex for small and micro businesses. This is critical as a large proportion of the population works in these small and micro businesses. The challenge is to develop an approach that matches the needs and knowledge of these businesses.

RESEARCH OBJECTIVE
The purpose of this research was to develop and test an approach to address the needs of small business for prevention of MSD.

METHODOLOGY

The project had four main parts: 1) developing the scientific evidence to support the concept underlying the message, 2) testing the message's effect of improving people's perception of low back injury risk, 3) surveying the needs and capabilities of micro and small business for low back pain hazards and controls and 4) testing the message and knowledge transfer method in small and micro businesses.

RESULTS

The review confirmed lifting height as the major, potentially modifiable risk factor for light to moderate loads. This supports a focus on avoiding lifting from low heights; below the knee level and especially from the floor. One counter-measure would be to have manually handled materials stored off the floor. A simple but powerful message about injury prevention during manual materials handling - "store-it-off-the-floor" – was developed. The message achieved its goal of improving hazard identification during lifting in controlled settings. The survey of small and micro business showed low to moderate knowledge of physical loading of the body and musculoskeletal disorders but in terms of controlling the hazards, they relied heavily on the ineffective control of "proper lifting ". They also expressed a preference for simpler knowledge transfer formats such as posters and tip sheets. The information above was then used to develop and test a low back pain prevention approach. The message, in conjunction with graphics, tips and explanations, was delivered in a letter-sized format that could function both as a small poster and as the basis of a "tool-box-talk". This was taken to a sample of 40 small and micro businesses who were followed up 2-4 later. The message and approach was found to improve businesses' knowledge of low back pain prevention and actually initiated appropriate controls in approximately one quarter of businesses surveyed.

DISCUSSION

The results of this study suggests that the action-oriented and simple messages by targeting work design and addressing lifting strategy for prevention of MSD is essential for micro and small businesses.

CONCLUSIONS

The message and approach was found to be effective in improving knowledge of hazards for the development of low back pain and for choice of controls. Given that it is difficulty to introduce "ergonomics" into micro and small business and the large proportion of workers employed in these companies, the effectiveness of the approach is encouraging. The findings of the project should be of use other researchers and practitioners in injury prevention and by the Health and Safety System to help develop low back pain and other musculoskeletal disorder prevention activities in micro and small businesses.

ACKNOWLEDGEMENTS

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Symposium B: Methods and Tools in Human Factors for Healthcare Environment Design

Symposium B: Méthodes et outils ergonomiques pour concevoir des milieux de santé

COLLABORATIVE DESIGN OF CANADA'S FIRST STROKE AMBULANCE

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KEYWORDS
Collaborative Design, Stroke, Ambulance, Mock-up Simulations, EMS

MAIN MESSAGE
Early diagnosis and intervention of strokes is essential for better patient outcomes. To improve response times, Alberta Health Services (AHS) with the University of Alberta Hospital Foundation undertook the task to design, build and introduce the first mobile stroke ambulance in Canada. A huge collaborative effort involving EMS and the Patient Care Simulation program, Workplace Health & Safety (WHS) and Ergonomics, Human Factors, Diagnostic Imaging, and Stroke Program Nurses and Physicians was undertaken to define program and user needs, construct and evaluate a mock-up of the proposed design using patient simulation, and finalize the stroke ambulance design for construction.

Une conception collaborative pour la première ambulance canadienne dédiée aux AVC

MOT-CLÉS
Conception collaborative, AVC, ambulance, simulations de maquette, sevices médicaux d'urgence (EMS)

MESSAGE PRINCIPAL
Lorsqu'une personne est victime d'un AVC, le diagnostic et l'intervention précoces sont essentiels pour obtenir de meilleurs résultats pour le patient. Dans le but d'améliorer les délais d'intervention, les services de santé de l'Alberta (AHS), en collaboration avec la Fondation de l'hôpital de l'Université de l'Alberta, ont entrepris la conception, la construction et le lancement de la première ambulance canadienne destinée aux AVC. Un énorme travail de collaboration, réunissant les services médicaux d'urgence, le programme de simulation de soins aux patients, des professionnels en santé et sécurité du travail, des ergonomes, des spécialistes en imagerie diagnostique ainsi que des infirmières et des médecins impliqués dans le programme des AVC, a été entrepris afin de définir les besoins des programmes et des utilisateurs, de fabriquer et d'évaluer une maquette de la conception proposée à l'aide de la simulation de patients et de finaliser la conception de l'ambulance dédiée aux AVC pour qu'elle soit construite.

PROBLEM
To improve response times for stroke diagnosis and treatment, the challenge was to design and build a complete Advanced Life Support ambulance that also incorporated a head CT scanner and blood lab analysis equipment within the patient treatment compartment to rapidly assess and begin treatment of a stroke. As there are so few of these vehicles worldwide there is no standard design on which to base the AHS design. It was unknown if

the proposed physical size of patient compartment would allow for the installation of the CT scanner while still enabling staff to move safely around the patient to access equipment and supplies to provide care as required (e.g., respond to a cardiac arrest or other emergency situation). As well geographical considerations such as frigid winter temperatures necessitate the relocation of staff during a scan to reduce exposure to the CT radiation, therefore additional workspaces needed to be incorporated. The main objective of this study was to test the proposed design using mock-up simulation techniques, to ensure the physical space would be adequate for the functional tasks, to optimize the design to meet user needs and improve the efficiency and effectiveness of care provided in the vehicle.

CONTEXT

AHS is a provincial healthcare organization structured across five zones. In the Edmonton Zone of AHS, the University of Alberta Hospital (UAH) stroke program cares for approximately 2500 patients/year. An opportunity to expand stroke services and reduce response times to rural areas around Edmonton by providing a mobile CT scanner in an ambulance was identified.

At the time of this study there were only five mobile stroke ambulances worldwide, with two located in the United States, and three located in Europe. The mobile stroke ambulance to be designed and operationalized in Alberta Canada required unique patient care delivery processes, colder climates, and rural road conditions to be addressed in the design discussions. As this was going to be a new design with different elements than previous vehicles, the need to develop and mock-up the design using a collaborative approach was recognized, to optimize efficiency, patient safety and worker safety.

ACTIONS

A multi-disciplinary working group was formed to detail specifications for a mobile stroke ambulance response program and vehicle. The group included EMS and the Patient Care Simulation program, Workplace Health & Safety (WHS) and Ergonomics, Human Factors, Diagnostic Imaging, and Stroke Program Nurses and Physicians.

A sub-committee of the main working group consisting of EMS Patient Care Simulation, Human Factors and WHS Ergonomics focused on the creation and facilitation of a full-scale mock-up evaluation of the stroke ambulance using frontline EMS, Nursing and Stroke program personnel to enact specific clinical scenarios. The mock-up was considered to be an important part of the design process, to allow a “test drive” of the new environment, gather feedback on the design from frontline users and ensure the physical constraints of the vehicle would not impact patient care. The use of simulation based mock-up evaluations in designing new healthcare environments has been successfully used in a number of healthcare environments such as intensive care patient rooms, operating rooms and patient care spaces (Health Quality Council of Alberta, March 2016; Chisholm et al, 2008; Hignett et al, 2010) and was an ideal method to test out the confined space of the stroke assessment ambulance.

The physical mock-up environment of the proposed patient treatment compartment was constructed within the EMS warehouse and consisted of outer walls constructed from aluminum and metal framing (from the existing shelving) with cardboard walls. Both modular cardboard and real cabinetry were installed within the compartment to represent the size of supply storage areas, and these could be repositioned as needed allowing different configurations to be easily created and tested. A mobile CT scanner was built to specifications using medium density foam to within 2cm to mimic the mobility and physical size of the CT scanner within the vehicle. All additional equipment including chairs, cardiac monitors, computers, tablets, gloves, supplies and EMS kits were populated in the mock-up environment.

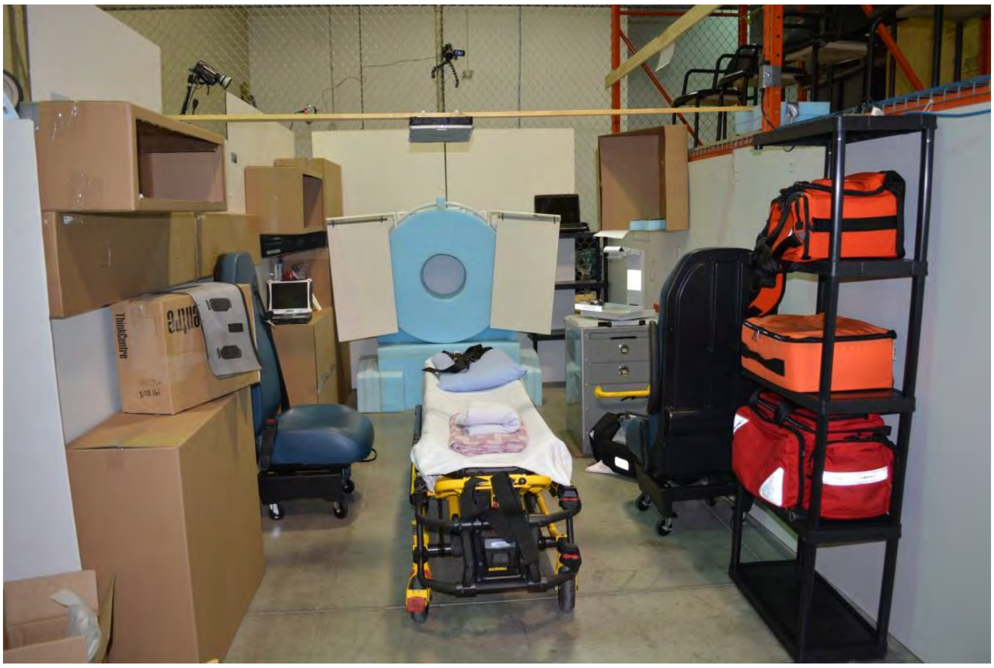

Figure 1. Initial mock-up of the proposed stroke ambulance design

Four simulated clinical scenarios were run by frontline practitioners (Two EMS Practitioners, Diagnostic Imaging CT Operator, Stroke Nurse, Stroke Fellow), with patients represented by high fidelity patient simulators, standardized patients, and use of a bariatric suit. The simulated clinical events included:

- Transfer of patient and information from EMS unit to the stroke ambulance
- Assessment of stroke patient (verbal, CT scanning, communication to the receiving hospital) and treatment of stroke through administration of thrombolytic therapy
- Cardiac arrest during CT scanning
- Bariatric patient simulation

An observer gallery space was available during the mock-up, allowing unobstructed views into the mock-up area. This allowed the multi-discipline working group members and other stakeholders to observe the events without impacting the workflow in the mock-up vehicle. Feedback, discussions, and problem solving strategies were explored verbally during the mock-up day during debrief discussions following each scenario, and in greater detail during a final debriefing of the mock-ups with both participants and observers at the conclusion of the evaluation day.

Video and photos of the simulated clinical events, and specific design modifications made through movements of the modular components within the vehicle, were captured throughout the day.

OUTCOMES

The mock-up simulations generated a lot of feedback and identified a number of good features and challenges with performing patient care within the environment and working with the CT scanner. With the flexibility of the mock-up space, adjustments to the layout of equipment and storage locations could be made based on debriefing discussions and feedback from the broader working group. Re-tests could then be done in the new layout during subsequent scenario enactments in the mock-up environment to ensure it improved the design and did not introduce new challenges. Compared to the initial test layout which was based on other existing stroke ambulance layouts, some key changes that were made included:

- Swapping the RN and EMS positions and associated equipment in the compartment for clearer pathways (reduce tripping hazard with the cardiac monitor cables)
- Relocating the diagnostic imaging workstation from the head to the rear of the patient compartment
- Identifying the need for a flip down seat and a flip down work surface at the rear of the patient compartment to provide usable work areas when required, yet ensure clearance for physical movement in the compartment when not in use
- Removal of the equipment tree
- Consideration for lead shielding in the front portion of the patient compartment (to protect workers from CT radiation, while they are in the front cab to keep warm from winter elements during CT operation by the DI Operator)

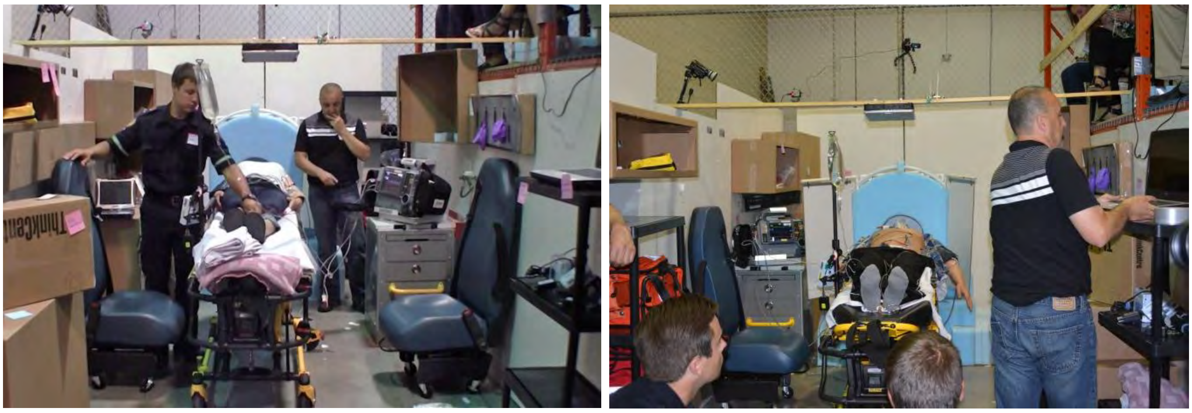

Figure 2. Original layout (left) with tripping hazards and new layout (right) with cardiac monitor on opposite side

DISCUSSION

The mock-up and simulation events facilitated the finalization of the patient treatment compartment design for the stroke ambulance. The inclusion of the various teams and disciplines ensured that the appropriate expertise were utilized and brought to the table early in the design process, which allowed for design changes to be made to the stroke ambulance to ensure it was optimized to meet the stroke program's needs.
Simulation based scenario enactments in mock-up environments enable participants to perform their work as they normally would rather than just "imagining" how they might work in a new space and provide insight on how to optimize the environment. These evaluation methods are more realistic, immersive, and results in more applicable recommendations for design improvements that are effective. Mock-ups are a useful tool to test out the physical size of a space, optimize equipment storage based on workflow and observe the interactions between the personnel and their environments.

The stroke ambulance has now been built, and a full-scale simulation and training event was run in January 2017 with the actual vehicle to finalize processes and workflows and make any last tweaks needed before beginning patient care. The vehicle has been in operation since February 2017. Between February 6th and May 17th 2017, the stroke ambulance has responded to 17 patients, for which 17 CT scans have been completed, and thrombolytics have been administered 7 times as a result of the CT scan.

CONCLUSION

While mock-up simulations require time and resources, they are invaluable for testing and improving on designs in a cost-effective and evidence-based manner resulting in an optimal final product. In this project, the benefits of the tested and effective mobile stroke ambulance design are now being realized by both practitioners and patients.

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HOSPITAL ROOM MOCK-UPS: OPTIMIZING RETURN-ON-INVESTMENT AND PATIENT SAFETY

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KEYWORDS
Simulation-based mock-up evaluation, mock-ups, hospital design, ROI, patient safety.

MAIN MESSAGE
Conducting simulation-based mock-up evaluations as part of the design process can enhance patient safety, staff efficiency, user experience, and can yield financial returns. Using virtual-reality mock-ups offers additional distinct advantages such as cost efficiencies, increased interaction capabilities earlier in the design process, and automated data collection / analysis. The advantages and disadvantages of using two different types of mock ups, physical and virtual reality, to evaluate a medication room will be discussed. Predictive validity of the findings will also be discussed.

Maquettes de chambre d'hôpital : optimiser le rendement du capital investi et la sécurité des patients

MOTS-CLÉS
Évaluation de maquettes, maquettes, conception hospitalière, RCI, sécurité des patients safety.

MESSAGE PRINCIPAL
En procédant à des évaluations de maquettes dans le cadre du processus de conception, cela peut améliorer la sécurité des patients, l'efficacité du personnel, l'expérience utilisateur et la rentabilité. L'utilisation de maquettes virtuelles offre d'autres avantages distincts tels que des économies de coût, des capacités d'interaction accrues plus tôt dans le processus de conception et des outils automatisés de collecte et d'analyse de données. Les avantages et les inconvénients associés à l'utilisation de deux maquettes différentes, soit une maquette physique et une maquette virtuelle, pour évaluer une salle de préparation de médicaments seront discutés. La validité prédictive des résultats sera également abordée.

PROBLEM
Designing or renovating a physical environment for healthcare is a complex process, and is critical for both the staff and patients who rely on the environment to support and facilitate patient care. A poorly designed space can inadvertently introduce hazards for both the patient and healthcare workers. Many of these hazardous scenarios can be anticipated and avoided by involving users in the design process to help the end product meet their needs.

CONTEXT
The Health Quality Council of Alberta recently released the Simulation-based Mock-up Evaluation Framework (HQCA, 2016) which is intended to be a guidance document for evaluating healthcare environment mock-ups. In this project, three different types of mock-ups (simple, detailed, and virtual reality) are evaluated to develop evidence-based guidelines

outlining which type of mock-up would optimize cost effectiveness (return-on-investment) and outcomes (identified hazards, design opportunities, etc.). A simple mock-up is built using tape and cardboard boxes to indicate walls and cabinets. A detailed mock-up is built with walls, real cabinets, and is furnished. A virtual reality (VR) mock-up uses immersive and interactive 3D visualisations within a virtual environment.

ACTIONS

A simulation-based mock-up evaluation was performed within two of the three mock-up types: simple and virtual reality (see Figure 1). The third mock-up type, a detailed mock-up, will be performed in the near future. Two medication room layouts were evaluated using each mock-up type. The first layout replicated an existing surgical in-patient medication room. Data from the two mock-ups was compared to data from a post-occupancy evaluation (POE) of the existing medication room revealed design successes and opportunities that the mock-up evaluations were attempting to predict. The second layout used the same foot print as the existing medication room but items within the room were reconfigured to incorporate design recommendations generated by the POE (see Figure 2).

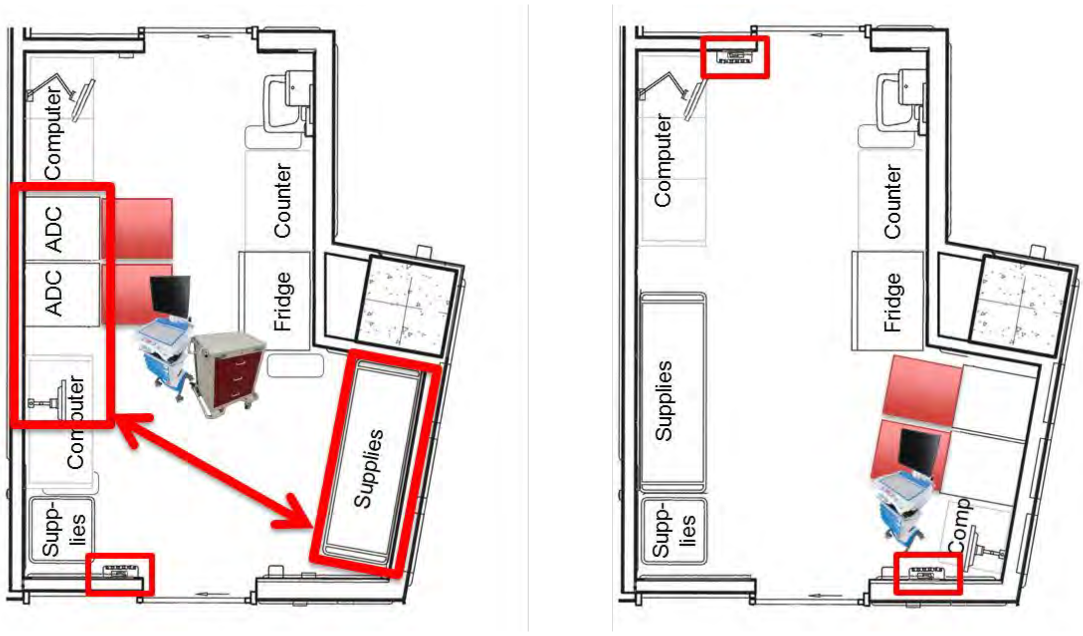

Figure 1. Evaluations were conducted within the existing medication room (left), simple mock-up (center), and virtual reality mock-up (right).

Figure 2. Two medication room layouts were tested. One was modelled after an existing medication room (left) and one incorporated design recommendations generated from a POE of the existing medication room (right).

The mock-up evaluations followed the evaluation process described in the Simulation-based Mock-up Evaluation Framework (www.hqca.ca/humanfactors; HQCA, 2016), which was recently released by the Health Quality Council of Alberta. This involved developing relevant clinical scenarios which were performed by clinical teams within a medication room mock-up. Four scenarios were developed which involved a range from one to four people preparing or stocking medications. Each mock-up type was evaluated over three days. Each day involved having five clinical staff (nursing and pharmacy) enact the four scenarios in each of the room layouts (totalling eight scenario enactments). The order that each room layout was evaluated was counterbalanced. Fifteen people participated in the evaluation of the simple mock-up. Fourteen people participated in the evaluation of virtual reality mock-up.

Following each of the eight scenario enactments, focus groups and surveys were used to solicit feedback from participants regarding the design of the medication room. Evidence-based data was also collected through video analysis, specifically behavioral coding and link analysis. Behavioural coding categories included access issues, adjustments of equipment inside the room, bumps, communication issues, congestion, cord or cable snags, distractions, excessive reaches, interruptions, line snags, searching behaviours, tripping hazards, usability issues, visibility issues, verbalized suggestions, and time spent in room. The link analysis involved transcribing lines onto an architectural drawing to indicate where individuals involved in the scenario enactments moved from and to in order to visualize workflow within the existing medications room, the simple mock-up, and the virtual reality mock-up (see Figure 3). The VR software allowed data analysis (both behavioural coding and link analysis) to be fully automated.

Figure 3. Link analysis depicting workflow over two hours in an existing medication room (left) as well as a simulation scenario enacted within a simple mock-up (center) and a virtual reality mock-up (right).

OUTCOMES

The POE of the built medication room indicated that congestion was one of the most common causes of interruptions during medication preparation. Research clearly demonstrates linkages between interruptions and medication preparation errors. Secondly, findings suggested that access to medications and supplies was hindered when multiple people prepared medications simultaneously; specifically interruptions, congestion, or bumps were three times more likely to occur with each additional person in the room. An alternate room configuration was proposed and tested using each mock-up type. Data analysis is in progress.

To assess validity of automated data analysis, some scenarios will be manually coded for comparison. To assess validity of the mock-up evaluation process, findings from the mock-up evaluations will be compared to findings from the POE. Return-on-investment will be calculated using the ROI Methodology (ROI Institute, 2014). The ROI Methodology is a balanced approach to measurement that captures six types of data:

1. Reaction and Planned Action
2. Learning
3. Application and Implementation
4. Business Impact
5. Return on Investment
6. Intangibles

CONCLUSION

To maximize effectiveness, the evaluation scope should be determined before the design process begins. The scope should include evaluation objectives, time and costs required, and identify when in the design process the evaluation should occur.

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INTEGRATING RESEARCH, EDUCATION AND PRACTICE IN THE HEALTHCARE FACILITY DESIGN PROCESS THROUGH THE USE OF PHYSICAL MOCK-UPS

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KEY WORDS
Operating room design, mock-up evaluations, systems approach

MAIN MESSAGE: Iterative development and testing of design ideas through physical mock-ups of different levels of fidelity can be a promising approach to support design innovation during early design phases. Physical mock-ups can also be extremely helpful in supporting design decision-making among diverse stakeholders including students, architects, clinicians and researchers.

Intégrer la recherche, la formation et la pratique dans le processus de conception des établissements de santé à l'aide de maquettes physiques

MOTS-CLÉS
Conception de salle d'opération, évaluations de maquettes, approche systémique

MESSAGE PRINCIPAL : Le développement itératif et l'évaluation des idées de conception au moyen de maquettes physiques de divers niveaux de fidélité peuvent s'avérer une approche prometteuse pour appuyer l'innovation au cours des premières phases de conception. Les maquettes physiques peuvent aussi se révéler très utiles pour appuyer les décisions de conception entre les divers intervenants, à savoir les étudiants, les architectes, les cliniciens et les chercheurs.

PROBLEM - Clinicians struggle with understanding and interpreting architectural drawings while architects face challenges with understanding the complexity of healthcare tasks, especially during early design phases. There is a critical need for a human factors approach while designing complex healthcare environments that takes into account the interactions between stakeholder needs, technology, processes and the physical environment.

CONTEXT - The incidence of adverse events such as surgical site infections and surgical errors are a huge problem in the operating room (OR) due to the highly vulnerable state of the patient and the complex interactions required between providers of different disciplines and a range of equipment, technology and the physical space where care is provided. The dynamic medical technology and clinical practice in the OR has been changing rapidly. Increasingly, diagnostic and imaging capabilities are being incorporated in the surgical domain and procedures and surgical practices are transitioning from mostly open procedures to 'closed' techniques that are less invasive and more equipment intensive. There are many new players and sub-specialties involved in providing care in the OR. These disruptive developments are driving changes in surgical suite and procedure room design with major implications for how procedures will be done and overseen. In order to design safer and more effective OR environments, it is critical to understand how the environment supports the critical tasks that need to be performed in this environment.

Clemson University and the Medical University of South Carolina has been awarded a 4-year grant from the Agency for Healthcare Research and Quality (AHRQ) to develop a patient safety learning lab titled “Realizing Improved Patient Care through Human Centered Design in the OR” (RIPCHD.OR). This is a multidisciplinary initiative involving architects, human factors experts, industrial engineers, nurses and anaesthesiologists. The goal of the project is to develop a safer OR design that can be incorporated into two proposed ambulatory surgery centers at MUSC. The purpose of this paper is to share the iterative simulation based mock-up evaluation process that was undertaken during the pre-design phase to support a collaborative and participatory design process aimed at developing a the OR prototype for this project. The process involved graduate students of architecture, clinical stakeholders, researchers and practicing architects.

ACTIONS – The project builds upon an existing simulation-based mock-up evaluation framework developed by the Health Quality Council of Alberta (Shultz, 2016). The HQCA framework provides 6 key principles for conducting a simulation based mock-up evaluation that includes identifying suitability of process based on design phase, planning to maximize effectiveness of the process, timing of evaluation with mock-up construction efforts, delineating roles and responsibilities, creating scenarios that test objectives and then providing recommendations based on the findings from the scenario enactments. The current study built upon these principles to support the goals of the RIPCHD.OR project.

The current study was conducted within the context of a semester long graduate studio project undertaken by students in the Architecture + Health program at Clemson University. The design of the prototype OR went through 4 phases of development supported by three distinct phases of mock-up construction and evaluation conducted by the RIPCHD.OR research team. The research team also developed tools to support the mock-up evaluation with the intent of disseminating findings to the design team to facilitate iterative design development.

The team developed design guidelines to guide the development of the prototype. These guidelines were based on work conducted in the first year of the RIPCHD.OR project and included literature reviews as well as in-depth observation and coding of 35 surgeries. The design guidelines are intended to link desired OR outcomes (such as reduced distractions and disruptions, improved flows or increased flexibility) with design features that may contribute to those outcomes. The OR prototype design solutions responded to these design guidelines. Different aspects of the OR design such as OR size, location of doors, locations of workstations, and zoning within the OR were all determined as key factors contributing to these outcomes. The purpose of the mock-up evaluation was to understand how variations in these design elements (for example, different door locations) might impact the desired outcomes within the context of simulated tasks performed by surgical team members.

A range of different mock-ups were developed and evaluated over the course of four months corresponding to different degrees of design detail. The earliest mock-up was conducted using tape on the floor to support design decisions related to room size, orientation of surgical table, intra-room zoning and location of doors. Simple scenarios were developed to test the layout of the room and movement in and out of the room during different surgical phases. Feedback from the surgical team members from orthopedics and pediatrics helped to inform key decisions and narrow down the range of options. The next iteration consisted of a cardboard mock-up with a range of real OR equipment (or simulated equipment). More realistic scenarios were constructed and enacted by surgical team members and the subsequent feedback supported additional decisions regarding the location of the scrub sink, circulating nurse workstation, location of doors and types of wall-mounted displays. The final mock-up involved further narrowing down design options and development of new design ideas around alternative workflows to improve efficiency and patient experience. The enactment of the scenarios within the third mock-up helped to narrow down design options and identify innovative new ideas that could be incorporated within the prototype.

Parallel to design development and physical mock-up construction, the research team developed tools and templates to structure the mock-up evaluation process. Three key tools were developed to support the mock-up evaluation process. A master document outlined the logistics for the evaluation process (overall agenda for the evaluation, roles and responsibilities of team members, schedule for the evaluation) and the specifics of the prototype evaluation process (design objectives to be evaluated, scenarios developed to address those design objectives, tasks to be performed by participants, list of equipment and objects that needed to be included in the mock-up). The sequence of the different options that were to be evaluated was also defined in this document.

A simulation director guide was developed with a specific set of instructions for the individual directing the mock-up evaluation. A research team member who is an anesthesiologist undertook the role of the simulation director. The guide included a script introducing the project and goals of the session as well as the sequence of the scenarios and the tasks that the participants would be asked to perform. Only the simulation director, the participants (surgical team members from MUSC) and two note takers were allowed inside the mock-up during the simulations. The simulation director led a focus group discussion at the end of the scenario enactments for each option. The simulation director guide includes the questions for directing the focus groups. The format also allowed for the participants and observers to ask questions and discuss options at the end of the focus group sessions.

The third tool that was developed was a note takers template. This was designed such that it was parallel to the simulation director's guide and included the scenarios and associated tasks for each participant in the correct sequence. The note takers template was set up like a checklist to allow the note-taker to identify any environmental challenges to performing tasks. For example, the note taker would be asked to observe 'if there was a clear path of movement from the door to the surgical table' as the task of bringing in the patient stretcher was being performed by the anesthesia surgical team member. Additionally, the format allowed the note taker to take open-ended notes as needed.

Given the fast-paced cycle of design development and evaluation (similar to timelines in live healthcare facility design projects), the research team worked closely with the design students throughout the process to ensure that evolving design ideas that needed to be tested were included effectively within the mock-up evaluation protocol. This was a critical part of the process and the close coordination between the design and research team members was critical to the success of the project.

OUTCOMES - The iterative mock-up evaluation process undertaken early in the design process allowed for close interaction between students, architects, clinicians and researchers to address OR design in a holistic manner that incorporated an understanding of user roles and processes, technology and equipment interactions and spatial needs to support these interactions.

All stakeholders gained significantly from the process. The student team were able to observe first hand the potential impacts of their design on tasks and processes. Their interactions with the clinical teams helped them understand better the type and range of tasks different team members needed to perform and the role of the environment in supporting those tasks.
The use of the physical mock-ups allowed the surgical team members to easily visualize the proposed design. The simulation based mock-ups allowed the participants to perform clinically relevant tasks and provide useful feedback to the designers. The architects from the architecture firm contracted to build the new surgery centers were also present at all the mock-up evaluation sessions and contributed their perspective throughout the process. Their involvement also allowed the students to understand the practical concerns associated with different design options. The engagement of the architects was also critical in terms of translating the student design concepts into proposed designs for the new surgery center.

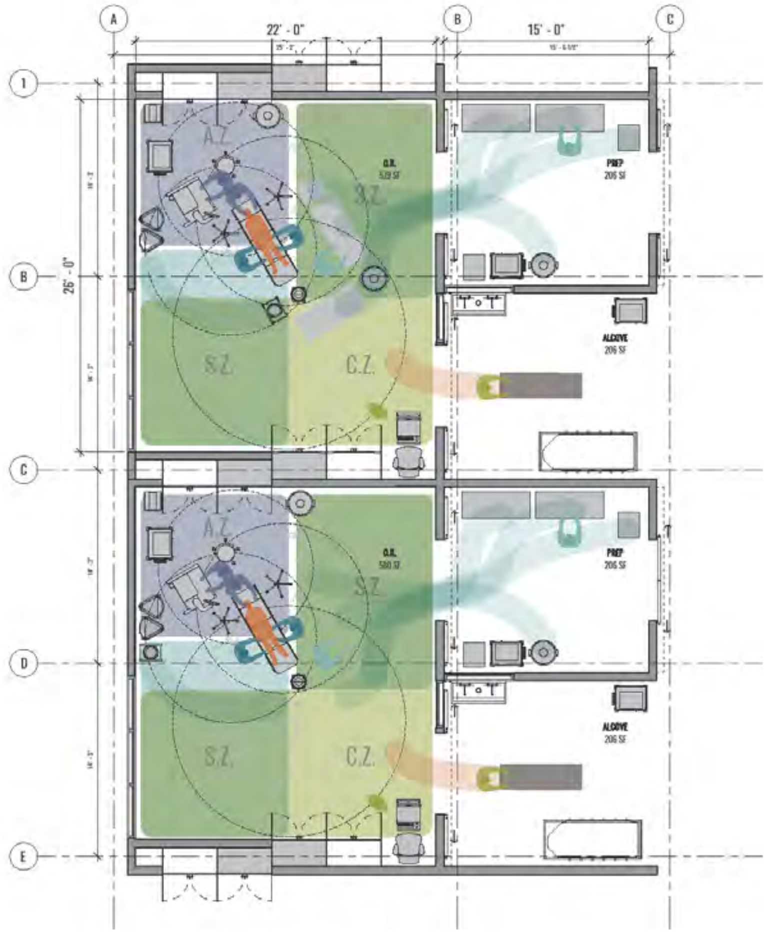

Figure 1: Final OR prototype design

The use of the different mock-up evaluation tools allowed for a structured and systematic evaluation process. The process ensured that all key design features of interest were effectively tested. The tools also allowed for quick turnaround from the evaluation phase into the next cycle of design. The mock-up design and evaluation process was integrated into a fast paced graduate studio design project and significantly contributed to an innovative end product that effectively addressed a range of diverse user needs and functional considerations (Figure 1). This OR prototype design that was developed will be constructed as a high fidelity mock-up and will include the wall and floor systems, equipment and furniture included in the final design. The mock-up evaluation tools including the clinical scenarios will be further refined and another round of simulation based mock-up evaluations will be conducted to further refine the final design. These design concepts will then be incorporated into the designs for the new ambulatory surgery centers being planned at MUSC.

DISCUSSION - The project was successful due to the iterative nature of the mock-up evaluation process that allowed for increasing degree of refinement in the design, the physical mock-ups and also the evaluation protocol. The involvement of the surgical team members in the mock-up evaluations was critical. The process, location and timing for the evaluation should facilitate the most effective use of the participants' time. The process supported the deep engagement of all stakeholders and sharing of ideas and information. Close coordination between research and design team members was also very important to the success of the project given the extremely tight timeline. A structured evaluation process was beneficial. However, there was a tendency for participants and observers to engage in discussions during the scenario enactment and sometimes break apart into smaller groups. This interrupted the flow of the simulation and also made it difficult for the note-takers to follow the different conversations. The simulation director plays a key role in managing the flow and order of the process.

CONCLUSION – There are huge benefits to undertaking an iterative mock-up design and evaluation process early in the design process as a way of spurring design innovation and team building. Detailed planning and structured tools are critical for the success of such simulation based mock-up evaluations. However, the process should also allow for some degree of flexibility to capture ideas and discussions that may emerge.

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COMPARING THREE METHODS FOR PARTICIPATORY SIMULATION OF HOSPITAL WORK SYSTEMS

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KEYWORDS
Simulation; participatory design; healthcare; hospital work systems

SUMMATIVE STATEMENT
This study compared three participatory simulation methods using different simulation objects: Low resolution table-top setup using Lego figures, full scale mock-ups, and blueprints using Lego figures. It was concluded the three objects by differences in fidelity and affordance addressed different elements of a hospital work system.

Comparaison de trois méthodes de simulation participative dans les systèmes de travail hospitaliers

MOTS-CLÉS
Simulation, conception participative, soins de santé, systèmes de travail hospitaliers

SOMMAIRE
Dans le cadre de cette étude, trois méthodes de simulation participative ont été comparées à l'aide de divers objets de simulation : des pièces de Lego sur ordinateur de faible résolution; des maquettes à échelle réelle ; et des modèles utilisant des pièces de Lego. Nous avons conclu que les trois objets, par des différences de fidélité et de mise à disposition, prenaient en compte différents éléments d'un système de travail hospitalier.

PROBLEM STATEMENT
Different methods for simulating the future work system for healthcare professionals have been applied in a number of green field and renovation design projects of hospitals in Denmark (Andersen & Broberg 2015; Andersen & Broberg 2017; Broberg & Edwards 2012). The methods differed in the type of simulation objects representing the work system. Hence, this was an opportunity to study if these differences influenced which elements of a work system were in focus when healthcare professionals simulated and evaluated future work. Preliminary observations indicated this was the case but it was not understood how and why this influence took place.

RESEARCH OBJECTIVE/QUESTION
How does the simulation object influence which elements of a work system are being evaluated in participatory simulation events?

METHODOLOGY
Observation notes and video recordings of three types of simulation events using different objects were analyzed in respect to which elements of a work system were being targeted. A

work system was defined as consisting of human work practices embedded in the three interdependent dimensions: space, organization and technology. All simulation events were based on participants playing clinical scenarios using the objects.

RESULTS

Full scale mock-ups significantly addressed the local space and technology/tool elements of a work system. In contrast, the table-top simulation object addressed the organizational issues of the future work system. The blueprint based simulation addressed the organizational issues in combination with a global space outlook, e.g. the layout of an entire department.

DISCUSSION

It is proposed that the simulation objects influence on work system focus is based on two attributes: Fidelity and affordance. Fidelity concerns the degree of resolution or the level of detail of what are being manifested by the simulation object. The affordance is a property of the object concerning how simulation participants will perceive how it may be used. When having a low-resolution model of a work system as in the table-top setup it is much easier to test a number of “what if” scenarios on how to organize the work in different spatial layouts.

In addition to the object attributes other factors may play a role in what work system elements are being addressed. An important one seems to be at which point in the hospital design process the simulation is carried out.

CONCLUSIONS

Different simulation objects may to a certain degree influence what part of a work system is being addressed in participatory simulation events. For human factors practitioners in hospital design projects it is important to pay attention to this when planning and facilitating simulation events to evaluate different designs.

ACKNOWLEDGEMENTS

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Technical Session 5: Cognitive & Sensory Ergonomics

Séance technique 5: Ergonomie cognitive et sensorielle

JOB DEMANDS AND JOB RESOURCES IN NURSERY SCHOOLS: A DIARY STUDY WITH KINDERGARTEN TEACHERS

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KEYWORDS
Nursery schools, job strain, job demands resources model, diary study

SUMMATIVE STATEMENT
A diary study in nursery schools (n = 70 employees, daily data collection over five work days) confirmed noise and time pressure as highly relevant stressors. Social support seems to be the most relevant job resource for kindergarten teachers' well-being.

Les exigences de l'emploi et les ressources dans les maternelles : étude des journaux de bord d'enseignantes de maternelle

MOTS-CLÉS
Maternelles, stress au travail, modèle de ressources des exigences physiques, étude des journaux de bord

SOMMAIRE
Une étude des journaux de bord d'enseignantes de maternelle (n = 70 employées, collecte quotidienne de données sur cinq jours de travail) a confirmé que le bruit et les contraintes de temps étaient des facteurs de stress de grande pertinence. Le soutien social semble être la ressource professionnelle la plus utile pour le bien-être des enseignantes de maternelle.

PROBLEM STATEMENT
Societal changes and the growing needs of families lead to increased demands in many educational fields in the Western world. As compared to other areas of educational work (e.g., school teachers) there is comparable little research dealing with job demands and the quality of working life of kindergarten teachers in nursery schools. Furthermore, most of the (few) existing studies are cross-sectional. These studies often indicate that work in nursery schools is a highly demanding job profile in this area of human service work. A wide range of stressors, stemming from the work environment, the task design and the organizational context, but also from social and societal conditions, are observable (e.g., Thinschmidt, 2009).

As a result, psychosomatic complaints like musculosceletal disorders, emotional exhaustion and sleeping disorders were found (e.g., Rodow, 2004; Viernickel & Voss, 2013). A study referring to a representative sample of kindergarten teachers in Germany (Viernickel et al., 2014) describes, that 9% of their sample were even diagnosed with burnout.

Detailed studies focusing on which specific job demand and job resources are linked to daily job strain in kindergarten teachers are still missing. Since job demands may fluctuate from day to day (Fisher & To, 2012; Ohly et al., 2010), a daily diary study was conducted to capture such changes.

RESEARCH OBJECTIVE/QUESTION

The aim of the current study is the investigation of the links of daily job demands and daily job resources to daily job strain in kindergarten teachers. To investigate day-level stressor-strain relationships, a diary study approach was used (e.g., Fisher & To, 2012; Ohly et al., 2010). Based on the Job Demands-Resources (JD-R) model (e.g., Bakker & Demerouti, 2007), the study focuses on job demands related to specific tasks and the working environment of kindergarten teachers. Based on the JD-R model, we expected that job resources reduce day-level strain in kindergarten teachers.

METHODOLOGY

A diary study approach is based on multiple measurement occasions within a comparably short period of time (Fisher & To, 2012; Ohly et al., 2012), thus allowing the analysis of within person relationships. Another advantage of diary studies is the observation of daily working life, while at the same time reducing memory distortions.
Based on a comprehensive literature analysis, expert interviews, and a focus group, a list of specific job demands of kindergarten teachers was compiled. Noise, time pressure and job interruptions were finally selected as the three most relevant job demands. Social support and job control were selected as important job resources. As indicators of job strain daily cognitive irritation and emotional exhaustion were measured.

Because a diary approach was realized, all variables were measured using three-item short scales that were adapted for the context of a daily diary study (see Table 1).

Table 1: Scales used in the diary study

DIMENSION	SOURCE	MEAN CRONBACH'S ALPHA
Emotional exhaustion	MBI; Schaufeli et al., 1996	.86 - .87
Cognitive irritation	Mohr et al., 2007	.89
Noise	ISTA; Semmer et al., 1999	.90
Time pressure	ISTA; Semmer et al., 1999	.74
Interruptions	ISTA; Semmer et al., 1999	.79
Social support	SALSA; Rimann & Udris, 1997	.65
Job control	ISTA; Semmer et al., 1999	.78

Three daily measurements (in the morning before work, in the afternoon after finishing work, and in the evening before bedtime) over five consecutive working days were realized (see Figure 1). Emotional exhaustion was measured in the morning and in the evening. Cognitive irritation was measured in the evening. The specific job demands and job resources of each working day were evaluated in the afternoon at the end of the respective working day. The study participants received SMS reminders on their cell phones for each measurement.

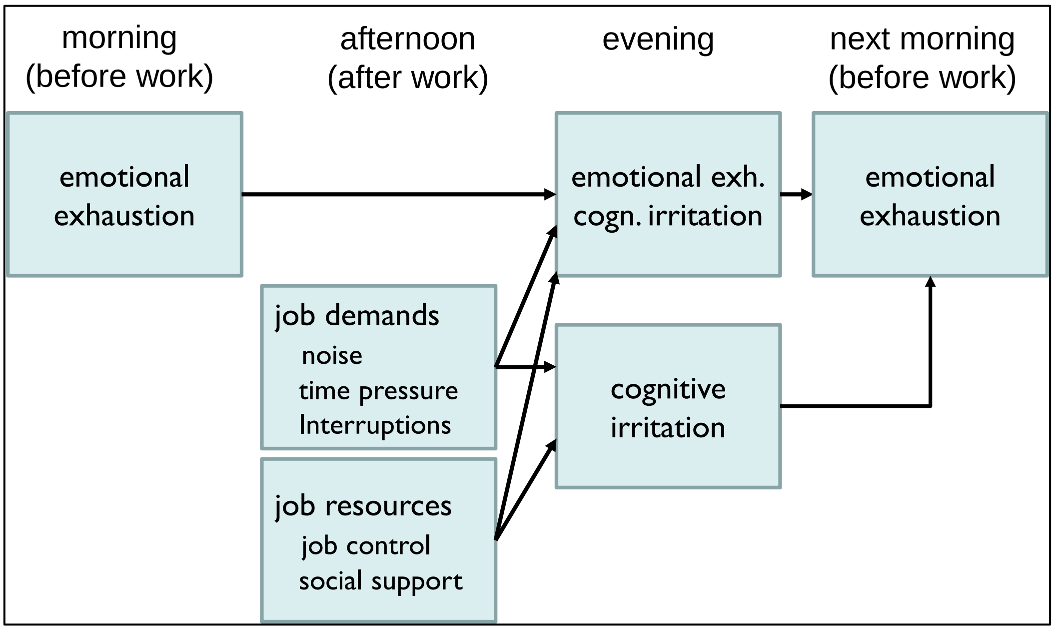

Figure 1: Summary of the research model.

The study sample consists of 70 kindergarten teachers in Austria. All participants were female and their average age was 36.8 years. Mean job tenure was 14.2 years. Most of the study participants were working full-time (mean= 35.3 hours per week). Overall, 349 day-level data sets were available for multilevel analyses in Mplus 7.3 (Muthén & Muthén, 1998–2012).

RESULTS

Table 2 shows the descriptive overall results. As expected there was substantial within-person variance in all study variables calling for multilevel analyses to investigate day-level within-person relationships.

Table 2: Means, standard deviations, and correlations of the study variables (range: 1-5).

	M	SD_b	SD_w	1-ICC	1	2	3	4	5	6	7	8	9
1 EE (morning)	1.66	0.56	0.66	58%	-	.18	.08	.05	-.14	-.08	.26	.06	.07
2 Noise	2.39	0.68	0.79	57%	.38	-	.37	.38	-.20	-.21	.27	.19	.22
3 Time Pressure	1.85	0.48	0.60	61%	.33	.44	-	.67	-.12	-.24	.16	.23	.14
4 Interruptions	2.09	0.68	0.64	47%	.31	.47	.95	-	-.15	-.23	.09	.18	.13
5 Social Support	4.10	0.81	0.53	30%	-.26	-.43	-.53	-.44	-	.31	-.28	-.21	-.18
6 Job Control	3.93	0.73	0.76	52%	-.22	-.26	-.48	-.37	.49	-	-.23	-.09	-.12
7 EE (evening)	2.31	0.75	0.20	53%	.61	.46	.47	.45	-.42	-.09	-	.47	.35
8 CI (evening)	2.44	0.85	0.87	51%	.41	.34	.56	.53	-.48	-.10	.45	-	.27
9 EE (next day)	1.66	0.58	0.65	55%	.99	.40	.38	.37	-.34	-.23	.66	.44	-

Note. Correlations below the diagonal are person-level correlations (N=70); correlations above the diagonal are within-person correlations (n=349); EE = emotional exhaustion; CI = cognitive irritation; 1-ICC = within-person variance.

Multilevel multiple regression analyses with predictors centered at the person mean (see Table 3) revealed that daily noise at work was more strongly related to emotional exhaustion during the evening as well at the next day before work, whereas daily time pressure predicted cognitive irritation during the evening. Day-level interruption at work affected neither of the outcome variables. Day-level social support had beneficial effects on both emotional exhaustion during the evening as well as cognitive irritation during the evening, whereas daily job control only showed beneficial effects on emotional exhaustion during the evening.

Table 3: Multilevel multiple regression analyses predicting job strain indicators.

	EE (evening)		**Cogn. Irritation (evening)**		**EE (next day before work)**	
	b	***SE***	***b***	***SE***	***b***	***SE***
Intercept	2.29***	0.10	2.43***	0.11	1.65***	0.07
EE (before work)	0.20**	0.01	-0.03	0.08	-0.14	0.08
Noise (after work)	0.18**	0.06	0.11	0.07	0.14*	0.07
Time Pressure (after	0.14	0.10	0.25*	0.12	0.06	0.11
Interruptions (after work)	-0.14	0.10	0.01	0.11	0.02	0.10
Job Control (after work)	-0.14*	0.06	0.03	0.07	-0.07	0.06
Social Support (after	-0.29**	0.09	-0.30**	0.10	-0.15	0.10
-2LL	862.43		958.62		629.44	
L1 intercept variance (*SE*)	0.52 (0.05)		0.71 (0.06)		0.45 (0.05)	
L2 intercept variance (*SE*)	0.56 (0.11)		0.71 (0.15)		0.23 (0.06)	

Note. Predictors were person-mean centered before analyses.

Because multilevel multiple regression analyses showed no effects of day-level interruptions on any outcome variables (compare Table 3) and also because day-level interruptions showed a rather high within-person correlation with daily time pressure (compare Table 2), we excluded interruptions from further analyses.

Results from multilevel structural equation modeling (e.g., Preacher et al., 2010) are shown in Figure 2. The main effects were comparable to those of the previously conducted multilevel multiple regression analyses. As expected, a strong main effect of perceptions of noise on emotional exhaustion was found. Time pressure showed significant negative effects on cognitive irritation. Significant positive direct effects of job control and perceptions of social support on emotional exhaustion in the evening confirmed their role as important job resources.

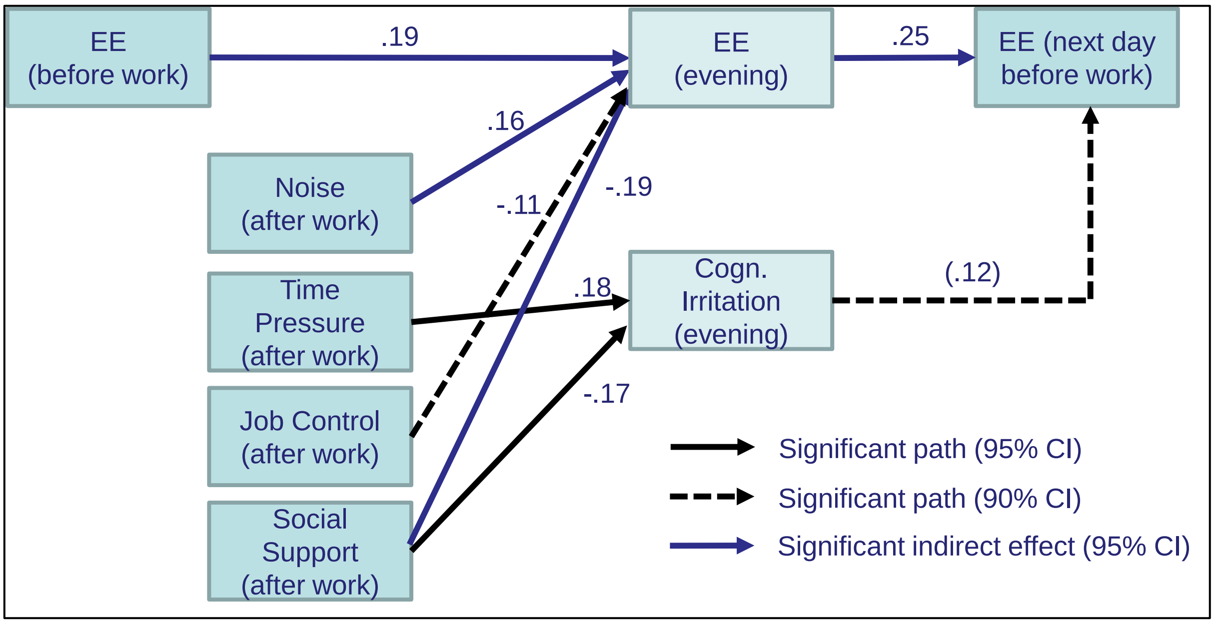

Figure 2: Within-person results from multilevel structural equation modeling.
Note. For parsimony only significant relationships are depicted.

Based on the multilevel structural equation modeling we also calculated the indirect effects of daily job demands and job resources on emotional exhaustion on the next day before work via both emotional exhaustion during the evening as well as cognitive irritation during the evening. Results of these multilevel mediation analyses showed that daily noise at work as well as daily social support at work indirectly affected emotional exhaustion on the next day before work via emotional exhaustion during the evening. All other indirect effects of job demands and job resources on emotional exhaustion on the next day before work were not significant.

DISCUSSION

The study confirmed noise and time pressure as highly important daily job demands for kindergarten teachers. Time pressure at work leads to an increase in cognitive irritation in the evening, but did not affect emotional exhaustion. On the other hand, noise at work leads to an increase in emotional exhaustion, but not in cognitive irritation. If one takes into account that cognitive irritation is a short-term strain indicator, whereas emotional exhaustion is an indicator of longer term strain reactions, one may conclude that noise – which also shows comparable high mean values, i.e. stress perceptions - may even lead to negative long-term strain effects. Thus, in line with earlier studies, noise was confirmed as an especially relevant stressor in nursery schools. On the other hand, time pressure showed only short time effects, which might be buffered by job resources (e.g., Kühnel et al., 2012).

Social support was confirmed as the most relevant job resource for kindergarten teachers since it reduced not only short time strain effects, but also emotional exhaustion as a long-term strain outcome. Also job control was confirmed for this occupational group as an important job resource.

One may only speculate why job interruptions did not show any negative effects on the outcome variables. One reason may be that job interruptions – usually by the diverse needs on many different kids – may be perceived as core part of the job, and not as a demand or stressor as in many other jobs. It may also be that a higher frequency of interruptions goes along with perceptions of higher time pressure and thus day-level interruptions might affect job strain indicators via increased (perceptions of) time pressure.

The diary study approach shows its advantages in this relatively under-researched type of job. We were able to capture not only between-subject effects, but also within-subject variations in demands, daily resources, and outcome measures. All in all, about 50% of the variation in the study variables occurred within persons, indicating a job profile with strong fluctuations in job demands over time.

CONCLUSIONS

As a consequence of the diary approach, our study contributes to the literature by providing insights into day-level effects of job demands and job resources in kindergarten teachers. Additionally, from a practitioners' perspective, the study provides empirically confirmed recommendations for job design for this highly important work field. Especially the high levels of noise in the nursery school rooms should be taken seriously. Such an environmental stressor might only to a certain degree be buffered by job resources. Workplace design measures, like sound-absorbing furniture, or even an active noise cancelling system are indicated. Classic job resources help to buffer the negative effects of job stressors. Training measures may help to increase these resources and to keep the jobs actively and positively demanding.

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ASSOCIATION BETWEEN PERCEPTUAL SENSITIVITY TO OBJECT FORM AND GRASP SCALING PERFORMANCE

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KEYWORDS
Visual Perception, Object Form, Prehension, Kinematics

SUMMATIVE STATEMENT
The aim of this study was to assess the association between visual perception of object form and grasp performance during binocular and monocular viewing. Results showed that perceptual and motor performance were both significantly better during binocular viewing in comparison to monocular viewing. However, no significant association was found between the perceptual accuracy and precision of form discrimination and the motor task involving matched grip aperture (MGA) (matching hand to width of target object).

Association entre la sensibilité perceptuelle à une forme d'objet et le mouvement de préhension

MOTS-CLÉS
Perception visuelle, forme d'objet, cinématique

SOMMAIRE
Cette étude avait pour but d'évaluer l'association entre la perception visuelle de la forme d'objet et le rendement de la préhension lors de la vision binoculaire ou monoculaire. Les résultats ont montré que la performance perceptivo-motrice était nettement meilleure lors de la vision binoculaire que la vision monoculaire. Cependant, aucune association significative n'a pu être décelée entre la précision perceptuelle et la précision de la discrimination de la forme ainsi que la tâche motrice nécessitant une ouverture de la main correspondante (MGA) (c.-à-d. la main correspond à la largeur de l'objet ciblé).

PROBLEM STATEMENT

The reach to grasp movement is common and essential to our everyday experience in both professional and recreational settings. Simple tasks such as reaching for a daily cup of coffee or a document demonstrate its importance in terms of quantity; while the accuracy and precision are imperative during the performance of skillful movements, such as surgery or mechanical repairs in dangerous spaces.

Prehension movements have been studied widely in previous literature in terms of motor planning and control. In the field of kinematics, researchers have identified reach to grasp movements to be faster, more accurate, and precise when performed binocularly (both eyes) as opposed to monocularly (one eye) (Servos and Goodale, 1994; Melmoth and Grant, 2006; Jackson et al., 1997). Alternately in the field of visual perception, researchers have identified more accurate and precise perception of object form during binocular viewing (Steeves et al., 2003). In combining these findings, a gap in literature exists regarding the potential relationship between the perceptual and kinematic performance; in other words, does seeing better lead to more efficient interaction with surrounding objects?

The emergence of new research suggests a more complex visual processing system beyond the dichotomous ventral "what" and dorsal "where" streams (Wang et al., 1999; Culham et al., 2003 Cloutman, 2012). This advancement provides a platform for this study to explore the perceptual-kinematic relationship of object form that has not previously been studied. Building on current understandings of the visuomotor system by identifying a potential contributor to kinematic performance can allow further advancements in human factors design, performance optimization through perceptual training, and predictive assessment.

RESEARCH OBJECTIVE/QUESTION

Objective

The objective of this study was to explore the association between the performance of an object form perception task and a precision grasping task.

Question

Is enhanced perceptual sensitivity (i.e., lower perceptual threshold and just noticeable difference [JND]) to object form positively associated with more accurate and/or precise scaling of grip aperture to target object?

Hypothesis

Participants with a higher sensitivity to object form will exhibit a more accurate and precise grip aperture when scaling their hand to target object.

METHODOLOGY

Participants

Thirty visually healthy participants (14 males, 16 females; Mean age: 21.3, SD:2.43) were included in the study. Participants had 20/20 (or corrected to) visual acuity and a stereoacuity of 40 seconds of arc or less. Eye and hand dominance were recorded such that all participants were right eye and hand dominant. Study protocols were approved by the University of Waterloo Research Ethics Committee. Participants signed a written consent prior to participating.

Study Design

The study consisted of two sections: a psychophysical approach to measure perceptual performance, and a reach to grasp component for capturing movement kinematics. A within subject design was implemented for each approach as viewing condition was manipulated. Changes in perceptual and kinematic performance among viewing conditions were used to explore the perceptual-kinematic relationship.

Assessment of perceptual sensitivity to object form

Psychophysical tests were presented using the VPixx software (VPixx Technologies, QB). Sensitivity to object form was tested using two established stimuli for object form perception: radial frequency (RF) shapes, and motion defined form (MDF) (Steeves et al.,2003; Giaschi et al.,1997). For each stimulus, a psychophysical staircase protocol was completed to estimate a perceptual threshold for each participant. Subsequently, a method of constant stimuli protocol was employed using a 2-alternative forced choice paradigm to obtain a more accurate and precise threshold for object form perception.

RF stimuli were circular shapes with slight deformities around the outer edge. These deformities, measured in visual angles, were manipulated between trials to measure the smallest deformation in object form that participants were able to detect. MDF stimuli were moving dots in which the contour of a shape (rectangle in the case of this study) was embedded through a contrast in motion. Specifically, dots surrounding the rectangle moved in one direction while the dots within the rectangle moved in the opposite. The stimulus variable manipulated between trials was the percentage (%) of dots that were moving coherently to define the shape. For example, a shape is less likely to be perceived with a lower percent dot coherence value because fewer dots that are defining the shape are moving in the same direction. Figure 1 illustrates the RF and MDF stimuli.

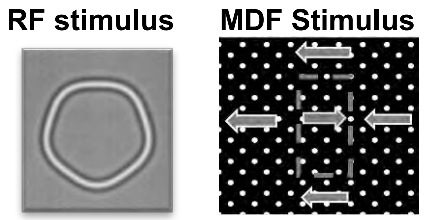

Figure 1. Visual presentation of psychophysical stimuli

Assessment of prehension kinematics

Kinematic measures were recorded using the Optotrak motion capturing system (NDI, ON) at a sampling frequency of 500Hz. Two small infrared emitting diodes (IREDs) were placed on the thumb and index finger of the dominant hand. Target objects were 3 small wooden cylinders 3 cm long, and diameters of 0.5, 1, and 1.5 cm. They were located directly in front of the participant at 3 different distances: 40, 42, and 44 cm. Each of the 9 object conditions (3 sizes x 3 distances) was repeated 10 times for each viewing condition (binocular, monocular) for a total of 180 reach to grasp movements. Randomly embedded between the reach to grasp trials were “scaling” trials. These trials demanded the participants to scale their grip aperture to the diameter of the target object as accurately as possible without the reach component. The absence of the reach component allowed a more direct study of sensorimotor transformation in terms of object form perception. There were 3 trials of each object condition (9) per viewing condition (2) for a total of 54 scaling trials.

Participants were seated with their head supported by a chin rest and began the trial with their eyes closed. Index and thumb began at a standardized start position. A single target object was placed on a curved surface located at one of the three distances. The curvature was introduced to this platform to further increase the visuomotor demand for spatial accuracy as errors will cause the object to fall. A verbal cue was used as a “go” signal, whereby participants opened their eyes to complete the reach to grasp task (grasp the cylinder, transport onto the stencil of the respective object size, and return hands back to the needle). The stencil was included to maintain visuomotor demands throughout the movement by giving purpose to the grasping component. Participants were instructed to perform this movement as fast as possible while maintaining accuracy.

RESULTS

Perceptual sensitivity to object form

The RF threshold, a measure of perceptual accuracy, was calculated using a logistic regression as the stimulus intensity at which the participants responded 75% correctly. The JND value, a measure of perceptual precision, was calculated as the difference in stimulus intensity between the 75% and 50% correct responses. A typical psychometric function for the RF task performed during binocular and monocular viewing for one subject is presented in Figure 1. The leftward shift in the binocular condition indicates a lower threshold, or greater perceptual accuracy in comparison to the monocular condition.

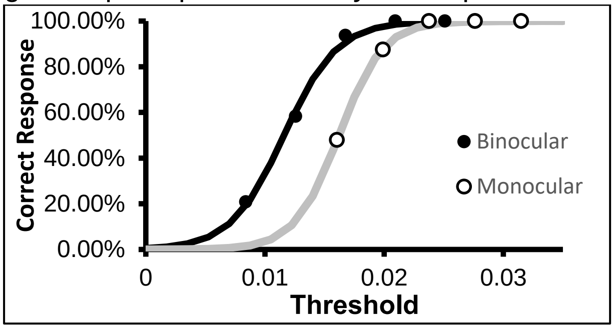

Figure 1. Binocular and monocular psychometric curve for RF task

Results showed that 28 of the 30 participants demonstrated a binocular advantage in terms of lower perceptual thresholds and JNDs. The mean threshold during binocular viewing was 1.16%, which was statistically different compared to the threshold in the monocular condition which was 1.34% (p=0.00003). Statistical significance was also found for the JND measures between the viewing conditions (binocular: 0.21 %, monocular: 0.28%, p=0.00128).

The threshold and JND for MDF task were calculated in the same manner as the RF task. Logistic regression could not be used to fit the data for 4 participants; therefore, they were excluded from further analysis. Results showed a statistically significant difference between the two viewing conditions in perceptual threshold (p=0.010), and the JND (p=0.0106). The mean perceptual thresholds during binocular and monocular viewing were 26.69% and 33.91%, respectively. Mean JND values were 21.1% and 24.49%, respectively. Seven participants did not elicit a perceptual binocular advantage. Figure 2 highlights the differences in perceptual performance between viewing conditions for both psychophysical tasks.

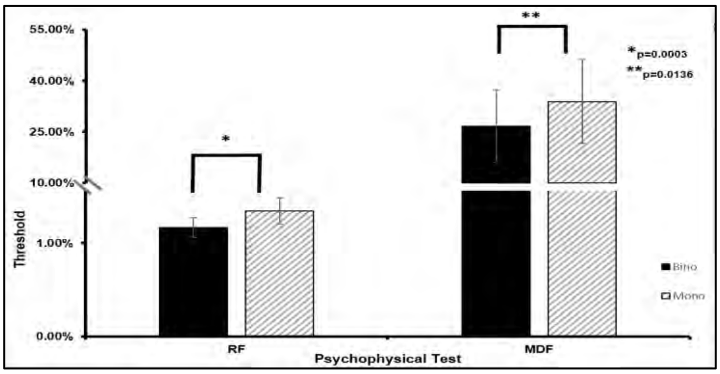

Figure 2. RF and MDF thresholds under binocular and monocular viewing condition

<u>Scaling kinematics</u>

MGA is used to describe the accuracy of grasping; or in other words, how closely participants are able to shape their hands to the contour of the object. A larger MGA indicates a more cautious approach, and increased variability may be indicative of less efficient control. The mean MGA obtained from the “scaling” trials demonstrated a statistically significant difference between the two viewing conditions such that a smaller MGA was found during binocular viewing (p=0.00196). In contrast, the precision of the scaling (i.e., standard deviation [SD] of the MGA) was not significantly different between the two viewing conditions (p= 0.107). The binocular advantage for MGA accuracy was significant across all object sizes and distances as demonstrated by Figure 3. In addition, MGA scaled with object size, but not object distance.

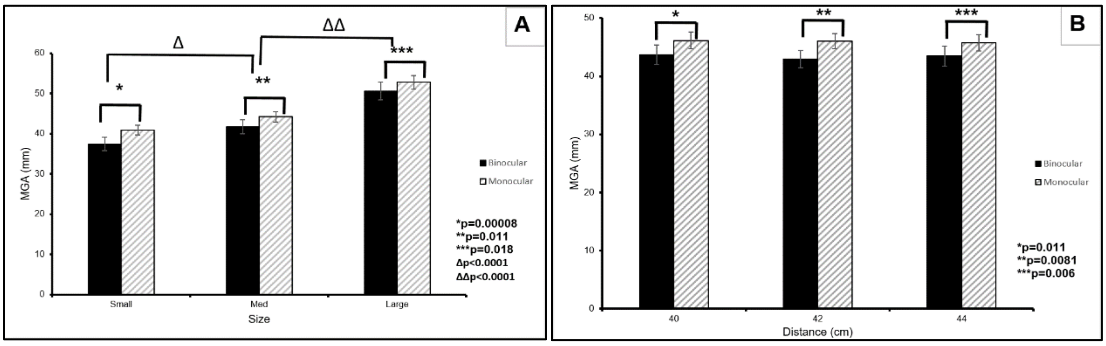

Figure 3. Mean MGA for object size (A) and Distance (B) under both viewing conditions

<u>Perceptual – Kinematic Relationship</u>

Results from the Pearson correlation analysis between the perceptual and prehension measures in terms of accuracy (perceptual threshold and mean MGA) and precision (JND and MGA SD) were insignificant for both RF and MDF tasks. Binocular advantage (MGA ratio, RF/MDF ratio) was calculated as a quotient of the monocular/binocular measures such that a value of 1 indicates equal performance and values of above 1 reflects a binocular advantage. Correlation analysis between the binocular advantage in perceptual and kinematic accuracy (threshold ratio vs MGA ratio) demonstrated a moderate, statistically insignificant, negative association (RF: r=-0.30, p=0.11; MDF: r=-0.27, p=0.15). A statistically insignificant relationship was also found for binocular advantage in precision (RF: r=0.23, p=0.22; MDF: r=-0.26, p=0.16). Figure 4 demonstrates the association between binocular advantage in perceptual and scaling tasks.

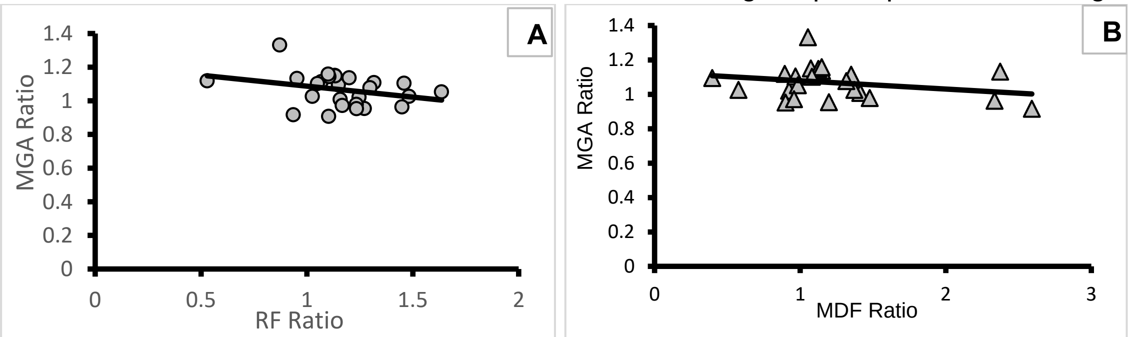

Figure 4. Association between perceptual-kinematic measures for the RF task (A), and the MDF task (B).

DISCUSSION

A binocular advantage was found for the perceptual threshold and JND measures obtained from the RF and MDF tasks, which replicated previous research (Steeves et al., 2004) MGA measures during “scaling” trials also demonstrated the expected binocular advantage. The scaling effect of MGA to object size was in accordance with previous research (Paulignan, 1997), which provided confidence in the experimental design in correctly capturing the desired outcome measures.

In contrast to the hypothesis, the association between the perceptual and scaling measures yielded non-significant results. The kinematic literature which was used to develop this study reported MGA during a reach to grasp task, rather than a scaling task. While this study intends to study MGA during reaching, only the MGA measures from the “scaling” trials have been analyzed to date, and are reported in this paper. As “scaling” trials do not include a reaching component nor the closing of the fingers around the object, it is a different movement altogether. The lack of error consequence and the lower demand for spatial accuracy and precision for this scaling task may not challenge the visuomotor system to a large enough degree, where the subtle perceptual advantages in binocular viewing become evident. Previous research has shown slower, and larger margin of error for MGA during reach to grasp trials involving obstacles or delicate objects (Flatters et al., 2011). Pilot studies of this experiment have shown similar results as a binocular advantage was not identified for MGA measures in less visuomotor demanding reach to grasp movements (i.e., target object located on flat surface and no transport following the grasp).

"Scaling" trials were included in this study to distinguish the interaction between the reach and grasp phases of the movement. Having measures of solely the scaling portion of the movement allows for comparison to how it changes with the addition of a reach and grasp component. Additional outcome measures such as MGA during the reach, time spent in deceleration on approach to the object, and time spent in grasping phase is currently under analysis These outcome measures will allow for an in-depth look into the influence of object form perception on previous studied phases of the reach to grasp movement. Decreases in reach to grasp kinematic performance has been well documented during monocular viewing (Servos and Goodale, 1994; Jackson et al., 1997; Melmoth and Grant, 2006). Much of this difference has been attributed to the diminished ability of target localization in depth (Loftus et al., 2004). With evidence of enhanced object form perception during binocular viewing, perhaps this can also positively impact kinematic performance.

CONCLUSIONS

Perceptual accuracy (threshold) and precision (JND) in RF and MDF psychophysical tasks are not associated with the performance of scaling grip aperture under static conditions when the actual reaching movement is not performed. However, the scaling task is not representative of a reach to grasp task as it does not include several movement components. Additional kinematic measures during an actual reach to grasp movement may provide alternative and more in-depth representation of this perceptual-kinematic relationship.

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MENTAL WORKLOAD ASSESSMENT BY CORRELATION COEFFICIENTS BETWEEN SEVERAL INDICES DERIVED FROM ECG SIGNALS

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KEYWORDS
Mental Workload, ECG, correlation coefficient, autonomic nervous system

SUMMATIVE STATEMENT
In this paper, we investigated the relationships between all the pairs of eight indices derived from ECGs and considered whether the correlation coefficients obtained from these indices are useful for the assessment of mental workload.

Évaluation de la charge de travail mentale au moyen de coefficients de corrélation entre plusieurs indices découlant de signaux ECG

MOTS-CLÉS
Charge de travail mentale, ECG, coefficient de corrélation, système nerveux autonome

SOMMAIRE
Dans le cadre de cette recherche, nous avons étudié la relation qui existe entre les huit paires d'indices découlant des ECG puis examiné si les coefficients de corrélation obtenus de ces indices pouvaient être utiles pour évaluer la charge de travail mentale.

PROBLEM STATEMENT

It has been reported that spectral analysis of heart rate variability (HRV) and Poincaré plot analysis can provide indices of autonomic nervous system activity indices (Akselrod et al., 1981. And Toichi M. et al., 1997). It is widely known that the high frequency (HF) component and the cardiac vagal index (CVI) are related to the cardiac vagal tone, and that the ratio of low frequency component (LF) to HF and the cardiac sympathetic index (CSI) are used as markers of sympathetic nervous system activity.

We investigated that the relationships between the eight indices derived from the same ECG signals by Poincaré plot and HRV spectral analysis in our previous study using correlation coefficients among participants, and we found that eight indices derived from the same RR interval data reflected different responses. These findings may be useful for the consideration of physiological meanings, but they are imperfect for the assessment of mental workload.

RESEARCH OBJECTIVE

In this paper, we attempt to explore possible indices for the assessment of mental workload. The sequential changes and the correlation coefficients of eight indices in individual participants were investigated. The relationships between the correlation coefficients and the subjective assessment were analyzed.

METHODOLOGY

ECGs were recorded from 106 participants (52 male and 54 female) aged 20-67 years during the performance of two mental tasks and resting periods. The experimental procedure consisted of four blocks (pre-test, post-test, and two mental tasks). The duration in each block was five minutes. The task order was counterbalanced between participants (gender and age group). The National Aeronautics and Space Administration Task Load Index (NASA-TLX) was used to obtain subjective assessments. The NASA-TLX, a widely used subjective workload assessment technique, consists of six subscales: Mental Demand (MD), Physical Demand (PD), Temporal Demand (TD), Own Performance (OP), Effort (EF), and Frustration level (FR). The weighted workload (WWL) is obtained by the individual subscale score and the weighting of the paired-comparison (Hart and Staveland, 1988). The Adaptive Weighted Workload (AWWL) is calculated by weighting the coefficients defined by the rank order of the raw scores (Miyake and Kumashiro, 1993).

We calculated four indices of HRV (LF, HF, LF/HF, and coefficient of variation of RR intervals (CVRR)) and four parameters from the Poincaré plot (length of the longitudinal axis (L), length of the transverse axis (T), CVI (=log LT), and CSI (=L/T)). When the sequence of the consecutive RR intervals defines the following as $RR_1, RR_2, \ldots, RR_n$, the Poincaré plot is constructed by plotting RR_{k+1} against RR_k ($k=1, 2, \ldots, n$). L is the length of the longitudinal axis of ellipse which is parallel with the line $RR_k=RR_{k+1}$. T is vertical to the line $RR_k=RR_{k+1}$.

MENTAL WORKLOADS

The participants performed two mental tasks, mental arithmetic (MA) and mirror tracing (MT). In the MA task, which is based on the MATH algorithm proposed by Turner et al (1986), a numerical calculation is displayed on a computer screen for two seconds, after which the word “EQUALS” and a target number appears at 1.5-second intervals. Participants are required to press the left mouse button within 1.5 seconds if the target number is correct and to click the right mouse button if not. The next equation appears whether participants have responded or not. Therefore, the equation is displayed every five seconds. All participants executed sixty equations in five minutes.The MA task contains five levels of difficulty, as shown in Table 1. The initial level is always level 3. When the response is correct, the level goes up. If the response is incorrect or the participant did not respond within the time limit, the level of the next equation goes down.

In the MT task, participants are required to trace a zig-zag pathway on a computer screen with a mouse whose horizontal and vertical control elements are interchanged. The task screen is shown in Figure 1. All participants were instructed to trace “as precisely as possible without deviating from the pass way”.

Table 1. MA task level

Level	Formula
1: easy	2-digit ＋ 1-digit
2	2-digit ＋/－ 1-digit
3	2-digit ＋/－ 2-digit
4	3-digit ＋ 2-digit
5: hard	3-digit － 2-digit

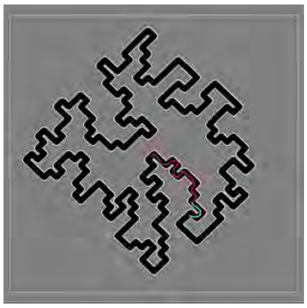


Figure1. Mirror Tracing task (MT)

STSATICAL ANALYSIS

The data of twenty participants in the age group of 20's was used for analysis. Eight indices (L, T, CSI, CVI, CVRR, LF, HF, and LF/HF) were calculated at every 20 seconds in each block. The correlation coefficients in all the pairs of eight indices were obtained from fifteen points because the duration in each block was five minutes. The criterion for the strong correlation was |r|=.76 (p<0.001, n=15).

RESULTS

All of the $r_{CVRR\text{-}L}$ among all the participants and all the blocks were extremely high. The $r_{CVRR\text{-}T}$ of fourteen participants were not stable among blocks. These tendencies of fluctuations were different in each participant and block.

There were no any correlations between the CSI x LF/HF ratio (the marker of sympathetic nervous system activity) and the CVI x HF (the marker of cardiac vagal tone). The $r_{T\text{-}LF}$ and $r_{T\text{-}HF}$ fluctuated variously between four blocks.

The trends of L and T of one participant are shown in Figure 2. In this case, there was a particularity in the MA task period. A few other participants had the same tendency, but not many of them.

In the MT task, there was a strong relationship between the $r_{T\text{-}LF}$ and the TD score on the NASA-TLX (r=0.5692, p<0.01, n=20). Significant correlation between the $r_{T\text{-}HF}$ and TD (r=0.5375, p<0.05, n=20) was found in MA task (Figure 3).

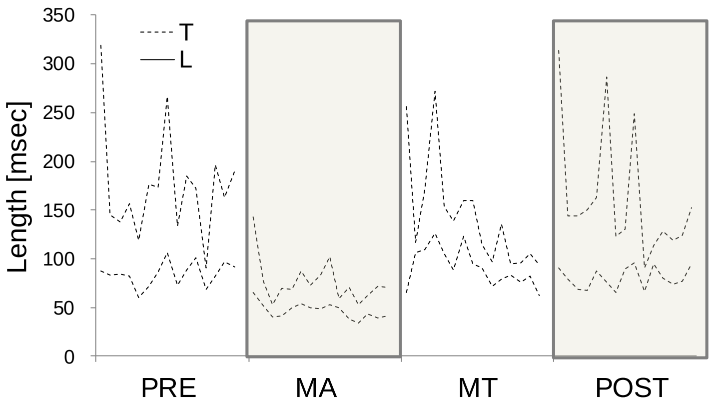
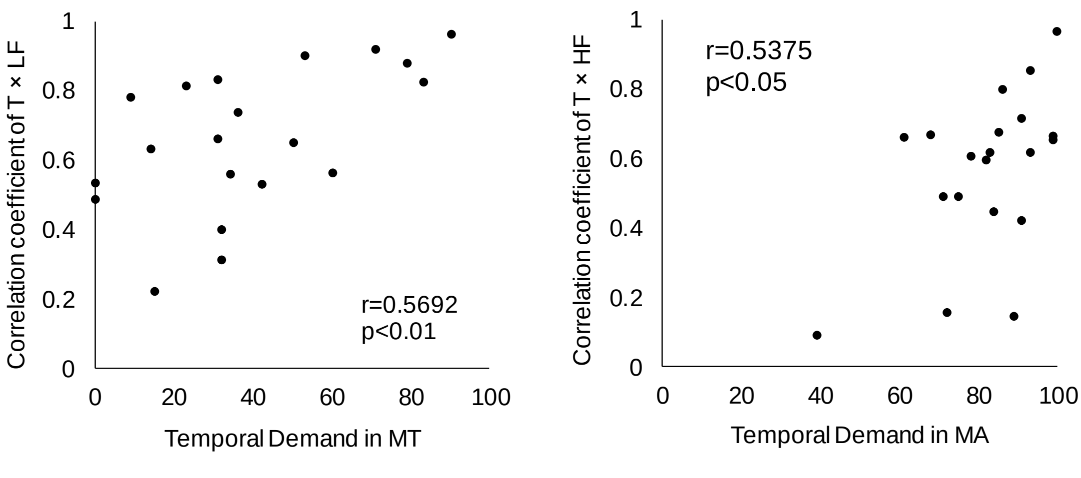


Figure2. Lengths of L and T through all blocks. (one participant)



(a) T x LF and TD in MT task

(b) T x HF and TD in MA task

Figure3. The relationships between the correlation coefficients and TD scores on the NASA-TLX.

DISCUSSION

The high $r_{L\text{-}CVRR}$ is due to the calculation formulae. The length of L indicates the dispersion of RR intervals as same as CVRR.

We can suppose that T would become longer during the task periods than the resting periods. Figure 2 shows that the length of L in the MT task was slightly longer than in the other blocks. However, in the MA task, the lengths of T and L were shorter than in the other periods. Moreover, these tendencies were different among participants. Individual differences in physiological responses are observed even when they perform the identical mental task, making it reasonable that there were various fluctuations in the correlation coefficients.

It is suggested that the correlation coefficient between T and HRV spectral indices can be useful for the assessment of mental workload, although the results of HRV spectral analysis are less reliable due to the short data length (20 sec) used in the calculations.

It is widely known that the low frequency (LF) component is related to both SNS and PNS activities and that the high frequency (HF) component is used as a marker of parasympathetic nervous system activity (Akselrod et al., 1981). Sensory-rejection tasks such as the MA task evoke an increase in heart rate, known as Pattern I responses (Lacey et al.,1978; Schneiderman et al.,1989). Conversely, sensory-intake tasks such as the MT task decrease the heart rate, described as Pattern II responses. It is supposed that time pressure increases the sympathetic nervous system activity, but the results in TD may indicate that the physiological mechanisms in the Pattern I and Pattern II responses are different. If the correlation coefficient were a useful marker, it could be possible to assess mental workload absolutely. Physiological meanings of these parameters must be clarified.

CONCLUSIONS

It is suggested that the correlation coefficients between length of the transverse axis (T) from Poincaré plot and HRV spectral parameters can be used as a marker of time pressure during mental workload. The physiological meanings of these parameters will be clarified in a future study.

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BACK-UP ALARMS: USE, PERCEPTION & SAFETY – ARE THEY EFFECTIVE?

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KEYWORDS: Broadband alarms, perceptions, safety

SUMMATIVE STATEMENT
Reversing vehicles pose a significant safety risk due to poor visibility. Broadband alarms (BBAs) are gaining popularity as a means to mitigate risk from reversing equipment. Few studies have evaluated workers' perceptions regarding the BBA sound and/or the effect they have on worker safety. This study shows that the BBA captures attention however, interpretations of what the alarm is signaling and the meaning it carries are undetermined.

Les avertisseurs de recul : utilisation, perception et sécurité – sont-ils efficaces?

MOTS-CLÉS : alarme large bande, perceptions, sécurité

SOMMAIRE
Les véhicules qui reculent présentent un risque important pour la sécurité en raison d'une piètre visibilité. Les alarmes de recul à large bande gagnent en popularité comme moyen de réduire ces risques. Peu d'études ont évalué les perceptions des travailleurs concernant l'alarme large bande ou les répercussions entraînées sur la sécurité des travailleurs. Bien que cette étude démontre que l'alarme large bande attire l'attention, la signalisation et la signification de cette alarme ne sont pas connues.

PROBLEM STATEMENT
When equipment or vehicles – especially large ones - are reversing, people and objects may not be in the driver's view due to the size of the vehicle, the equipment on board, or others working in the vicinity. Acoustic backup alarms are one method used to alert those nearby of the impending danger. The aim is to provide an audible warning to those in the area so that they know to take the necessary safety action (Burgess, 2009). Conventional, single-tone, backup alarms are the most prevalent on worksites across B.C. They are used extensively in industries such as Forestry, Agriculture, Manufacturing, Construction, Transportation and Warehousing. Recently however, a technology – relatively new to B.C. – the broadband alarm (BBA) is gaining popularity as a means to mitigate risk from reversing equipment.

Despite the availability and use of audible alarms, accidents and fatalities involving reversing vehicles continue. According to the U.S. National Highway Traffic Safety Administration (NHTSA), "backovers" as they're labelled– kill 292 people in the United States every year. According to the Occupational Safety & Health Administration's Integrated Management Information System, about 360 backover-related fatalities occurred in the workplace over a six-year period. Data from the Bureau of Labor Statistics indicates that 79 backover fatalities occurred in 2011 alone. More incidents tend to occur in trucking terminals or at road construction sites with dump trucks. Figures from WorkSafeBC's data warehouse identified 550 that backover incidents occurred from 2001 to 2015. Among the identified incidents, 13 workers were killed when they were pinned, struck or rolled over by mobile equipment or vehicles that were reversing.

In one example, a foreman was fatally struck by a reversing forklift while he was directing the driver of a delivery truck. In this incident, the forklift operator shoulder-checked, didn't see anyone, and began reversing. As this was occurring however, the delivery truck arrived, and the foreman began directing the newly-arrived truck. The foreman was not looking at the forklift. As the delivery truck driver drove forward, he looked into his passenger-side mirror and saw the forklift strike the foreman.

In addition to audible alarms, spotters are sometimes used to both direct and clear the path of the reversing vehicle. While spotters can be helpful, they are not always available or reliable. Detecting *all* traffic is difficult as spotters have inherent visual and auditory limitations as all humans do, making spotters themselves vulnerable as well.

The ubiquitous conventional single-frequency (beep…beep…beep), often referred to as "tonal", reversing alarms have a typical volume of 97-112 decibels (dB) and a sound that propagates up to three kilometers from the danger zone. They have therefore often been identified as a source of nuisance noise in surrounding communities (Holzman, 2011). The single-frequency sound is not easily attenuated, or reduced in intensity, with distance. Furthermore, because the sound is so common even in situations far from danger zones, many are habituated to it and no longer associate the sound with danger, such that the alarm does not warn as effectively as intended. As well, with the use of tonal alarms, "the uniformity of the sound field behind the vehicle is not guaranteed" (Nelisse, et al., 2011). Sound levels vary widely and are not always related to the distance from the danger, contributing to the difficulty spatially localizing or pinpointing the tonal alarm – especially for workers wearing hearing protection devices (HPDs) (Laroche et al., 2011, Laroche, 2006).

When we look at environments in which the background noise levels are constantly changing, "audible" also becomes dubious. For example, busy construction sites can be particularly noisy with various pieces of equipment and machinery constantly arriving, working and leaving the site, many of which also emit beeping and alarm noises. Tonal alarms can be masked by the ambient noise so might not be audible. If workers are wearing hearing protection devices, "audibility" again shifts.

The BBA emits a unique "pssht....pssht.." sound comprised of all audible frequencies from 400-10, 000 Hertz broadcast simultaneously, rather than a single frequency like that of the tonal alarm. The BBA is therefore not as easily masked by another noise. The primary advantage of the broadband sound is that has a more uniform sound propagation without abrupt dips in sound pressure levels (Vaillancourt et al., 2014), it is easier to localize, or pinpoint, and identify which vehicle is reversing. The broadband alarm is also directional, meaning that the sound is concentrated in the danger zone, causing less noise pollution than the conventional tonal alarm. As mentioned, tonal alarms broadcast well beyond the danger zone often needlessly alerting others considerable distances away (Vaillancourt, et al., 2013).

Broadband alarms have many potential benefits, but few studies have investigated workers' real-world perceptions to the BBA that ultimately effect worker safety.

RESEARCH QUESTION

This study was launched to investigate workers' perceptions, interpretations and reactions to the BBA signal, and the effect these may have on worker safety. An alarm signal should provide answers to three questions: what is the hazard; where is the hazard and when is it a hazard (Withington, 2004)? It is hypothesized that respondents will find the broadband alarm effective in signalling the location of a hazard, but have limited effect in signalling what the hazard is and when it is a life threatening hazard.

METHODOLOGY

Survey development & deployment

Numerous research papers illustrate that broadband alarms appear to have several advantages. There is limited research however, on workers' perceptions about the BBA signal or their effect in contributing to workers' safety.

A multidisciplinary, internal team at WorkSafeBC came together on this initiative to develop a survey to assess workers' perceptions regarding the broadband alarm. The research was conducted as a controlled experiment by exposing respondents to the sound followed by a survey. The survey asked participants if they had heard the broadband alarm before. If the participant affirmed that they had heard the BBA sound before, they were asked to complete the survey comprised of 15 questions. If respondents indicated they hadn't heard the broadband alarm, the survey jumped to the outro page where respondents were thanked and exited out of the survey.

Questions 1-3 asked to assess overall awareness of the BBA, question 4 probed reaction to the BBA, question 5 assessed comprehension of the sound, question 6 asked about association with a reversing vehicle, questions 7-9 asked about interpretation as a warning, questions 10-11 asked if noises interfere with the BBA, questions 12-13 asked about levels of annoyance with each alarm, and questions 14-15 asked about training for the BBA.
1: Listen to the broadband alarm. Have you ever heard it before?
2: Where have you heard the broadband alarm?
3: How many times have you heard the broadband alarm?
4: What was your first reaction to hearing the broadband alarm?
5: What did you think the sound meant?
6: How long did it take you to associate the broadband alarm with a vehicle backing up?
7. When you first heard the broadband alarm, did you perceive it as a warning signal?
8. When you first heard the broadband alarm, did you feel it indicated imminent danger?
9: When you first heard the broadband alarm, did you interpret it as a signal to move out of harm's way?
10: Have you found that noises interfere with hearing the broadband alarm?
11: Are you able to hear the broadband alarm while wearing hearing protection?
12: On a scale of 1 to 10, how annoying do you find the broadband alarm?
13: On a scale of 1 to 10, how annoying do you find the tonal alarm?
14: Have you received training about the broadband alarm?
15: What type of training have you received regarding the broadband alarm?

Participants

The link to the survey was sent via ENews, posted on the WorkSafeBC website and listed in an article in WorkSafe Magazine distributed across BC. 176 respondents responded to the survey. The link remains accessible on the WorkSafeBC.com website until the fall of 2017. Respondents were asked to supply their age according to 6 age categories. 2 percent identified being between 15 and 25 years of age; 15 percent were between 26 and 35 years of age. 24 percent reported being between 36 and 45 years of age while the majority (53%) reported falling in the 46 to 65 age category. Only 3 percent did not wish to disclose their age.
Respondents were also asked which service sector they worked in. 28 percent of respondents indicated they were from the public service sector or other sectors not listed. 20 percent of participants worked in the construction sector while 16 percent worked in the manufacturing sector. The remaining reported working in healthcare (2%), retail (1%), and hospitality (1%), were unemployed (2%) or did not wish to disclose (2%).

RESULTS

The total number of respondents was 176. Of those, 109 respondents (or 62%) had heard the broadband alarm before. Among those, 68% heard it at work; 32% heard it near a construction site; 23% heard it in a loading bay. 19% of respondents heard the alarm elsewhere not listed. With the option to select multiple answers, some may have heard it while at work which is near a construction site or possibly a loading bay. 42% of respondents chose multiple answers.

Three quarters of respondents claimed to have heard the BBA more than 10 times with only 3% having heard it 6-10 times and remainder of respondents having heard the BBA five times or less.

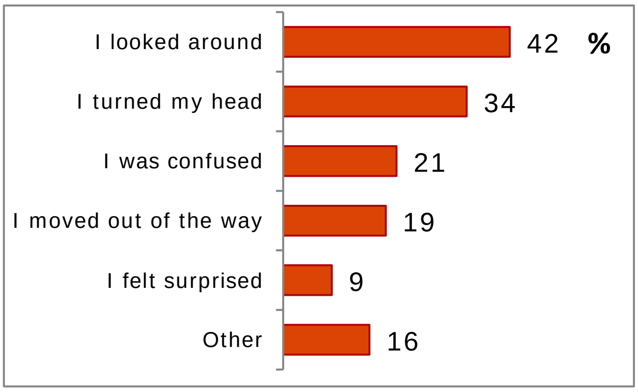

Fig 1. Q. 4: What was your first reaction to hearing the broadband alarm?

When asked the question, what was your first reaction to hearing the broadband alarm (question 4), individual respondents experienced multiple reactions upon first hearing the BBA. 75% of respondents looked around and/or turned their head as their first reaction to hearing the BBA (figure 1 above). As an initial reaction to the BBA, 21% of respondents were confused, 19% moved out of the way and 9% were surprised. 16% of respondents had other reactions not listed.

Of the 16% of respondents that had other reactions, a few remarked they thought it was a bird. Others, thinking it sounded like ducks, ignored it. Others reacted with intrigue looking in the direction the sound was coming from. Others were pleasantly surprised by the sound; based on the sound frequency and tonal level, some were able to tell if the vehicle was facing them, moving towards or away from them.

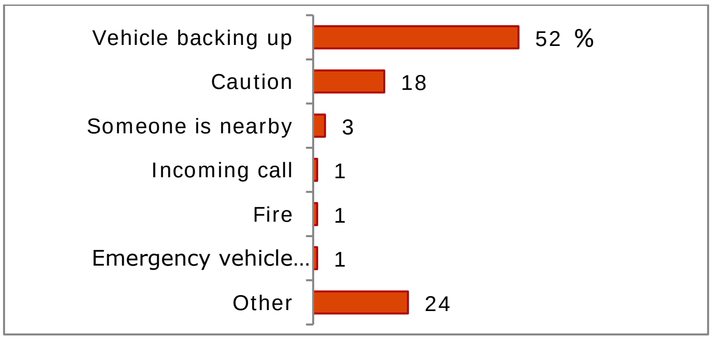

Fig 2. Q.5: What did you think the sound meant?

When asked, what did you think the sound meant (question 5), half of respondents (52%) associated the sound with a vehicle backing up (Fig 2 above); but only 18% of respondents thought it indicated caution while curiously, a quarter (24%) thought the sound was not signaling any of the responses listed.

Of the 24% some respondents thought it sounded like a bird in distress. Others thought the alarm sounded like strange duck noises. Several others believed the sound meant something was broken and not working properly on a piece of equipment such as an air leak or a problem with vehicle reserve gear. Others thought it meant there was an issue with the alarm; believing the beeper might be broken. Still several others indicated that they had no idea what the sound was. Not knowing what it was, and unsure where it was coming from they looked around trying to figure it out. A couple of respondents thought it meant a TV was either disconnected or left on. A couple of respondents thought it meant, “Pay attention, something is going on”. One respondent remarked knowing what the alarm meant but that it's weak and easily dismissed.
Those who associated the alarm with a vehicle backing up (52% of total respondents) were asked the question; how long did it take you to associate the BBA with a vehicle backing up. Among those, 89% of respondents immediately made the association. The remaining 11% took a few minutes or more to make the association.

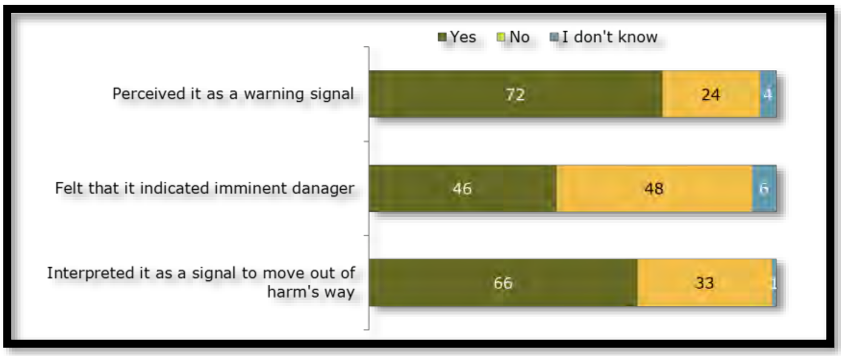

Fig 3. Interpretation as a Warning/Danger

Fig 3 (above) summarizes the percentage of responses related to perception and interpretation of the BBA signal. There were multiple, varying perceptions found as to how the signal was taken. Many respondents (72%) perceived it as warning signal, while a slightly lower number of respondents (66%) thought it meant to move out of harm’s way. Only 46% of respondents felt it indicated imminent danger.

In response to question 10, have you found that noises interfere with hearing the broadband alarm, almost half of respondents (47%) indicated noises never interfere with hearing the broadband alarm while just over a quarter (27%) of respondents indicated noises sometimes interfere with hearing the BBA. 6% of respondents found noises always interfere with hearing the BBA. 20% of respondents didn’t know if noises interfered with hearing the BBA.

In response to question 11, are you able to hear the BBA while wearing hearing protection, over a quarter of respondents (28%) indicated they could hear the BBA all the time while wearing hearing protection devices (HPDs). 20% of respondents could either usually or sometimes hear the BBA while wearing HPDs while 2% could not hear the BBA at all while wearing HPDs. For 50% of the respondents, this question was not applicable.

In response to questions 11 and 12 asking how annoying each alarm sounded, the majority of respondents (36%) found the tonal alarm to be extremely annoying while another 39% ranked the tonal alarm as either very annoying or moderately annoying. 13% thought the tonal alarm sounded fairly or slightly annoying. The remaining respondents (13%) found the tonal alarm sounded pleasant with 2% ranking the alarm very pleasant and another 2% ranking it extremely pleasant. 26% of respondents thought the BBA alarm sounded fairly to extremely annoying. 28% thought it sounded only slightly annoying. A total of 305 of respondents found the BBA sounds slightly or fairly pleasant with the remaining respondents

(17%) ranking it as either very or extremely pleasant. As respondents had the opportunity to respond using multiple categories, response percentages exceed 100%.

Fig 5. Training on the broadband alarm

In response to question 14 asking respondents if they have received training on the broadband alarm, 61% of respondents indicated having received no training for the broadband alarm (Fig 5 above). The remaining 39% have received training. Question 15 asked what type of training respondents received. 71% received a demonstration of the alarm. 55% watched a video, 36% received an education session, 29% were given safe work procedures, and another 17% received their training in a tailgate meeting. The total percentage of responses amounts to 218%. This indicates respondents have received training through a combination of different training means. 10% of respondents received training via other means not listed.

Of the 10%, respondents noted they read material such as the Brigade Electronics study information and did research on broadband alarms via the internet and self-discovery.

Discussion

Results support the hypothesis. Results demonstrate for a first reaction, the BBA captured attention. 53% of responses indicated respondents looked around or turned their head in response to hearing it. This is consistent with the hypothesis the broadband alarm would be effective in capturing attention to signal where the hazard is. As per our hypothesis, results suggest limited effectiveness of the BBA in signalling what the hazard is and when it is a hazard.

Specifically, while the majority made the immediate association of the alarms with a reversing vehicle, "other" was surprisingly high. More surprising perhaps was the nature of these 'other' responses that focused on non-hazard aspects (e.g., sounds of birds, ducks, and electronics).

Another interesting finding is that those who associated the alarms with a reversing vehicle skewed to respondents 46 years and older, while those associating the alarm with non-hazard aspects skewed to younger respondents (45 or younger). It is unclear from this study what is driving this, but it is presumed to be related to experience. Older respondents may have had more opportunities to hear different types of alarms and/or repeated exposure to education around BBAs making it clearer to them about what the alarm means.

Furthermore, there were inconsistent interpretations of the meaning of the signal. Between 46 to 66 respondents had varying interpretations of the alarm including an almost equal mix of those thinking it was a warning signal while others thought it meant to move out of harm's way and still others felt it indicated imminent danger. Nearly 50% of respondents felt it did not indicate danger and 33% didn't interpret the signal to mean to move out of the way. A quarter of respondents didn't perceive the warning signal as a warning signal at all.

Education around the BBA seems to correlate with clarity of the meaning of the sound. In addition to the correlation to age and the hypothesis that older respondents have had increased exposure to BBA and/or education on it, one respondent shared, “We had studied this and educated our team before these arrived on our site. When we were first introduced to the sound, it did not immediately suggest a warning sound to most of our team”. However, only a third (39%) had prior education on BBA, with varying and inconsistent education methods.

CONCLUSIONS

Providing a warning when a vehicle is reversing is important to protect those in the vicinity who may need to move out of the way of the vehicle to avoid an accident. Single-frequency tonal alarms are most widely used to alert of the reversing motion. However, the alarm signal propagates up to 3 km beyond where a person is potentially at risk, the tonal sound is difficult to pinpoint, and can be masked by other alarm noises on site. This can create a risk of people ignoring the alarm as they not associate it with danger, confusion about which vehicle is associated with the alarm and potentially the alarm might not be heard at all. These properties make the tonal alarm signal ineffective at consistently warning and protecting people potentially at risk.

This study highlighted several favourable features of the BBA including that it is easier to localize, and because it projects a more uniform sound field behind the vehicle, the BBA alarm signal is more focussed in the area where a person may be at risk. It is less likely to be masked by other noises on a worksite and causes less noise annoyance for neighboring communities. However, as the BBA is relatively new to worksites in B.C., focus is needed to boost understanding of the meaning of the broadband signal and its interpretation as both a warning signal to move out of harm's way and as an indicator of imminent danger.

In conclusion, the research supported our hypothesis that respondents will find the broadband alarm is effective in capturing attention to indicate the location of the hazard ***but*** has limited effect in signalling what the hazard is and whether it is a life threatening hazard.

Learnings from this study add to the body of research around this topic. The key addition to existing knowledge is that worker education around the BBA relates to perception of the alarm and increases the alarm's effectiveness in signaling life threatening hazards. Another interesting finding is that older respondents more often correctly associated the BBAs with a reversing vehicle compared to younger respondents.

Further understanding of the above will help in developing effective education programs that become part of any employee orientation and/or safety discussion across industries when deploying new technology such as the BBA.

Following this study, 4 key limitations were identified:

Method: An experiment design, while consistent with the current research methods for the body of research available to us, includes biases given the expectations it builds that a sound is being tested. A more ‘in-field’ kind of design assessing spontaneous awareness of a sound in replication of real life situation may be more reliable in assessing the true impact of BBA.

Exclusion of those not have heard the BBA sound before: A third of the sample completing the survey claimed to have not heard the sound before and as such was not asked further questions about the alarm. A lot can be learnt from those with no prior knowledge of the alarm sound that can enhance our understanding on the use of BBAs.

Sampling: The reader is reminded that this is a convenience sample via self-selection and as such, the findings are not necessarily projectable to the population at large.

Question wording biases: These are inherent in many research programs. Cautious is required, in any future research, around whether to provide response options or not. If providing options, clarity of wording to align with the lowest level of respondents' education is key. Words such as hazard, imminent, warning signals may need further clarification or different word options for increased reliability of responses.

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A HUMAN FACTORS APPROACH TO EVALUATING LED LIGHT FIXTURES FOR USE IN RAILROAD LOCOMOTIVE HEADLIGHT APPLICATIONS

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KEYWORDS
Glare, LED, Light, Headlight, Locomotive

MAIN MESSAGE
As lighting technologies change, it is essential to consider the impact that different characteristics of the lighting (luminous intensity, spectral distribution, color temperature, etc.) could have on workplace ergonomics and other individuals exposed to the light.

Une démarche d'ergonomie pour évaluer les dispositifs d'éclairage led utilisés dans les phares de locomotives

MOTS-CLÉS
Éblouissement, LED, lumière, phare, locomotive

MESSAGE PRINCIPAL
À mesure que les technologies d'éclairage évoluent, il est indispensable d'examiner les répercussions que peuvent avoir les différentes caractéristiques de l'éclairage (intensité lumineuse, distribution spectrale, température de couleur, etc.) sur l'ergonomie du lieu de travail et les personnes exposées à la lumière.

PROBLEM

LED lighting has become a popular alternative to conventional lighting for several reasons: energy efficiency, working life, and more recently, cost effectiveness. Several Class 1 railroads have started to retrofit their existing locomotive fleets with LED headlights or are ordering new locomotives with OEM LED headlights. Aside from Federal Railroad Administration (FRA) requirements (49CFR229, 2006), there are no consensus standards for the different characteristics of the light. As a result, the conventional halogen headlight fixtures (Figure 1) are being replaced by a wide variety of LED locomotive headlight fixtures (Figure 2) currently on the market. Employees at one railroad reported that the LED locomotive headlights are excessively bright and a source of disability/discomfort glare (Figures 3-6).

Figure 1: Typical Halogen Headlight Fixture

Figure 2: Typical LED Headlight Fixture

Figure 3: Typical halogen headlight on dim setting

Figure 4: Typical LED headlight on dim setting

Figure 5: Typical halogen headlight on bright setting

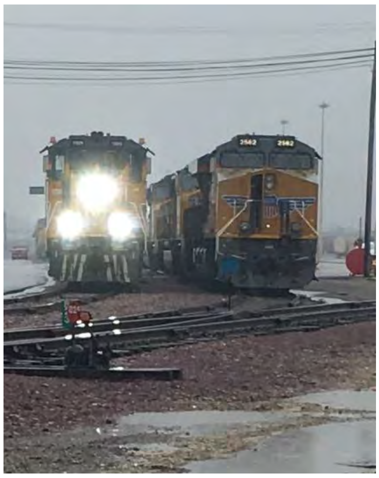

Figure 6: Typical LED headlight on bright setting

CONTEXT

The FRA specifies a minimum luminous intensity for locomotive headlights when measured at 0°, 7.5°, and 20° of offset. The FRA also requires that on the mainline, a person 800 feet in front of the locomotive (300 feet in the yard) should be illuminated. Finally, the headlights must be dimmable. It is thought that misinterpretation of the FRA regulation has led some manufacturers to develop prototype LED fixtures that exceed the intended levels of luminance, both in through-freight and yard applications. Although some LED headlights only moderately exceed the minimum peak luminous intensity requirement of 200,000 cd (some are rated at 230,000 to 270,000 cd) they have been perceived to be much brighter than conventional halogen headlights measured at similar levels of luminance. This is especially true at a visual angle of 7.5° or less. A railroad technical advisory group has been formed and tasked with developing a specification for LED locomotive headlights that will provide guidance on lighting characteristics beyond minimum luminance requirements.

ACTIONS

After receiving complaints about discomfort/disability glare due to prototype LED headlight fixtures on locomotives in yard service (switching locomotives) near Chicago, IL, a study was performed to compare the prototype headlights to the conventional halogen headlights. The purpose of the study is to determine the cause of the LED's increased perceived brightness in order to protect railroad workers in train yards, the public, and oncoming train crews on adjacent tracks from the effects of discomfort/disability glare. Two locomotives retrofitted with LED headlights and two locomotives with conventional halogen headlights were studied at different times of day and during varying weather conditions.

Three measurements of each headlight were made from a distance of 5 feet using the Sekonic C-7000 Spectromaster. This spectrometer provides spectral distribution data over the entire visible spectrum as well as color temperature data, reported in Kelvin (K) and illuminance in Lux (lx). Ambient lighting and weather conditions were recorded.

OUTCOMES

Table 1: Headlight Measurement Results

	Dim Setting		Bright Setting	
	Halogen	LED	Halogen	LED
Illuminance (lx)	13,533	15,433	36,633 - 41,900	97,733 - 123,667
Peak Wavelength (nm)	776	433	776 - 779	439 - 442
Dominant Wavelength (nm)	532	503	583 - 584	483 - 488
Color Temperature (K)	2,842	5,921	2,900 - 3,197	5,946 - 6,254

The results of the light measurements are shown in Table 1. For the bright setting, results from two different locomotives are shown as a range.

The measured illuminance of the LED headlight was higher than the measured illuminance of the halogen headlight for both the "bright" and "dim" settings. Most notably, the LED headlight was measured to have about three times the level of illuminance of the halogen headlight when set to "bright."

The peak wavelengths for the LED headlight were found to be more in line with the peak photopic/cone (555 nm) and peak scotopic/rod (500 nm) spectral sensitivities than the halogen headlight (Wei, 2014). At about 440 nm for “bright” and 433 nm for “dim,” the LED headlight could contribute to disability glare in both the primary and peripheral vision more readily than the halogen headlight, which had peak wavelengths of 778 nm for “bright” and 776 nm for “dim.”

The color temperatures for the LED headlights were measured to be about 6000 K while the halogen headlights were about 3000 K, another factor indicative of increased discomfort glare from the LED headlight. (Wickens, et al., 1998).

DISCUSSION

Glare

Glare is the result of light-scattering in the optical media of the eye.

Discomfort glare is the sensation of annoyance, or even pain, that we experience when we see a bright light in our field of view (Boyce, 2003). Situations where illumination is too intense or variable can contribute to discomfort glare (Mainster & Turner, 2012).

Disability glare is a reduction in visibility due to scattered light in the eye. This scattered light, or retinal straylight, is known as disability glare when it casts a veiling luminance on the retina and reduces the contrast of the retinal image (Mainster & Turner, 2012).

Disability glare and discomfort glare can occur simultaneously or independently of each other. For example, daylight can cause disability glare for seeing dashboard displays, even if it does not cause any sensations of discomfort. Conversely, transitioning from indoors to outdoors on a sunny day can cause sensations of discomfort without necessarily impairing vision (disability glare).

Other factors contributing to straylight include pigmentation and age, where younger people with heavily pigmented eyes show the greatest resistance to straylight (Coppens, et al., 2006). Recovery time from disability glare can take nearly 3X longer for older people (age 65-74), with middle-aged people (age 40-55) taking about 500ms longer than younger people (age 18-24) (Adrian & Bhanji, 1991). Hemoglobin found in the eye wall acts as a filter, reducing the amount of light above 620 nm that is absorbed by the eye. Wavelengths below 620 nm, therefore, are absorbed more readily and have greater potential to contribute to straylight (Franssen, et al., 2007).

Phototropism

There is a natural tendency for our eyes to move toward brighter light. This phenomenon, known as phototropism, not only distracts from the task at hand, but the resulting transient adaptation can cause a temporary reduction in visual acuity when the eye focuses back on the task (Wickens, et al., 1998).

Correlated Color Temperature (CCT)

For prolonged exposures to cooler color temperatures, such as ambient lighting in office spaces, luminous intensities of 5000 Kelvin can be perceived to be of greater intensity than equally luminous light sources at 3500 Kelvin. Despite the perception that the 5000 Kelvin work space was brighter, workers’ self-reported visual comfort, satisfaction, and productivity were compromised (Wei, et al., 2014). The AMA recommends “using the lowest emission of blue light possible to reduce glare” (AMA, 2016).

Photopic Luminosity Function

From a human factors perspective, the Photopic Luminosity Function (Figure 7) shows the relative efficiency of light at each wavelength as perceived by the human eye. A radiant flux at 555 nm has the greatest luminous efficiency and will appear to be brighter than an equal quantity of radiant flux at 450 or 650 nm, for example.

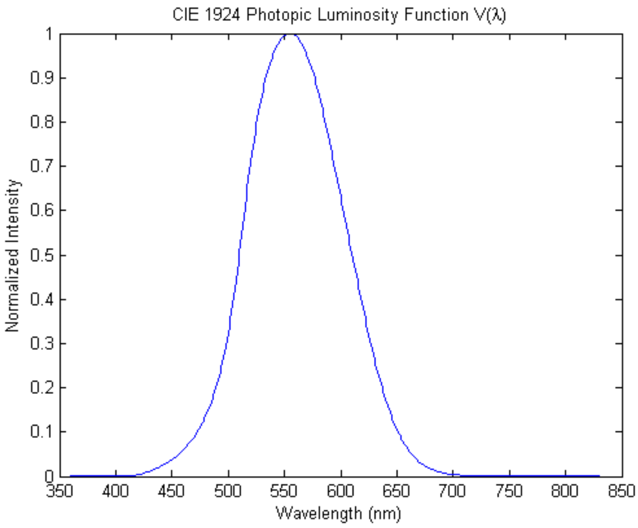

Figure 7: CIE 1924 Photopic Luminosity Function V(λ)

Figures 8 & 9 show the spectral distribution of each headlight type. When compared to the Photopic Luminosity Function, the spectral distribution of the LED headlight aligns more closely and clearly shows greater luminous power than the halogen headlight.

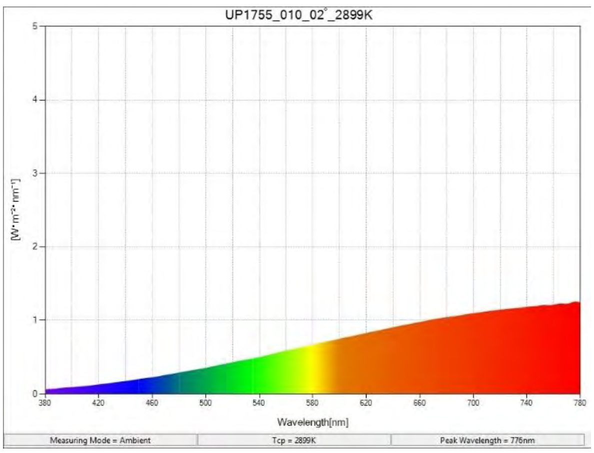

Figure 8: Spectral Distribution: Halogen Headlight

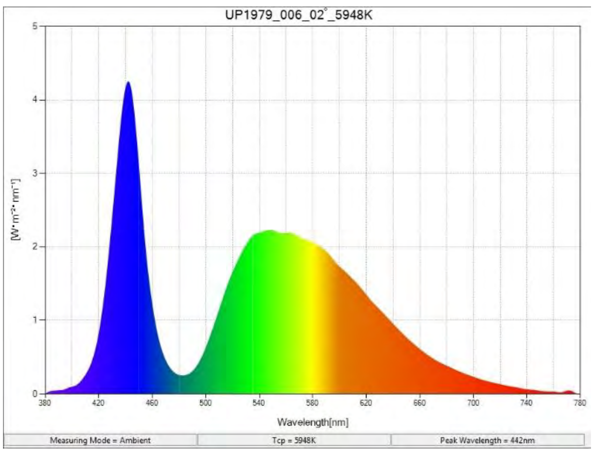

Figure 9: Spectral Distribution: LED Headlight

One study found a connection between the discomfort glare caused by halogen headlights and that of high-intensity discharge (HID) headlights, which have spectral qualities similar to

LED headlights. The study found that halogen headlights must supply 25-50% more illuminance to the eye than a HID headlight in order to cause the same level of glare (Bullough, 2003).

White LEDs expose the retina to higher levels of violet, indigo, and blue light than more traditional light sources. Behar-Cohen cautions that the effects of exposure to blue light are largely unknown (2011). Just last year, the American Medical Association (AMA) adopted guidance for communities in the selection of LED street lighting, however many communities have already transitioned to LED lighting in pursuit of energy efficiency and longer-lasting fixtures (AMA, 2016). In addition to warning that “discomfort and disability from intense, blue-rich LED lighting can decrease visual acuity and safety,” the AMA also points out that LED streetlights can suppress melatonin, with an estimated impact on circadian sleep rhythms five times greater than conventional street lamps. The AMA also reported that some LED light sources may disrupt animal species that thrive in dark environments, noting that they can become more easily disoriented. This may be especially relevant to wildlife in the path of an oncoming locomotive.

Changes to the design of the LED headlight assembly could help to improve the level of discomfort glare, but it is difficult to predict the potential benefits of such changes. In one study, researchers replicated the characteristics of a HID light source using a modified, blue-filtered halogen light bulb, however the test subjects did not report the same levels of discomfort glare as they did for a genuine HID light source (Wei, 2014).

CONCLUSION

At close range, the illuminance levels of the LED headlight far exceeded the halogen headlight when set to “bright.” In “dim” mode the illuminance levels of the LED headlight were only slightly higher than for the halogen headlight, but the LED headlight was perceived to be much brighter, especially at a visual angle of 7.5° or less. The characteristics of the LED headlight are more likely to lead to glare inside and outside of the train yard.

The increased level of illuminance, color temperature, and spectral distribution of the LED headlight could contribute to glare levels for the general public as well. For instance, drivers may experience greater physical discomfort due to discomfort glare from an oncoming locomotive traveling on a track parallel to the road, especially in dark environments and within 7.5° from the center of the LED headlight’s beam. Drivers may also experience increased occurrences of disability glare, causing them to lose the ability to focus on the task of driving, especially in dark environments and within 7.5° from the center of the LED headlight’s beam. Someone who experiences disability glare while in the path of an oncoming locomotive may lose the ability to recognize the distance between the two auxiliary lights, potentially effecting his or her depth perception of the oncoming train.

As a result of this study, LED headlights were banned on some railroads pending the development and acceptance of a specification by a technical advisory group (TAG). The TAG is made up of representatives from the Association of American Railroads (AAR), FRA, major railroad mechanical departments, locomotive headlight suppliers, and the ergonomists who authored this study. The goal of the TAG is to come to a consensus on the technical and mechanical requirements for a standardized LED headlight. This study data is being used to develop prototype LED headlights with light output that more closely resembles that of the halogen headlights currently in use. When several headlight prototypes are developed, it is expected that they will be tested for FRA compliance and further scrutinized through a comprehensive subjective evaluation, including participants both inside and outside of the locomotive cab. It is likely that the TAG will recommend that the prototype that excels in subjective testing has its lighting characteristics carried forward to the future specification for LED locomotive headlight/auxiliary lights.

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Symposium C: ODAM and Sustainable Development

Symposium C: ODAM et le développement durable

GREEN BUILDING DESIGN NEEDS ERGONOMICS

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KEYWORDS
Green buildings, LEED, WELL, Fitwel, post-occupancy evaluation

MAIN MESSAGE
Green building rating systems, such as LEED, WELL and Fitwel, are starting to focus more on occupant health and well-being. However, these systems typically do a poor job of incorporating good ergonomic program elements into the building design process and the final built product. This paper highlights the importance of integrating ergonomic design considerations into any green building rating system.

La conception de bâtiments écologiques a besoin de l’ergonomie

MOTS-CLÉS
Bâtiments écologiques, LEED, WELL, Fitwel, évaluation après l'occupation

MESSAGE PRINCIPAL
Les systèmes d’évaluation des bâtiments écologiques tels que LEED, WELL et Fitwel commencent à s’intéresser davantage à la santé et au bien-être des occupants. Cependant, ces systèmes réussissent généralement mal à intégrer les bons éléments d’un programme d’ergonomie dans le processus de conception du bâtiment et le produit final. Cette communication souligne l'importance de prendre en considération les facteurs de conception ergonomique dans tout système d’évaluation des bâtiments écologiques.

PROBLEM

The United States Green Building Council (USGBC) was established in 1993 with a goal of promoting more energy efficient and sustainable building and construction practices. In 2000, the USGBC launched the first U.S. Green Building Rating System™ which they titled the Leadership in Energy and Environmental Design (LEED®) certification program. The goal of LEED was to better guide the design, construction, operations and maintenance of buildings and communities toward greater energy efficiency and sustainability. Now updated to version 4 of the original rating system, LEED certification is based on the design of a project satisfying various prerequisites plus a point score for series of credits. Any new construction or existing building project can be rated to achieve points to attain one of four certification levels: Certified (40-49 points), Silver (50-59 points), Gold (60-79 points) or Platinum (80-100 points). A building project must satisfy all prerequisites and earn a minimum number of points to be certified. The various credits available in LEED v4 cover Integrative thinking, Energy, Water, Waste, Materials, Location & transportation, Sustainable sites, Regional impacts, Innovation, and Global, Regional, and Local considerations, and Health and human experience. The Health and human experience credits are within the Indoor Environmental Quality (EQ) section and the requirements focus on the use of low volatile organic compound (VOC) emitting materials and on performance-based indoor air quality assessment. Interestingly, there is a credit for an “Ergonomics approach for computer users”, but this is presented in the LEED Pilot Credit library rather than being a component of the Indoor Environmental Quality (EQ) section. This LEED credit for ergonomics is worth 1 point and it was updated in March 2016. The requirements of the latest version of the credit are summarized in Table 1.

Pursuit of the LEED ergonomics credit should enhance occupant health and wellbeing in a LEED green building; however, to date it seems that relatively few projects have sought the credit for various reasons, such as the lack of need for an additional credit point e.g. if the building already has 80 points then it will be a LEED platinum building and additional credits will be unnecessary, a widespread lack of awareness that the credit is available because it is placed in the Pilot credit library rather than in the EQ section of LEED v.4, and the widely held assumption that if a building is a LEED building then by definition the indoor working conditions must be healthful.

Table 1. LEED Building Design + Construction: New Construction - LEED v4 - Ergonomics approach for computer users (http://www.usgbc.org/node/4631863?return=/credits)

Intent
To improve occupant well-being (human health, sustainability and performance) through integration of ergonomics principles, specifically in the design of work spaces for all computer users*.

**Computer users are defined here as full time equivalent staff that utilize a computer for more than 50% of their workday. Occupants that are not computer users are encouraged to be included in the ergonomics strategy but not required.*

Requirements

1. During the conceptual or schematic design phases:
   - Engage an Ergonomist or Health and Safety Specialist to assist in the development of the ergonomics strategy
   - Make a commitment to integrate ergonomics principles into the overall design
2. The Ergonomist or Health and Safety Specialist, in conjunction with the client, must develop a description of the ergonomics strategy that will be implemented and include the following:
   - Statement identifying the goals of the ergonomics strategy
   - Description of occupant needs, including occupant characteristics and/or demographics, tasks, and machines, equipment, tools and work aids (METWA's) used to perform these tasks.
   - Process for selecting workstation layouts and furnishings based on relevant standards or guidelines. For computer workstations, refer to one or more of the following (or the most up-to-date versions of the following):
     - BIFMA G1-2013
     - ANSI/HFES 100-2007
     - CSA Z412-00 (R2011)
     - ISO 9241-5:1998
   - Education program for move-in and during ongoing operations
   - Process for evaluating and maintaining occupant well-being upon move-in and during ongoing operations to ensure the ergonomics strategy goals are being met. Select appropriate metrics and/or measurements for this evaluation, the evaluation frequency, and how soon after implementation the process will begin.

LEED BUILDING PERFORMANCE

In recent years, several studies have investigated the effects of working in a LEED building on the health, wellbeing and productivity of occupants. In a survey of 11 LEED-certified buildings in the Cascadia region of the USA, Turner (2006) fund that occupants reported high levels of satisfaction with air quality and lighting, but only moderate satisfaction with temperature, noise and speech privacy. Only a minority of occupants said that their perceived temperature conditions helped their work performance. Most occupants complained of uneven heat distribution, inaccessible temperature controls, and drafts. Unfortunately, she did not investigate work-related musculoskeletal discomfort (WRMSD) among occupants or any other indicators of ergonomic design.

Lee and Guerin (2009) analyzed survey data for 3,769 occupants in 15 LEED-certified office buildings to determine the effects of IEQ design criteria (office layout, office furnishings, thermal comfort, indoor air quality, lighting, acoustics, cleanliness and maintenance) on the occupants perceived satisfaction and performance. They found that indoor air quality affected only the occupants' performance whereas the quality of office furnishing affected their satisfaction. Once again, levels of WRMSDs were not investigated.

In a retrospective survey investigation of a LEED silver (n=142) and LEED platinum (n=33) office building, Singh et al., (2010) found that the improved perceived indoor environmental quality in the LEED buildings reduced perceived absenteeism and lost work hours from asthma, respiratory allergies, depression, and stress. It also resulted in an average 2.6% increase in perceived productivity per employee. But again, no evaluation of the effects of the LEED buildings on WRMSDs was made.

Newsham et al. (2013) conducted post-occupancy evaluations (POEs) of 9 green (3 LEED platinum, 3 LEED gold and 1 LEED silver, 3 unspecified) and 10 conventional office buildings across Canada and the northern United States. Measures of thermal conditions, air quality, acoustics, lighting, workstation size, ceiling height, window access and shading, and surface finishes were made at 974 workstations. A sample of 2,545 occupants completed an online questionnaire that asked about environmental satisfaction, job satisfaction and organizational commitment, health and well-being, environmental attitudes, and commuting. Although overall results showed that 'green' buildings outperformed similar conventional buildings for satisfaction with the environment, with thermal conditions, with exterior views, aesthetic appearance, less disturbance from heating, ventilation and air-conditioning (HVAC) noise, workplace image, night-time sleep quality, mood, physical symptoms, and lower levels of airborne particulates, there was considerable variability among buildings and some conventional buildings outperformed their green counterparts. Unfortunately, no data on WRMSDs were gathered in the study.

Hedge et al. (2014) compared 2 green buildings with a conventional building and found occupant experiences in a green building were not always better than those in a conventional building, and their overall workstation designs and WRMSDs were not always better in the green buildings. Dorsey and Hedge (2013) conducted a POE on a LEED platinum building and found that only a minority of occupants expressed satisfaction with their environmental conditions, and they identified a series of WRMSD concerns.
In a 3 years' follow-up on the same building they found persistent issues with IEQ and WRMSDs and health measures had worsened over the intervening time (Dorsey & Hedge, 2017).

IMPACT OF THE LEED ERGONOMICS CREDIT

To date there is a paucity of research on LEED buildings that have obtained the ergonomics credit to determine the value of this credit for improving the health, well-being and productivity of occupants. Hedge et al. (2010) reported on a qualitative study of occupants working in a LEED silver building of BD Biosciences in San Jose, California. Some 200 employees moved into this new location over a two months' period, and they completed pre-ergonomic surveys. Employees were given various ergonomic products: either an adjustable keyboard tray was installed or the worksurface was lowered and employee was given a footrest, employees were given an ergonomic chair. Rest-break software was installed and employees were encouraged to take at least a 10-second breaks every 15 min and longer (1-3 minutes) stretch breaks every hour or two. Employees were trained on proper workspace set-up and proper use of their keyboard and mouse. A post-move ergonomic evaluation was conducted for everyone. In the year prior to the move, 7% of employees reported a compensable WRMSD, in the year of the move this fell to 4% and in the year post-move this fell to 2%. The impact of the ergonomics credit was beneficial, yet at present it seems that most LEED buildings are neglecting the importance of the ergonomics credit and many are unaware of its existence.

WELL Building Standard™ (WELL) (http://delos.com/services/programs/well-building-standard)

The WELL Building Standard™ (WELL) is based on the idea that the design of the built environment can support human health and well-being. It is a new building standard that applies to buildings in use and, unlike LEED certification which is based on the initial design of a building, WELL certification occurs repeatedly every 3 years over the life of the building. It is administered by the International Well Building Institute (IWBI), and the WELL Building Standard sets performance requirements in air, water, nourishment, light, fitness, comfort and mind, all of which it is argued are relevant to occupant health. Like the LEED system, WELL Certification can be at Silver, Gold and Platinum levels.

According to the IWBI, WELL Certified™ spaces can help create a built environment that improves occupants' nutrition, fitness, mood, sleep patterns, and performance. However, WELL does a poor job of addressing ergonomic workstation design considerations. For the #73 requirement: Ergonomics: Visual and Physical, the stated intent is "to reduce physical strain and maximize ergonomic comfort and safety". However, simply providing height and distance adjustable computer screens meets the visual requirement, and the physical requirement can be met simply by providing occupants with a chair that has an adjustable height and seat depth, compliant with the ANSI HFES100 standard, and having at least 30% of workstations that allow sit-stand working. The sit-stand requirements are not internally consistent because the #71 requirement: Active furnishings, calls for 3% or more of employees to have access to either a treadmill desk, a bicycle desk or a portable desk peddle or stepper machine, and at least 60% of workstations should allow adjustable height standing work. Unfortunately, there are no research studies to date that have documented the impact of these requirements on WRMSDs.

FITWEL (https://fitwel.org/)

Launched in April 2017, Fitwel is a new "cost effective, high impact, health promoting building certification" system that is administered by the Center for Active Design in New York city. As with WELL, Fitwel's vision is that every building should be designed to support the wellbeing of its occupants and surrounding communities. The development of Fitwel was led by a 5 years long joint project by both the US Centers for Disease Control and

Prevention (CDC) and the US General Services Administration (GSA) involving studying 89 buildings across the USA, and that ended in 2015.

Unlike LEED and WELL, Fitwel does not require any potentially expensive or unsuitable pre-requisites. Fitwel presents strategies for existing buildings as well as for the design of new construction facilities. Fitwel's certification process is much simpler than LEED or WELL, and a request for certification can be submitted through a user-friendly web-based tool. Fitwel addresses how the building or project increases physical activity, promotes occupant safety, instills feelings of well-being, provides healthy food options, reduces morbidity and absenteeism, supports social equality of vulnerable populations and impacts community health. The Fitwel scorecard has 12 sections with a total of 63 requirements that can sum to144 points (items can be worth between 1 and 5 points) and certification is awarded as 1,2 or 3 stars. Fitwel is being offered as a low cost, unique building certification system that is designed to positively impact the health and productivity of occupants. Unfortunately, ergonomics is overlooked in this system and the only item that possibly relates is "Provide active workstations (such as treadmill desks) within the workspace", and as ergonomics research shows this is a contentious requirement because studies have reported that treadmill workstations can reduce typing and mousing performance (Dinesh et al., 2009; Straker et al., 2010; Botter et al., 2013).

CONCLUSION

Post-occupancy research surveys of LEED green buildings typically have identified numerous ergonomic design issues that impact the comfort, health and performance of occupants. There is a clearly a need for LEED buildings to pursue the ergonomics credit to give specific attention to the human element of green building design. The LEED rating system now incorporates an optional ergonomics credit and when applied this improves the indoor environmental impact on occupants. However, LEED is predominantly building focused rather than occupant focused. New rating systems, such as WELL and Fitwel, are focusing more on occupant health and well-being. However, neither WELL nor Fitwel does a comprehensive job of evaluating the ergonomic design of a workplace. These developments neglect highlighting the importance of integrating ergonomic design consideration into any green building rating system. There is clearly a need for ergonomics professionals and their respective societies to work to promote awareness of the LEED ergonomics credit and to lobby for changes in the certification requirements for WELL and Fitwel to better reflect the importance of ergonomics as an integral component in promoting the design of healthful and sustainable workplaces. Post-occupancy surveys of LEED, WELL and Fitwel buildings should assess the prevalence of WRMSDs, in addition to assessing occupant satisfaction and comfort. Finally, there is a pressing need to identify LEED buildings for which the ergonomics credit has been attained to determine what impact it has had on the overall health, comfort and productivity of occupants, and to use these results to fine tune that credit and to provide evidence for the need for a similar ergonomics credit in the WELL and Fitwel rating systems.

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HUMAN FACTORS AND PRO-ENVIRONMENTAL BEHAVIOUR

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KEYWORDS
Pro-Environmental Behavior, Psychology, Socio-Technical Systems

SUMMATIVE STATEMENT
This paper uses a literature review to explore how human factors may improve the outcomes of sustainable design and support pro-environmental behavior.

L’ergonomie et les comportements pro-environnementaux

MOTS-CLÉS
Comportement pro-environnemental, psychologie, systèmes sociotechniques

SOMMAIRE
La présente recherche a eu recours à une revue de la documentation afin d'explorer la façon dont l'ergonomie pouvait améliorer les résultats de conception durable et soutenir les comportements pro-environnementaux.

PROBLEM STATEMENT
How can human factors aid individuals in behaving in environmentally sustainable ways? Many approaches to reducing energy usage, cutting waste or achieving other environmental outcomes are technology led, the role of user behaviour and decisions are under acknowledged. This paper sets out to question how human factors knowledge and approaches may improve the outcomes of sustainable design and support individuals in enacting pro-environmental behavior.

RESEARCH OBJECTIVE/QUESTION
How can human factors aid individuals in behaving in pro-environmental ways and improve the outcomes of sustainable design?

METHODOLOGY
A literature review was conducted to explore the potential synergies between human factors, psychology and design in supporting pro-environmental behavior.

RESULTS & DISCUSSION
The topic of sustainability is receiving increased attention amongst human factors and ergonomics researchers (Haslam & Waterson, 2013), however, there are limited studies that explicitly address how to promote sustainability in practice. This paper argues that there is an opportunity for the discipline to aid the promotion of pro-environmental behavior (“behavior that intentionally pursues reduction of the negative impact of people’s actions on the natural world”, Stern, 2000). There is the opportunity to make use of the design of buildings and technologies to promote and reinforce desired pro-environmental behavior – for example, the interface, placement and presentation of feedback on energy usage can all influence the extent to which individuals change their energy consuming behavior (e.g., Stedmon, Winslow, Langley, 2013).

Moreover, human factors expertise and design can be used to aid behavior change, potentially helping to 'nudge' the behaviors of occupants or users (Watson et al, 2015). For example, configuration of offices and homes can influence the uptake of environmentally sustainable activities, for instance, by making sustainable behaviors more convenient and reducing perceived behavioral barriers or by making the pro-environmental behaviors more salient. This is demonstrated by the location of recycling receptacles, with their placement found to influence recycling rates in buildings (Ludwig, Gray & Rowell, 1998). The implementation of design cues, prompts, and feedback present the opportunity to both initiate pro-environmental behavior and to promote the formation of long-lasting habits (Davis & Challenger, 2015). Furthermore, socio-technical systems perspectives have been used to identify barriers and linkages between initiatives and technological changes aimed at promoting sustainability (Davis, Challenger, Jayewardene & Clegg, 2014).

CONCLUSIONS

Human factors' rich knowledge base regarding holistic design, user needs and the anticipation of human responses to changes in technology and physical environments has an important role to play in supporting pro-environmental behavior and sustainability.

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'SHUT THE FRIDGE DOOR': USING SOCIO-TECHNICAL WORK REDESIGN TO IMPROVE ENERGY EFFICIENCY IN SUPERMARKET RETAIL STORES

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SUMMATIVE STATEMENT: We describe a set of intervention involving job redesign and the realignment of HRM policy with with training and performance management systems, as well as organisational performance goals within a large UK retailer. Together the interventions led to substantial improvements in energy efficiency in the company stores.

« Fermer la porte du frigo » : redéfinir les tâches en utilisant la conception sociotechnique pour améliorer l'efficacité énergétique dans les supermarchés

Sommaire: Cette communication décrit un ensemble d'interventions touchant la redéfinition des tâches et la réorientation des politiques en matière de gestion des ressources humaines avec la formation et les systèmes de gestion du rendement, de même que les objectifs liés au rendement organisationnel, auprès d'un grand détaillant du secteur de l'alimentation au R.-U.

PROBLEM STATEMENT: Energy management has become a key part of organizational life across all industries and is proving an area of increasing interest as a response to carbon reduction targets. We carried out a two-year qualitative case study with a large UK retail organization that utilised a socio-technical framework (Christina et al., 2015) in order to examine the interaction between environmental behaviours, goals and building infrastructure.

RESEARCH OBJECTIVE / QUESTION: How can job redesign help to improve energy efficiency in large companies? What other aspects of company Human Resource Management (HRM) might help to reduce energy use? How is job redesign related to other company-wide HRM developments?

METHODOLOGY: A total of 131 participants took part in either semi-structured interviews or focus groups. We included a wide range of staff in these focus groups, including shop floor staff, departmental managers and team leaders from across the UK store network.

RESULTS: The study indicated that most staff agreed that energy efficiency is important for the organization, and that certain individuals in stores show high levels of motivation to comply with energy efficiency tasks. However, across the 29 stores visited, focus group participants exhibited little personal intrinsic interest in carbon reduction either in or outside of the organization. The strongest motive for household energy efficiency is reducing personal financial costs and we found that the impetus of financial motivation does in part translate to the workplace for management staff, but not necessarily for those working at junior staff level. Our initial data inspired two job design interventions that were implemented in over 1000 stores, focusing on energy management accountability and performance management. We set out to improve performance against energy goals by increasing the chances of the energy task being completed in a multiple goal environment through alignment, rather than trying to raise the relative importance of the energy goal against other store goals. The emphasis on aligning with existing practices and goals is drawn from multiple goal theory, where alignment with an organizational goal is proposed to improve performance in a multiple goal environment. Previous to the research being carried out, an Energy Champion system had been running for a number of years. The initial data analysis indicated that while this system had successfully engaged key members of staff to perform energy-related tasks, the voluntary nature of the job, and the lack of universally-appealing motivation limited the potential for the initiative to sustain success. We hypothesised that this was associated with observed conflict with core store objectives. We further theorised that it was therefore counterproductive to see energy as a primary organizational goal in this context, as it risked the perception of opposition to primary sales goals in terms of staff time and effort. We therefore began to specifically design energy management as a secondary goal in the organization to be aligned with existing cultural characteristics through job design, practices and processes. This is consistent with existing theory on managing multiple goal conflict through simplification brought about through alignment with existing goals. A crucial advantage of the job-redesign intervention is that it aligns and normalises energy management with existing staff training and performance systems. The combined changes to job design and performance management measures are observed to have made a difference to the perception of difficulty of energy management for most of the participants that we spoke to. The managers appeared to feel more comfortable with a directive performance indicator than with the idea of controlling energy budgets, as it gives managers direct actions to take to achieve a goal. Again, this fits into the culture of the stores; they feel comfortable talking about how they get specific tasks completed. Managers at the headquarters of the organization valued the energy cost saving at £4 million in the first year of intervention. There are plans to roll out the intervention across all of the supermarket's 3500 UK stores, as well as globally. Initial findings have been from the study have been published (Christina et al., 2015); quantitative data covering the details of the intervention are currently the subject of a second paper (Christina et al., 2017, in press).

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CROWD WORK AND SUSTAINABLE WORK SYSTEMS: A CONTRADICTION?

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KEYWORDS
Sustainability, sustainable work systems, crowd sourcing, crowd work

SUMMATIVE STATEMENT
During the last years sustainability became a topic in HFE/ODAM. In a changing world of work new types of work (like crowd work) are of growing interest. To fulfill the preconditions of a sustainable work system, specific types of crowd work need to be improved. At the same time, we need to expand the definition of sustainable work systems.

Les systèmes d'externalisation ouverte et de travail durable : une contradiction?

MOTS-CLÉS
Durabilité, systèmes de travail durable, externalisation ouverte, travail participatif

SOMMAIRE
Au cours des dernières années, la durabilité est devenue un sujet de l'ergonomie de conception organisationnelle et de gestion. L'évolution du monde du travail fait en sorte qu'il y a un intérêt grandissant pour les nouveaux types de travail (p. ex., le travail participatif). Afin de satisfaire aux conditions préalables des systèmes de travail durable, il faut améliorer certains types de travail participatif et, parallèlement, élargir la définition des systèmes de travail durable.

PROBLEM STATEMENT
The digitization of knowledge work based on internet technologies and respective platforms (like Amazon's Mechanical Turk or others) combined with the idea of "hyperspecialization" (Malone et al 2011) leads to new types of supply chains for knowledge work (crowd sourcing). This type of work may have some positive aspects (as freelancer work), but it may also go together with working conditions which are considered problematic from a HFE/ODAM point of view.

RESEARCH OBJECTIVE/QUESTION
Because of the before-mentioned ambivalence of crowd work, the potential contradictions between state-of-the-art implementations of crowd work and the HFE/ODAM view on sustainable work have to be identified. Based on this, it needs to be discussed how to redesign this form of crowd work so that it complies as far as possible with sustainable work system requirements. But – as the world of work is changing – we have also to consider, whether we need a new (broader) definition of sustainable work systems.

METHODOLOGY

To find out, whether crowd work (based on hyperspecialization) can fulfill the preconditions of sustainable work, the key components of the sustainable work system definition shall be compared with the key characteristics of crowd work as described in literature. So far, the study is literature based. In addition, two questions have to be answered: a) Are existing definitions of sustainable work sufficient to address the specific characteristics of this new type of knowledge work? b) Is it possible to redesign crowd work to meet the demands of sustainable work systems? This part of the paper is more conceptual in nature.

RESULTS

Outsourcing of work is not a new concept. In the past, mostly blue collar work in industries with a short life cycle like textiles, garments and electronics has been outsourced to Industrially Developing Countries (IDCs). Since some years also knowledge work came into focus of outsourcing: called “crowd sourcing”. This is an artificial term combining “outsourcing” with “crowd” (the sum of people getting offered work by an internet platform) (Howe 2006). Anyone (globally) with access to the internet can perform either micro-tasks like Amazon’s Mechanical Turk or multi-hour-tasks offered e.g. by upwork. Incentives and work structures vary tremendously. On the positive side, crowd work might provide higher self-determination regarding tasks, working place or working times, thus contributing to a better work-life-balance or to new employment possibilities for people who cannot leave their homes etc. On the negative side, crowd work realities often come with the risks of low remuneration without any social security, monotonous tasks based on a high standardization or a decomposition in very small pieces (“digital Taylorism”), danger of continuous electronic monitoring through crowd sourcing platforms etc. (Leimeister et al 2015).
Looking at sustainable work, the following elements are essential according to the definition: Concurrent development of economic, ecological, human and social resources; achievement of economic and operational goals, but at the same time development of human and social resources; work-based learning, development and well-being as precondition to deal with economic challenges; growth of social resources secured through equal and open interaction among various stakeholders; no exploitation of external resources (Docherty et al. 2009; Zink & Fischer 2013).
Comparing these elements with crowd work based on hyperspecialization, we can observe an exclusive focus on the development of economic resources (which might not be enough to live one’s life). Work based learning, development and well-being, however, is not organized in general, there is only an interaction with an internet platform with no growth of social resources e.g. through interaction with customers, hence exploitation seems to be possible (Zink 2017).
What should be done from a HFE/ODAM perspective to redesign this form of crowd work? Some first ideas have been formulated by Kittur et al. (2013): develop tools to support not only the work itself but also those performing the work; design the job as described e. g. by Hackman & Oldham (1980): providing skill variety, task identity, and task significance, timely and task specific feedback, as well as the opportunity for self-assessments to help workers to learn, persevere, and produce better work; create a broad set of motivations including fair payment but also reputation and credentials (like certification); create career ladders; improve task design through better communication; facilitate learning.
As crowd work is a global phenomenon, the “traditional” definition of sustainable work systems (Docherty et al 2009) which is (mainly) focused on one organization might not be sufficient for this type of work that expands beyond individual organizations.
This is related to the question, whether sustainable work is possible without sustainable employment: The answer should be: No! One possibility to broaden the definition of sustainable work given by Docherty et al (2009) could be to include the ILO definition of decent work, which is also reflected in goal 8 of the ILO 2030 Agenda for Sustainable Development. This definition sums up the aspiration of people in their working lives including the opportunity for work that is productive and that delivers a fair income, security in the work place and social protection for families, better prospects for personal development and social

integration, freedom for people to express their concerns, organize and participate in decisions that affect their lives, and equal opportunity and treatment for all.

DISCUSSION

While we discussed sustainable and decent work in the past related to blue collar work in international supply chains, it is time to look at new forms of outsourced knowledge work which has become possible through internet technologies and new possibilities of hyperspecialization (Zink 2016). As one result, crowd work is a growing part of the world of work (the Oxford Internet Institute is estimating 48 billion crowd workers worldwide, see Graham 2017). This type of work provides a lot of opportunities for the crowd sourcer (i.e. the companies) because work can be done much faster and of much better quality. But there are also risks for the crowd workers, which should be discussed by the HFE/ODAM community. As basis for an assessment of the quality of crowd work the criteria of sustainable work have been used. Results of research regarding crowd work in the form of micro-tasks (based on hyperspecialization) indicate a necessity to improve working conditions. In addition, it became clear that a definition of sustainable work systems mainly based on work in one organization might be to narrow. Therefore, a broadening of this definition has been proposed.

This study intended to show that it is time to deal with alternative forms of (knowledge) work. However, as the description of crowd work was only literature-based, more empirical data is required.

CONCLUSIONS

If we accept globalization and sustainability as challenges for HFES/ODAM we need some further developments of the discipline. HF in ODAM is no longer limited to one single organization, rather a system of systems approach is necessary (Zink 2014; Thatcher & Yeow 2016). These contents need to be included in a (macro) ergonomics curriculum dealing with new target groups like purchasing departments or supply chain managers.

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SYSTEMIC CHALLENGES IN SUPPLY CHAIN ERGONOMICS

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KEYWORDS
Supply chain ergonomics, system-of-systems, sustainability, developing countries, decent work

SUMMATIVE STATEMENT
This paper explores the competing demands facing the global labour system. Human factors and ergonomics (HFE) theory is applied to establish sustainable work systems. HFE is concerned with the human-in-the-system. The problems of safe workplaces, healthy working conditions, and the opportunity for decent work fall broadly within this domain. This paper explores these competing demands facing the global labour system in order to create sustainable work systems. This area of study within the HFE discipline is called supply chain ergonomics (Zink, 2014). The focus of this paper is the case of BRICS countries; a group of emerging countries that display a mix of both developed and developing countries.

Les difficultés systémiques dans l'ergonomie de la chaîne d'approvisionnement

MOTS-CLÉS
Ergonomie de la chaîne d'approvisionnement, système de systèmes, durabilité, pays en développement, emploi décent

SOMMAIRE
La présente communication explore les exigences contradictoires du système de travail mondial. La théorie en matière d'ergonomie est appliquée dans le but d'établir des systèmes de travail durable. Le domaine de l'ergonomie s'intéresse à l'humain dans le système, et les problèmes liés aux lieux de travail sécuritaires, aux conditions de travail saines et aux possibilités d'emploi décent relèvent généralement de ce domaine. Cette recherche explore les exigences contradictoires auxquelles le système mondial de travail mondial est confronté afin de créer des systèmes de travail durable. Ce secteur d'étude, qui fait partie du domaine de l'ergonomie, se nomme l'ergonomie de la chaîne d'approvisionnement (Zink, 2014). La présente étude est axée sur la situation des pays BRICS; un groupe de pays émergents qui s'articulent autour de la notion de pays développés et en développement.

PROBLEM STATEMENT

Humans are currently restricted to living on a single planet, meaning that materials and resources (including human resources) required for our survival and wellbeing are limited and also asymmetrically distributed. In dealing with the these asymmetries, organisations often set up complex global supply chain networks where primary manufacturing is moved closer to the raw materials (or where labour costs are lower) often at the expense of the health, wellbeing, and safety of the human resources at these locations. Thatcher and Yeow (2016a) have described these as (1) resource asymmetries, (2) asymmetries in the accumulation and distribution of waste, and (3) legislative asymmetries which have led to a set of interconnected, negative human and environmental consequences (see Table 1).

Addressing these asymmetries is a challenge for sustainable development where eradicating these inherent social inequalities must be balanced against possible damage to the life-supporting ecosphere. Zink and Fischer (2013) have called this “human factors and sustainable development” with a number of theoretical perspective emerging including green ergonomics (Thatcher, 2013) and ergoecology (Garcia-Acosta et al., 2014). Zink (2014) argues that HFE needs to consider these asymmetries through supply chain ergonomics (Zink, 2014). This approach considers HFE issues across the whole value chain; the HFE issues associated with the extraction of raw materials, the HFE issues in the production and manufacturing processes, the HFE issues in the transportation and distribution of raw materials and products, the HFE issues in the purchase and use of products, and the HFE issues in the disposal and decommissioning of products. Traditionally, supply chain management has been concerned with physical materials and products, but increasingly supply chains also include less tangible aspects such as skills and services (e.g. call centre problem solving). Of interest here is ensuring that potential HFE issues are addressed at all stages of the value chain, not only at the end-user phase where Zink (2014) argues that the majority of HFE attention is currently paid. It should be noted that there have been geographical asymmetries in addressing HFE issues. Some geographical areas (i.e. Europe, North America, Far East Asia, and Australia) have a more mature approach to HFE and other labour concerns (see the legislative asymmetries in Table 1). Hasle and Per Langaa (2012) identified five challenges for HFE emerging from global supply chains; poor articulation of social sustainability criteria; differential key performance indicators in different parts of the world; too many organisational changes across the value chain; participatory approaches are difficult to implement; and HFE has little agency or regulatory control across national borders. Zink (2014) therefore argued that the burden for investigating and addressing the HFE asymmetries should be borne primarily by “Western organisations” (p. 129). This paper examines the feasibility of that approach.

Table 1. Global asymmetries related to sustainability.

Problem	Human consequences	Environmental consequences
1. Resources asymmetries: Water, food, land, sanitation, energy, housing, education, jobs, healthcare, cultural expression	Poverty, hunger, disease, cultural subjugation and intolerance, exploitative labour practices; respiratory health	Land degradation, drought, deforestation, water pollution, monocultures, GMO, atmospheric pollution
2. Asymmetries in accumulation and distribution of waste: CO^2, CO, O^3 depletion, VOC, heavy metals, e-waste	Food security, health, disease spread	Global climate change, desertification, oceanic and land deadzones, ocean garbage patches, species extinction
3. Legislative asymmetries: Worker protections, technology transfer, labour broking, operational relocation	Child labour, modern slave labour, unequal compensation for work, culturally and anthropometrically inappropriate technology, social conflict	Land degradation, freshwater depletion, unequal global distribution of waste

The asymmetry problems are exacerbated for a group of countries characterised by a combination of high technological and infrastructure development together with low worker skill levels and high unemployment (Guimarães & Soares, 2008). A segment of this group is referred to as BRICS countries (Brazil, Russia, India, China, and South Africa). BRICS countries are characterised as being recently industrialised with a relatively high level of technological advancement, and significant local geographical influence. Goldman Sachs (2007) predicted that the production and income of BRICS countries would outstrip the G8 countries by 2030. However, there is also a negative side to the BRICS situation. BRICS countries are characterised by a dichotomy between a small “elite” who have access to resources, skills, education, and services and large populations who have few skills, very basic income, and who only have access to basic services which are often poorly resourced. Wadongo (2014) describes some of the difficulties associated with development on the African continent that serves as a parallel for BRICS countries. Many of the economies across the African continent are showing rapid economic growth. However, much of this growth has happened in the absence of significant policies to improve the livelihoods of the majority of people whose living conditions still remain difficult (Wadongo, 2014). Resources in Africa (and indeed in most other BRICS countries) are abundant but are extracted and exported with little value-added. While this fuels economic growth, most of these “growth” benefits are not experienced by the average citizen. Instead, Wadongo (2014) argues, small pockets of investors, shareholders, and government officials reap the benefits. Much work is needed to lift millions out of poverty and create jobs for the unemployed. This paper explores how supply chain ergonomics can be applied to build sustainable work systems that would encourage developing nations to transcend existing imbalances in current work systems.

RESEARCH OBJECTIVE/QUESTION

In this paper we question the sustainability of these imbalances and consider what an HFE perspective to global supply chain networks can contribute. In particular, some developed countries outsource work standards, safety, and wellbeing in pursuit of reduced direct and indirect costs. This places extreme human wellbeing and safety burdens on countries that are ill-equipped to take on these responsibilities, but who do so in the interests of being globally competitive while increasing employment opportunities for their national workforces.

METHODOLOGY

Since HFE is concerned with the human-in-the-system, the problems of safe workplaces, healthy working conditions, and the opportunity for decent work fall firmly within our domain. In this paper we use the sustainable system-of-systems (SSoS) model for HFE developed by Thatcher and Yeow (2016b). Following Wilson (2014), systems of interest to HFE are those that include at least one human. The SSoS model for HFE has three major components: (1) a nested hierarchy of complexity; (2) a focus on multiple, simultaneous goals; and (3) consideration of issues over time.

(1) A nested hierarchy of complexity notes that systems are organized into nested hierarchies based on their complexity, spatial influence, and relative time scale. The SSoS model for HFE represents possible HFE systems in a hierarchy of complexity and spatial influence. Thatcher and Yeow (2016b) used Wilson’s (2014) terms to describe the “target” system (the initial, specific system of concern), “sibling” systems (i.e. systems with equivalent complexity and spatial influence), “parent” systems (i.e. systems of greater complexity or spatial reach), and “child” systems (i.e. systems that are less complex with a tighter spatial reach).

(2) A focus on multiple, simultaneous goals is sometimes articulated as a balance of Elkington’s (1997) triple bottom line (social, economic, and natural capital). The triple bottom line should be seen as an example of the need to balance multiple goals and not necessarily a definitive list of goals. For Thatcher and Yeow (2016b) the multiple goals are inextricably linked, such that a failure to balance all the goals simultaneously will lead to a potential collapse (i.e. non-sustainability) of the SSoS.

(3) The consideration of issues over time recognises that natural systems do not exist indefinitely but have a natural lifespan. The length of that natural lifespan of a particular system is dependent on the relative position in the nested hierarchy (Costanza & Patten, 1995). Thatcher and Yeow (2016b) argued that a larger, more complex system should have a longer natural lifespan than smaller, less complex systems. If a system fails to reach its natural lifespan then this will result in instability/unsustainability across the hierarchy of systems. Similarly, if a system survived longer than its natural lifespan it would result in brittleness/unsustainability across the hierarchy as the SSoS would fail to adapt to changes.

Using Thatcher and Yeow's (2016b) SSoS model it is possible to place supply chain ergonomics in a simplified hierarchy of nested systems (see Figure 1). This SSoS is simplified to concentrate on the primary HFE issues. A more complete SSoS would involve multiple stakeholders from various disciplines, each identifying system components relative to their discipline. The hierarchical ordering is determined by the system's relative complexity, geographical influence, and expected natural lifespan. For example, the culture of an organisation is not expected to be as complex as the labour legislation of an entire country and will take longer to change. The nested hierarchy depicted in Figure 1 considers the "target system" (supply chain ergonomics) in the context of sibling systems of similar complexity (i.e. legislative frameworks, education systems, skill systems, and health systems for each geographical contest). The larger, more complex parent systems include the global ecological, financial, cultural, and social systems. First-order child systems include the organisational culture and the organisational safety culture. Second-order child systems include safety equipment and managerial accountability systems. Third-order child systems (and the smallest unit of analysis for an HFE investigation) would be work design considerations, in particular, a consideration of "decent" work.

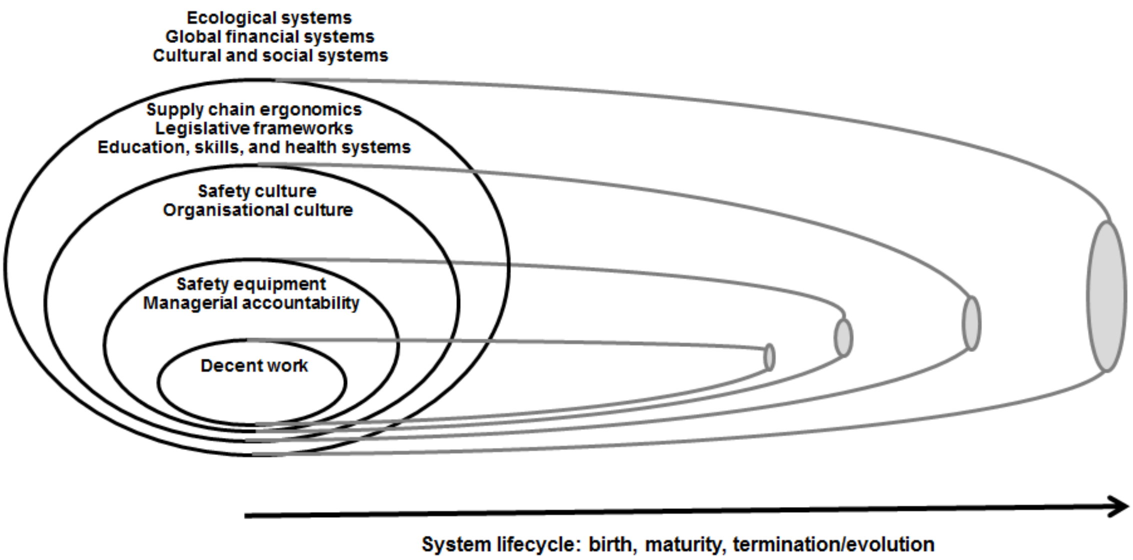

Figure 1. HFE sustainable system-of-systems for global supply chain ergonomics

RESULTS

From an HFE perspective the ultimate goal is envisaged to be the provision of decent work for all participants in the global supply chain (a third-order child system in this SSoS; Figure 1). The International Labour Organisation (2017) defines decent work as an aspirational goal to enable a worker to be productive, secure, have freedom of expression, opportunities for decision making, and equal treatment, all while receiving fair pay. While these components are certainly noble and desirable, Blustein et al. (2016) have noted that the definition is currently vague and therefore lacks global consensus about the priorities and values inherent in this goal. Some countries have already embedded many of these aspects in their worker protection policies but have criticised this definition for not taking the psychological meaning aspects of work into account (e.g. self-actualisation), whereas other commentators feel that the social justice aspects inherent in the original definition (which were aimed at protecting workers' rights and reducing harm) have been eroded in this current definition. For BRICS countries both these criticisms would apply, although the majority of workers are willing to take any job opportunity (regardless of the working conditions) simply to fulfil basic livelihood needs. Blustein et al. (2016) refer to such conditions as "precarious work" which is characterised by high powerlessness, high job insecurity, low worker protections, and low income. For example, extractive, transnational mining companies that have historically employed cheap, unskilled, manual labour largely dominate the South African economy (Ledwaba & Nhlengetwa, 2016). Working conditions in these mines are general extremely poor (Hermanus, 2007). Improved labour legislation has led to increased mechanisation in order to reduce exposure to these hazardous conditions. This has led to a requirement for higher skill levels, but with fewer workers working under only slightly better working conditions. This leaves thousands of previously employed people without any form of income and with no skills to find alternative employment. Recently, these circumstances have led to an increase in “illegal” mining activities, locally these illegal miners are called *zama zamas*, who return to disused parts of mines in order to eke out a marginal existence under the same hazardous working conditions, but now without sufficient support networks (Ledwaba & Nhlengetwa, 2016).

The first and second-order child systems each represent different levels of support systems for decent work. Of particular concern for supply chain ergonomics are the child systems that support safe and decent work. Second-order child systems include the provision of appropriate safety equipment (where hazards cannot be removed) or appropriate managerial oversight and accountability to ensure that safe and healthy working conditions are provided. In the context of high unemployment and the national imperatives to drive economic growth, the global supply chain experiences an imbalance between social capital (i.e. healthy, safe, meaningful work) and economic capital (i.e. profits) with the emphasis being placed on economic capital with social capital rights expected as an outcome of economic upliftment. As described by Wadongo (2014), economic upliftment is seldom an outcome because profits are only distributed amongst the few. This leads to poorly resourced support systems.

Three sibling systems are important to consider for supply chain ergonomics; legislative systems (especially labour legislative and the enforcement of this legislation), education systems (particularly the acquisition of higher-level knowledge and skills), and healthcare systems (which provide services to ensure a healthy working population and appropriate care for workers who are exposed to hazards). The quality and strength of these systems tends to be variable in BRICS countries. In China and Russia, the education and healthcare sibling systems are fairly robust but the worker legislative systems are poor. In Brazil, India, and South Africa, none of these sibling systems can be described as good, unless one is a member of the relatively smal group of elites. Worker protections, in particular, are poor across BRICS countries; partly an attempt to attract foreign investment through reduced labour costs and partly through poor infrastructure to monitor and punish infringements. Prosecuting infringements, or even trying to introduce legislation to protect workers, are often viewed by the political and economic elites as contrary to economic development.

The parent systems act at the global socio-political level and are sometimes (but not always) determined by numerous multinational agreements and discussions administered by global bodies (e.g. United Nations, International Labour Organisation, World Economic Forum, etc.). It is a fair critique to say that these multinational agreements are inconsistently applied by country-signatories. Governments change, resulting in withdrawals from previous agreements or weak enforcement of agreements if withdrawal is not possible or is perceived to take too long. In short, the parent systems arise out of negotiated settlements by the political and economic elites with seemingly little consideration for the personal wellbeing of the mass of workers, other than a narrow interpretation of economic upliftment.

DISCUSSION

What does this mean for HFE and the contributions that we can make towards supply chain management? First, the SSoS analysis reveals that successful contributions from HFE can only come from a more complete understanding of the various hierarchical levels of influence and the complex interactions between the levels. Attempts at providing decent work cannot succeed without the right type of supportive environments. Not all of these can be directly addressed by HFE, but we can use HFE tools and methods to identify the relevant systems and stakeholders. Second, an analysis of these systems requires the input of people with expertise in many disciplines but particularly economic and political science. Bottom-up, micro-ergonomics interventions that only concentrate on providing decent work (no matter how well-intentioned) are unlikely to succeed without a comprehensive understanding of the economic and political systems that support their monitoring and maintenance. Trying to drive change from "Western organisations", as Zink (2014) proposes, is highly unlikely to succeed (or at best, will only achieve short term success) unless supported by the parent systems in the host organisations/countries. Third, this analysis suggests that localised solutions that balance multiple goals (not just economic capital) are more likely to succeed and become locally sustainable. The need for local solutions is something Lange-Morales et al. (2014) emphasise in their set of values for sustainable HFE. Localisation also means looking at what value-added services might be incorporated close to the source, rather than being globally distributed. This provides greater opportunities for job creation and provides incentives to invest in education systems. Of course, this also means that products and services may become more expensive for those people living further away from the source, and that job transformations will also be required in those regions.

CONCLUSIONS

The solutions that emerge from ergonomics require finding "just transitions" between the need for modernisation through mechanisation/computerisation and the requirement to increase skill levels while protecting (and growing) employment. This is a global agenda that will have knock-on effects beyond BRICS countries, especially towards more industrially developed parts of the world. This links directly to Lange-Morales et al.'s (2014) argument that ergonomics should value equitable decision making. However, Carayannis et al. (2014) warn that these just transitions will be hampered by the personal agendas of influential people, hidden networks, and clandestine political motives.

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Technical Session 6: Macroergonomics - Interventions, Design Processes & Change Management

Séance technique 6: Macroergonomie : interventions, procédés de conception et gestion du changement

TERTIARY ERGONOMICS/HUMAN FACTORS PROGRAMMES WHO CARES, WHAT NEXT?

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KEYWORDS
Future, University, Education, Integration, Undergraduate, Postgraduate, Masters

MAIN MESSAGE
Since there have been in recent years around the world prominent closures of some Ergonomics/ Human Factors (EHF) university programmes, stronger efforts must be made within universities to redress widespread misunderstanding about the nature of EHF. A way forward would be to integrate EHF courses more widely at undergraduate and postgraduate levels across a broader range of academic disciplines.

Les programmes d'ergonomie du secteur tertiaire : qui s'en soucie et qu'adviendra-t-il?

MOTS-CLÉS
Avenir, université, éducation, intégration, 1re cycle, 2e cycle, 3e cycle

MESSAGE PRINCIPAL
Étant donné que de grandes universités, un peu partout dans le monde, ont mis fin à leur programme d'ergonomie au cours des dernières années, les universités doivent déployer de plus grands efforts pour corriger l'incompréhension générale au sujet de l'ergonomie. Un moyen d'aller de l'avant consiste à intégrer des cours d'ergonomie dans une plus vaste gamme de disciplines au premier et au troisième cycles.

PROBLEM

In recent years, around the world there have been prominent closures of some Ergonomics/ Human Factors (EHF) university programmes. For the authors, this was unsurprising since in 2000 one of us (Legg in: Vitalis, Walker and Legg, 2000) had questioned 'where ergonomics was headed' – Pion Dromo Ergoniomia? Wherefore Ergonomics?

CONTEXT

Until 2010, Massey University offered a postgraduate Diploma and Masters degree in EHF (Legg, 2008). This was primarily offerd in Distance mode, similar to those described by Watson and Horberry (2003) and by Richardson and Baird (2008). In 2010 budget restrictions and 'academic realignment based on student demand' resulted in recommendations to close both of Massey University's EHF qualifications. In 2014 Massey's EHF academic staff moved into a new College of Health with the aim of integrating EHF into a suite of novel health related qualifications but without clear advertising or promotion of EHF as a unique and useful qualification. Despite a report outlining innovative ways forward for EHF at the university (Stedmon, 2015), in 2016 the College formally closed the EHF qualifications on the grounds of low student demand and unprofitability. However, contemporaneously two new undergraduate courses in EHF (Healthy Workplace Design and Work and Health) were developed and integrated into a new Bachelor of Health Sciences degree. The EHF postgraduate courses were retained and incorporated into a Master of Public Health (as specific EHF option courses) and a Master of Health Sciences (as a specific EHF specialisation).

ACTIONS

In order to explore ways forward for EHF, a strategic EHF audit at Massey University sought a wide range of viewpoints from academics, administrators and managers via interviews and focus groups, essentially asking – 'who cares' and 'what next'?

OUTCOMES

There was widespread goodwill and empathetic support for EHF, particularly amongst academic staff and wide differences in (mis)-understanding about what EHF might be (more prominent amongst administrators and management). There were institutional barriers (a 'silo culture') to EHF integration across disciplines.

DISCUSSION

University management was driven by a need to pigeon-hole EHF within a specific single wider discipline area e.g. health, where it may fail to attract adequate students to make it profitable, particularly when no proactive promotional effort is made. A way forward would be for EHF to be taught in an integrated mode (internally and by distance-learning) and viewed in a context where it is clearly relevant to a number of wider discipline areas, such as science, health, public health, physiotherapy, occupational therapy, sport, psychology, design, technology, engineering, business, management, defence, security and aviation.

CONCLUSION

Stronger efforts must be made within universities to redress widespread misunderstanding about the nature of EHF. A way forward would be to integrate EHF courses more widely at undergraduate and postgraduate levels across a broader range of academic disciplines.

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A MACROERGONOMIC INTERVENTION ENABLED AN ORGANIZATION TO OVERCOME PRODUCTION DISRUPTION WHEN ADOPTING NEW TECHNOLOGIES

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KEYWORDS
Biotechnology; participatory ergonomics; human-systems integration

MAIN MESSAGE
Human consequences, such as workplace injuries, are the result of complex interactions that have origins at sociotechnical, organizational and technological levels. Solving the problems at the root level can have beneficial long-term consequences for success in adapting to change. A macroergonomics intervention improved human outcomes by changing the safety culture and organizational processes.

Une intervention macroergonomique permettant à une organisation de résoudre les interruptions de production par l’adoption de nouvelles technologies

MOTS-CLÉS
Biotechnologie, ergonomie participative, intégration des systèmes humains

MESSAGE PRINCIPAL
Les conséquences humaines, comme les accidents de travail, sont le résultat d'interactions complexes provenant de niveaux sociotechnique, organisationnel et technologique. Le fait de régler la cause du problème peut avoir des conséquences bénéfiques à long terme sur la réussite de l’adaptation au changement. Une intervention macroergonomique a permis d’améliorer les résultats pour les travailleurs en modifiant la culture de sécurité et les processus organisationnels.

PROBLEM
An unusually high rate of musculoskeletal injuries was the perceived problem that disrupted production and threatened the organization’s future. In reality, the problem was an organization transitioning from one level of production in a competitive arena to a higher level.

CONTEXT
This case study follows a biotechnology production facility over many years as it copes with increasing production output, increasing customer demands, and rapid technology adoption in a setting of poor systems integration. This created a disruption that manifested in rising employee injuries and production interruptions.

ACTIONS

The disruption was ultimately addressed through a comprehensive redesign of human-system relationships. Key elements included: a management team willing to examine the entire production system; a multidisciplinary team coordinating efforts toward a common goal; engaging staff through a participatory process of job redesign; building feedback channels to guide the actions of supervisors and managers; improving communications to workers; and modifying training programs. The entire production process was redesigned including all jobs with recommended work processes.

OUTCOMES

At the microergonomic level, injuries were reduced dramatically and have remained near zero after the intervention. From a macroergonomic perspective, the intervention changed the safety culture and morale of the organization. This enabled the organization to embrace additional new technology and compete in an arena beyond where they were before the intervention (from sequencing only human DNA to sequencing multiple species in much greater volume).

DISCUSSION

What appeared to be a simple ergonomics problem, with elevated worker injury rates, was really a symptom of a larger issue of an organization in transition with increasing customer production demands addressed with the rapid adoption of new technology. The macroergonomic intervention not only eliminated the injuries, but redesigned the entire organization, relationships, work flow and culture.

CONCLUSION

This macroergonomics approach is useful and necessary to help organizations undergoing dramatic change in technology. The human consequences (injuries) may be symptoms of larger organizational challenges.

ROLE OF THE ERGONOMIST IN SUPPORTING CHANGE MANAGEMENT: A CASE STUDY OF FORKLIFT OPERATION

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KEYWORDS
Change management, participatory approach, materials handling

MAIN MESSAGE
New advances in technology and updated product models may induce changes in process design and/or work methods. However, in many industrial workforces, change is not always embraced openly. Several types of ergonomics support can be effective tools in providing objective methodology to assist companies in implementing and managing these types of changes.

Le rôle de l'ergonomie pour soutenir la gestion du changement : une étude de cas sur l'utilisation de chariots élévateurs

MOTS-CLÉS
Gestion du changement, démarche participative, manutention manuelle

MESSAGE PRINCIPAL
Les nouveaux progrès technologiques et les produits modifiés peuvent entraîner des changements dans la conception des processus ou des méthodes de travail. Cependant, les changements ne sont pas toujours accueillis à bras ouverts par la main-d'œuvre de nombreux secteurs industriels. Plusieurs types d'outils ergonomiques peuvent s'avérer efficaces pour fournir une méthodologie objective qui aidera les entreprises dans la mise en œuvre et la gestion de ces types de changements.

PROBLEM
A company was purchasing new forklifts, as the lease with the current fleet was expiring. A new brand of forklift was selected based on cost with two potential electric models to be brought into the facility for trial. The majority of employees were comfortable and familiar with the operation of the current propane forklifts and did not want to change, which contributed to a negative perception towards trialing the new electric models.

CONTEXT
The company is an automotive manufacturing supplier, which fabricates and assembles parts for the interior of vehicles. Currently, the materials handling of packaging to/from trailers and throughout the facility is primarily completed via forklift operation.

ACTIONS
To obtain an objective evaluation of the new electric forklifts, the company requested an ergonomic assessment to compare the two models and provide recommendations. The first

model was a larger, 4-wheeled electric forklift, and the second model was a smaller, 3-wheeled, electric forklift. The following criteria were used to assess the forklifts; physical characteristics and adjustability, visibility, and subjective feedback from forklift operators. Table 1 summarizes the objective analysis of the electric forklifts.

Table 1: Objective analysis for comparison of electric forklifts

Features Assessed		Forklift Model	
		Larger, 4-wheel	**Smaller, 3-wheel**
Physical Characteristics	Seat suspension	No	Yes
	Seat material	Vinyl	Cloth
	Fork Controls	Lever controls located on right side	Finger controls located on right armrest
	Steering wheel diameter	31 cm	25 cm
	Step height	1st Step: 50 cm 2nd Step: 80 cm	One step: 54 cm
	Visibility	Higher cab design and wider forks reduce visibility	Lower cab design and narrower forks increase visibility
Adjustability	Seat suspension	Not applicable	Adjustable; tension controlled
	Seat backrest angle	Not adjustable; fixed at 100 degrees from seat pan	Adjustable; 4 different angle settings
	Seat pan depth	Adjustable; seat can be moved forwards/backwards	Adjustable; seat can be moved forwards/backwards
	Fork Controls	Not adjustable	Adjustable; armrest can be raised/lowered and adjusted front/back
	Steering column	Adjustable; angle of steering wheel	Adjustable; angle and height of steering wheel (telescoping)

Although both models of forklifts were at the facility for trial use, operators were not able to drive them due to lack of an electric charging station. Therefore, the subjective operator feedback was limited to reviewing the design, layout and adjustability of the forklifts.

Based on the results of the assessment, the smaller forklift was identified as the preferred option due to the seat adjustability features, control layout and increased visibility for the operator. The operator subjective feedback also indicated a preference for the smaller forklift, due to the lower height to enter and exit the forklift, the seat adjustability and the control layout. Due to differences in operation between the new electric model and the propane model, training on the adjustability features and use of neutral postures and ideal technique when driving was recommended for the forklift operators.

OUTCOMES

The company purchased the recommended model and gradually implemented the electric forklifts into the facility. Despite having included employee feedback in the selection process, concerns were raised by forklift operators early in the implementation process, and some even refused to try the new forklifts. To address these concerns, the company requested ergonomic support for individual sessions with each forklift operator to understand individual concerns, as well as review the adjustability features and ideal techniques when driving. Through this process, operators were educated on equipment adjustments, and ideal postures and techniques when driving. Concerns identified by employees were collected and shared with the company, along with potential risk mitigation and elimination recommendations.

DISCUSSION

Integrating ergonomic support which included user feedback allowed the company to make a more informed procurement decision in the selection of a new electric model forklift. However, the limitations around the facility trial prevented driving the equipment, which resulted in a missed opportunity to consider critical subjective feedback based on functional usage of the equipment.

Once the electric forklifts were implemented, forklift operators identified several concerns, which included:

- Increased reach required to scan labels based on forklift height reduction and scanner range
- Lack of back up handle with horn for reverse driving resulting in non-neutral neck posture
- Reduced cushioning on seat pan compared to the previous model resulting in reports of discomfort
- Reported difficulty with entering and exiting the forklift

To address these concerns, recommendations were provided which included retroactively modifying the forklifts, implementing external equipment, and job coaching on the adjustability features. Through job coaching, it was identified that the new forklifts had been delivered with two different models of seats which had different levels of adjustability. Following identifying this gap, the company was able to request the supplier of the forklifts to change all seats to the model with more adjustability features. Clear communication, training and continuous follow-up with employees and feedback to the company assisted with addressing concerns, which eventually resulted in successful implementation of the electric forklifts.

CONCLUSION

Implementing ergonomic evaluation early into planning phases is ideal for objective decision making. As demonstrated in this case, limitations to equipment evaluation can result in areas of risk or concern not being identified. In this scenario, if users were able to fully operate the equipment during the trial phase, the post-implementation concerns may have been revealed prior to purchasing, which could have impacted the decision making process. Determining the impact of making decisions with a partial evaluation compared to delaying decisions to permit a full evaluation must be considered.
Communication between the decision makers and the end users is important when considering and implementing changes (Morag & Luria, 2013). Utilizing a participative approach ensures all parties understand the reasons for the changes, as well as potential

issues with proposed changes. These are key factors on impacting decisions made, openness and perception to the change, and overall effectiveness of the change. Additionally, although continuous evaluation of proposals and trials can be time consuming, advance evaluation can permit cost effective changes to be made and also improve acceptance by the end user. Regardless of the preparation and planning method used, facilitating continuous feedback throughout implementation phases aids in identifying concerns and permits problem solving to occur in a timely manner.

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ERGONOMICS IN SERVICES' ECONOMY AND SOCIETAL CHALLENGES – A CASE STUDY RELATED TO PUBLIC SERVICES IN BRAZIL

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KEYWORDS
Services, macroergonomics, psychodynamics of work, magistrates, judiciary system

SUMMATIVE STATEMENT
The dynamics of services' operations introduces a real rupture with the industrial logic that supported the economy in the 20th Century. In this paper, the relation to time, territory, society; the mode of involvement of the worker (subjectivity) in productive activity, the overflow of the frontier of the productive organization (private or public) is a relevant perimeter related to the meaning of work and also to efficiency and actual results.

Les défis économiques et sociétaux de l'ergonomie des services – une étude de cas liée aux services publics au brésil

MOTS-CLÉS
Services, macroergonomie, psychodynamique du travail, magistrats, système judiciaire

SOMMAIRE
La dynamique du fonctionnement des services instaure une véritable rupture par rapport à la logique industrielle qui a soutenu l'économie au 20e siècle. Cette communication aborde la relation entre le temps, le territoire et la société; le mode de participation des travailleurs (subjectivité) dans l'activité productive; le débordement des frontières par les organisations productives (privées ou publiques) comme périmètre pertinent lié à la signification du travail; et l'efficacité et les résultats réels.

PROBLEM STATEMENT
Evaluating the useful effects of working activities, the immateriality of what is produced, a fortiori its value, are all vectors for deeply questioning what supports the bases of organization based on industrial paradigms. Services represent a huge opportunity to put in evidence coherences and contradictions of what is proposed in servicing processes since the relationship is not only dual – the company / institution and the worker – but also aggregates the customer / citizen. So, it's not only a question of aggregating value to production processes based on people's work, it's also a question of meaning for different actors, not only in terms of a something that one can buy and use, but also in terms of the effects in a short and long term. The results of servicing produce consequences not only for the person but also to the society, since the effects are disseminated (HUBAULT, F. & Du TERTRE, 2008); (Du TERTRE, 2011).

In terms of a macroergonomic approach (Imada, A. S., 2005; Carayon, P., 2006) it's very important to analyze, produce researches relating different aspects of services, not only because of the results themselves, but also because servicing is not any more something restricted to "service's companies", it's also that is spread among the hole economy since servicing activities are present in all fields of the economy.

Changes and innovations are at the heart of this paradigmatic rupture. The relationship to what is prescribed as servicing and the procedures to be respected by workers engaged in the relation with clients / citizens. In the economy of the service, the prescriptive source diversifies and aggregates: it no longer proceeds only from the command addressed by the hierarchy (the task), but also from the "beneficiary" who, is co-responsible of the operation related the production of the service. He does not merely buy / consume, thereby becomes a prescriber within a "relationship" (service relationship) in which the "worker" also participates in the development of what will be produced in a scenario proposed by the company / institution. Prescription and activity are no longer found in the diachronic ratio that classically describe the disciplines of work, especially ergonomics, precisely because of the original anchorage in the world of industry which, moreover, has been developed in the almost paroxysmal form of Taylorism and Fordism.

With the "servicialisation" of the economy and society, the issue related to the meaning of work and it's societal consequences rebounds and is deployed on a more strategic scale than ever before (HUBAULT et BOURGEOIS, 2001). It's not negligible the increasing incidence and prevalence of mental health disturbances related to work in different companies and institutions. Somehow it's related to organizational choices, that are based on old paradigms of labor division and also the hierarchy evaluates the ways people in their jobs.

This challenge is therefore disciplinary and societal, but for this reason, the way in which it is analyzed and solutions prosed by macroergonomics, and also by different disciplines like economy, sociology and others, depends on the conditions of society where companies are located. In this paper, it is important to put in evidence not only the characteristics of servicing production in a specific company but also to understand societal determinants and consequences related to work. It's important to put in evidence that servicing can not be understood only in a micro level, where working activities are evaluated only a cost – benefits relation. Mainly, a restrict point of view considers work as a cost and something to be restricted to a minimum necessary, but when the perspective is larger, it's possible to understand the contributions of lively work to society and also to the development of values in different society. Servicing activities but in challenge different aspects related to what actually is possible to understand as experiences of working together, of introducing different rationalities not only related to a strategic-instrumental perspective, and the centrality of work in terms of it's emancipatory vocation for the different protagonists (SZNELWAR, 2015).

RESEARCH OBJECTIVE/ METHODOLOGY

Case study related to the public sector in Brazil

This paper presents the aims and initial results of a research based on work processes of people involved at different points in the field of workers, health public policy and to consider the proposed relations inside the National Policy for Workers' Health and Safety (PNSST) in Brazil (LANCMAN et al, 2014). This is a case study under the research-action rubric to be carried out with different actors related to this policy, in this paper we'll discuss the primary results related to the Judiciary System specialized in work regulations and laws (SZNELWAR et al, 2013; WANDELLI et al, 2015). The research process contains an analysis of public policy documentation, the actions of judges and others actors engaged, the working process and reflection groups with guidelines from the psychodynamics of work in order to understand how different actors feel about what they are doing as well as the contributions to improve working situations and conditions in different sectors of the economy.

Different public institutions are in charge of workers' health in Brazil, the main goals are to promote the protection, promotion, recovery and rehabilitation of workers who have suffered accidents, diseases and other aggravations related to the work activity; it presents technical, but also political, social and economic dimensions (Brazil, MS, 1990). So different actions related to improving working conditions, work content, social security, epidemiological vigilance and access to justice are part of this system.

The results presented here are related to two different studies developed with magistrates in Brazil (WANDELLI et al.,2014); (SZNELWAR et al, 2015). The method is based on group discussions, composed by volunteers and for each group four sessions of about three hours where organized in order to promote free debates about their experiences as judges and the relationship with work organization and evaluation methods. A final session (fifth) was organized in order to validate de rapport written by the researches by the participants (UCHIDA, S., SZNELWAR, L. I., & LANCMAN, S., 2011). This approach is based on the proposals made by Dejours (1998, 2003, 2009) in the field of psychodynamics of work.

RESULTS

The principal element is the relationship of their actions with ethical issues. As it's a traditional profession, considered as one of the pillars of a democratic state, traditions, values and in accordance with equity principles are one of the most expressed preoccupations, specially when the scenario has radically been changed by new ways of evaluating their performance. The consequences related are the increasing of competitive behavior, loose of quality in the relationship between peers and a fear / evidence of actions that privilege quantity in detriment of quality. An other order of consequences are related to health issues, even if there are non validated statistical data, there are different testimonies that there is a significant increase in the use of psycho actives medicines and depressive disorders.

Their action considered as socially useful and this is central in their concerns. This is a very important issue, since decisions made by them interferes clearly in peoples' live as well as in companies and public institutions. Their doubts about how the judgments actually changes social relation, specially in the case of those related to work situation is one of the main sources of doubt and suffering. They express a sensation that the more they do, more demands they have, a feeling that nothing changes and they are not actually performing a significant work. This is even worst in the new scenarios where the feeling to improve is more related to shorten deadlines and to judge more cases. For then, this situation put in risk their identity as professionals. Considering the dynamics of the different professions and social changes, it's an important issue to understand their preoccupations; the historical importance Justice in different countries and in different periods are part of their self esteem and represents also a continued support for each one to overcome different professional challenges faced by them.

As defensive strategies, related to psychic issues and to reduce suffering, it's important to put in evidence the increasing of cynical attitudes that can be also highlighted by a certain "demobilization" or "disengagement" of colleagues. Some of them abandon the career and others behave "by the rules", improving the speed to judge and developing other strategies, like "exterminating" cases, in order to obtain quantifiable results. Loosing the sense of justice in order to fulfill the exigencies of productivity is in the horizon of this kind of conduct, reinforcing the risk of ineffectiveness for society.

Evaluating the performance based only on quantitative data is also a great risk since those criteria are not commensurate with their actual work. The effort made by each one in order to read, understand and correlate each case with laws; regulations and standardized jurisprudence cannot be measured. The relations established within the teams composed by different public functionaries that work at the Tribunals, as well as lawyers and the social parts of each case cannot be evaluated by quantitative data. For them those evaluating systems based only on the individual and his performance is not fair, since there are huge differences related to the region where each one is allocated, as well as the actual working conditions that are far from equitable.

Among their fears, it stands out at this moment, is the risk of becoming "machines of judgment". If everything is foreseen and if a significant part of the work is predefined by standardized procedures, the possibilities to judge and to act in discretionary way “disappears”. Bad judging as said before, is another fear as well as the fear of suffering aggressions that compromise their physical and moral integrity. Threats are not uncommon and there are a number of attempts to minimize or avoid them through strategies. This has a direct impact on the suffering of the judges, since they do not feel that there are effective protection mechanisms or institutional support.

Gender issues are also relevant; the judiciary system has been modeled over time based on a masculine perspective. Despite increasing female participation, they believe there is still a lot to be done in order to make relations fairer. It all starts in the competition itself when aspiring judges are questioned with regard to motherhood and, if indeed, are ready to sacrifice their personal and family life for the benefit of the profession. They are also tested on sticks, where different actors put them in difficult situations to know how they will act and if they are strong enough to be “good” and “strong” “judges”. They nevertheless feel constantly watched over and evaluated for their behavior, including their mode of dressing. Still noteworthy are the difficult experiences with regard to motherhood and parenting. In part, these problems also afflict others, since, in addition to feeling that they are being watched, they also face difficulties in accompanying their children and in finding favorable conditions for their families in certain places where they are assigned to work and live. The case of homosexuality remains a taboo

DISCUSSION

Thus, some subjects treated in this research show that the challenges to transform scenarios conducive to the emergence of pathogenic suffering are of great importance. The experience of the judges consists of distinct strands, it is no wonder that different themes emerge in their speeches and reflections. Many may seem, at first reading, to be contradictory. In the case the idea that the magistracy would be a type of priesthood, the result of a vocation, a deep desire to do something relevant could be confronted with a point of view where it is a profession in crisis and at risk of degradation despite being an authority representing the State. This is due to certain organizational choices that privilege certain aspects of the production, in a vision very focused on "productivism". One of the main issues is the question of the relevance of their work and contributions to meet the demands of citizens and society. They suffer from all this, especially with the anguish of not being able of handle with everything, on the other hand, the frustration stemming from the lack of recognition of peers, of the hierarchy, and other social actors with regard to the effort undertaken in their work.

CONCLUSIONS

We consider that the contributions of the different people that participated in this research were fundamental for the results obtained. However, we believe it is something initial and can be enriched and reinforced by more research. But this only makes sense if, in fact, it is useful to help generate transformations that are favorable to the construction of improvements in the Judiciary, aiming at both a more favorable work for the construction of health and the achievement of oneself, and to favor a work that reinforces their contribution build citizenship.

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ERGONOMICS IN THE DESIGN PROCESS WHEN DEVELOPING NEW PRODUCTS AT IKEA OF SWEDEN

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KEYWORDS
Universal design, perceptions of Ergonomics, human-centered design, product development

SUMMATIVE STATEMENT
This paper examines the presence of Ergonomics in the design process at IKEA of Sweden and how Ergonomics can be further integrated in the product development process. The study show the need to work in a more structured way with Ergonomics and involve experts on human needs as well as representatives for real users.

L'ergonomie dans le processus de conception de nouveaux produits chez IKEA en suède

MOTS-CLÉS
Conception universelle, perceptions de l'ergonomie, conception axée sur la personne, développement de produits

SOMMAIRE
Cette communication examine la présence de l'ergonomie dans le processus de conception chez IKEA, en Suède, de même que la façon dont l'ergonomie pourrait être davantage intégrée dans le processus de développement de produits. L'étude démontre qu'il faudrait travailler de façon plus structurée en tenant compte de l'ergonomie et en faisant appel à des experts en besoins humains et des personnes qui représentent les utilisateurs réels.

PROBLEM STATEMENT
In the year 2020, it is estimated that a quarter of Europe's population will be over 60 years old (Boverket, 2016). The global trend is also showing a more sedentary lifestyle, both at work and at home (Owen et al, 2010). The need for ergonomic furniture and products is therefore increasing. An important design task in the future will be designing products and environments that are inclusive and exclude as few potential users as possible, i.e. to create a universal design (Österlin, 2007).

In 2006, TMF, the Swedish Wood and Furniture Industry Association, launched a project called Plus Furniture. The project was initiated to meet the demands of older people. The project was linked to Swedish companies such as Lammhults, Stolab and Swedese. The idea in the project was that furniture should focus on the demands of modern life; flexibility, change and Ergonomics (Plusmöbler, 2016). In the Swedish design world, the project Plus Furniture seems to be fairly unknown. A relevant question is if a deeper knowledge of Ergonomics is missing or is it less status-filled design?

Earlier studies show that there is a lack of knowledge about Ergonomics, which may be related to the view on Ergonomics in a company. It is important not only to consider

Ergonomics as a goal, but rather as a knowledge tool to strengthen the company's competitiveness (Risberg, 2006). This is achieved by highlighting how Ergonomics can be meaningful in relation to company goals, also by giving legitimacy for Ergonomics on top levels in the company and by creating prerequisites for learning about Ergonomics (ibid).

Knowledge consists of both "knowing how" as the nature of practical knowledge and "knowing what", which is the traditional form of knowledge (Gustavsson, 2002). As a designer, both forms of knowledge are crucial and needed in the entire work process in design work. Designers build their products, they create, by knowing how and knowing what. This means that designers need knowledge that is both practical and theoretical in order to function professionally as designers. In order for designers to meet the needs of the future, Ergonomics knowledge must be included in educational programs.

This paper is based on a study carried out at IKEA of Sweden, the world's largest furniture producer. The company has a lot of variables to take into account in their design process and in the development of products. This includes the environment, sustainability and social responsibility. A future challenge for IKEA of Sweden is to meet the identified needs related to the changing patterns of living and people's different conditions, such as age, environment, climate, and economy. This challenge is interesting from a business perspective and a human perspective as well as with respect to social responsibility.

RESEARCH OBJECTIVE

The aim of this paper is to examine the presence of Ergonomics in the design process at IKEA of Sweden and to propose how IKEA of Sweden can implement more Ergonomics in their development process of new products.

METHODOLOGY

The study is based on semi-structured interviews (Kvale, 1997) with 13 employees at IKEA of Sweden. The selection criteria was that they worked with design and product development in different roles, see Table 1. The specific product areas included the dining business area, the workspaces business area, and the kitchen business area.

Table 1. Interview respondents in the design and product development process at IKEA of Sweden

Department/role	No of respondents
Design department	6
Specific product areas	3
Creative leaders	3
IKEA TestLab	1

Six women and eight men were interviewed. In addition, one interview was conducted with a design strategist at the design company Veryday. The interviews were analysed using the theory presented which includes the perception of Ergonomics (Rislund, 2011), the fallacies of Ergonomics (Pheasant & Haslegrave, 2006), Ergonomics as a tool (Rislund, 2006), anthropometrics (Hägg et al., 2010), universal design (Null, 2014) and human-centered design (Glomann, 2015).

RESULTS

The interviews showed that ergonomic aspects are not included in a structured way common for all areas when developing products at IKEA of Sweden. The study also identified a lack of knowledge of the subject Ergonomics among the interviewees.

"Ergonomics is important. At first it is not important, it´s not what I'm starting my projects with. But then, it's important if it makes a chair comfortable, the comfort is really important.

And that the usage is good. I mainly work with expressions and messages that one wants to communicate...."

Most of the interviewees stated that Ergonomics is important. Some of the interviewees described it as Ergonomics "emerges" when you hold and feel the products. One of the interviewees said that Ergonomics was included from the start of a project but in different ways depending on what product to develop. Some interviewees explained that they used "standard measurements" when they designed. Most of the interviewees expressed the need of information about Ergonomics, like a guideline. One observation was that there was greater knowledge and awareness of Ergonomics among the interviewees who had worked at IKEA for a long time, more than 10 years.

Regarding who is responsible for the ergonomic aspects of the product development, the interviewees did not have a common answer. There was no common strategy for working with ergonomics in the different product areas. One interviewee expressed it as:

"I would say that the people who are in charge of Ergonomics are the ones who run the projects. But those who really should focus on Ergonomics, that must be the designers. And I'm surprised sometimes how little time is spent on practical Ergonomics."

Another interviewee agreed that IKEA did not work with Ergonomics that much, and that it was more important with surfaces, shapes and looks.
Human size was not taken in consideration either: *"One develops furniture for the average customer. … We decided that we couldn't make chairs for small people and then make chairs for big people. … If the chair fits the average person, it will fit most customers as well."*

Regarding the involvement of experts to improve the design process, the design strategist at Veryday put forward that the expert could contribute with another perspective on the product and help set requirements, for example on Ergonomics and usage of the product. Most of the interviewees were very positive about using for example a physiotherapist or occupational therapist in the design process.

"It would be great to bring a prototype of a chair and getting expert help with Ergonomics and usage… That would be great."

However, one of the interviewees expressed that it was not necessary to involve a special expert. Instead, the product developer should be the expert and knowledge about Ergonomics should also be required from the designer.

"No, I don´t really think it's necessary to consult an expert. That might be up to the product development team… I don´t believe in a team of ergonomists or occupational therapists but rather that the product developer, for example, will be super good at Ergonomics...You can also ask for it from the designer… there must be someone who has the deep knowledge in this area so to speak."

To proceed with the implementation of the overall Ergonomics perspective in the design process at IKEA of Sweden, it is important to test and evaluate the prototype using an expert and test panels representing the potential customers and include the user experience in the product development. An interviewee stated that the products were basically only tested on the people in the house, i.e. the employees and visitors at the IKEA Democratic Center in Älmhult. Some interviewees also mentioned that sometimes they use home tests, but not in all product areas.

"I usually bring products home to test… See how they work, how they look in the kitchen, how they look in the bathroom and how they can be used. I think it's important to start there."

DISCUSSION

Overall, this study does not show a common approach to working with Ergonomics in the design process at IKEA. The interviewees had different work experience in their profession and that can affect how they work with Ergonomics in their design process. It was interesting to note that there was greater knowledge about Ergonomics among those who had been employed for a longer time. One of the interviewees commented on the absence of Ergonomics in IKEA products the last 10 years. This is an indicator that it may have been a greater focus on the aesthetics rather than on Ergonomics in the development process during the last few years.

During the interviews, Ergonomics was described in terms of “Ergonomics is emerging” during the development process, not paid attention to in the early phases, or expressed as “comfort”. This demonstrates the potential benefit of learning about Ergonomics to increase the degree of human-centered design and supposedly develop products that fit the human even better. Working with anthropometric data from measurements of different populations could be one way to meet demands in different markets.

A majority of the interviewees at IKEA were positive to use an expert in the design process, such as an occupational therapist or physiotherapist. The designer is trained for product development and, for example, an occupational therapist has a different perspective. They have accumulated knowledge about the frequency of various injuries, and the therapist also has a sense of how common some injuries are. The majority of the interviewees also expressed that there should be a tool available such as an ergonomic guideline with information.

It is important to evaluate the product throughout the design process. For IKEA, this means test groups consisting of a wide variety of different people. This way it is possible to observe how the use is affected by different body measurements such as length, range or hand grip. Then the product can be modified in different steps and, depending on the complexity of the product, more prototype tests can be performed. This way the product can also be modified to suit a specific market.

The interviewees showed an aspiration and a desire for Ergonomics to be present in the design process, but there was no structure for how to work with Ergonomics. An interviewee expressed that Ergonomics automatically happens when you hold and feel the product. By that, the product may be ergonomic for that person, but this does not mean it is conscious Ergonomics for all possible users. This raises the question of who is the user. If the aim is that as many people as possible can use the product, then Ergonomics becomes a key and important part of the design process. If the goal is that the product is developed only for usage by a "healthy 25-year-old in the middle of life", then the requirements for Ergonomics decrease. Then the company can “afford” being more form-oriented. The challenge is in all cases to combine shape, function and Ergonomics in the product development process.

IKEA has the whole world as their market and it means that they have the opportunity to design products that cater to the dimensions of different populations. It is a strong business incentive to make Ergonomics a prominent tool in the product development process. As Risberg (2006) identifies in her research, it is about using Ergonomics as a tool instead of a goal. There are many advantages using Ergonomics as a tool in the product development process. You can use the presence of Ergonomics in the product later as a sales argument, which strengthens the value of the product. This was clearly expressed by one interviewee reflecting on higher product quality, a longer life cycle for the product, and the value of giving health to people.

In the dissertation "Ergonomics as a tool" Rislund (2006) puts forward that Ergonomics requires learning. It is related to the idea that unless Ergonomics is included as a professional knowledge, it will not be applied. Here, higher education has a major responsibility when educating future designers. If Ergonomics is not included and presented as an important part of the design process, the future designers will not use it in their profession. Furthermore, if the designer is to be considered the person who is the expert on Ergonomics in the product development process, knowledge about Ergonomics must also be a key part of the design training.

Finally, it is important to classify Ergonomics as useful and meaningful from a corporate perspective. There are substantial gains in product development for a larger group; there is great competitiveness in including as many users as possible and thereby creating universal design.

CONCLUSIONS

This study shows that IKEA works in different ways with Ergonomics in the design process, depending on product category, and a structured way needs to be implemented. Ergonomics can be included as a strategy and activity in the design process at IKEA by creating a guideline for the designers; involve experts, e.g. physiotherapists or occupational therapists in the product development process; involve test groups representing different target customers; meet users; use test groups to evaluate prototypes and products; and to assist experts in current research.

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Technical Session 7: Simulation & Modelling

Séance technique 7: Simulation et modélisation

MODELLING WORKLOAD AND QUALITY USING SYSTEM DYNAMICS IN HEALTHCARE

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KEYWORDS
Nurse workload; burnout; quality of care; System Dynamics; ergonomics

SUMMATIVE STATEMENT
System Dynamics modelling was used to help understand the effect of HF-related policy issues on nurses' health and quality of patient care. The model results showed that nurse burnout increased 6 times and medical errors increased 150% as nurses worked longer shifts or work weeks. Burnout and medical errors also rose by up to 200% if nurse absence was restricted or the recovery duration was shortened in a simulation of early return to work.

Modélisation de la charge de travail et de la qualité en utilisant la dynamique des systèmes dans les soins de santé

MOTS-CLÉS
Charge de travail des infirmières, qualité des soins, dynamique des systèmes, ergonomie

SOMMAIRE
Une modélisation de la dynamique des systèmes a été utilisée pour nous aider à comprendre les questions touchant les politiques en matière d'ergonomie sur la santé des infirmières et la qualité des soins aux patients. Les résultats du modèle ont révélé que les cas d'épuisement étaient six fois plus élevés et que les erreurs médicales augmentaient de 150% lorsque les semaines de travail ou les quarts de travail des infirmières étaient plus longs. Les erreurs médicales et les cas d'épuisement pouvaient aussi augmenter de 200% lorsque la période d'absence était limitée ou la durée de récupération était raccourcie dans une simulation de retour au travail rapide.

PROBLEM STATEMENT
CNA estimates a nurse shortage of 60,000 FTE registered nurses by 2022, in the absence of any workplace reforms (Canadian Nurses Association, 2013). Nurse burnout is a major contributor to nurse shortage, with burnt-out nurses leaving their profession. This nursing shortage makes it critical to improve nurses' work conditions for better employee retention. This study aims to use modelling to help senior management understand the importance of Human Factors (HF) in the design and operation of the healthcare system by linking HF to both nurses' health and quality of patient care.

RESEARCH OBJECTIVE/QUESTION

The objective of this study is to explore how System Dynamics (SD) modelling can be used as a tool to understand the effect of HF on nurses' health and quality of patient care in a healthcare environment.

METHODOLOGY

A conceptual causal loop diagram (CLD) was developed using the cause-and-effect relationships available in the healthcare literature, showing the links between nursing workload and quality of care within a nursing unit. The CLD was then translated into a simulation model using empirical relationships and quantitative data from the literature. If data around a model parameter or relationship was limited or unavailable, estimates by subject matter experts were used instead. The simulation model was run with two sets of inputs: (1) base case values, which were average values for a given model parameter acquired from the literature; and (2) sensitivity analysis values, where each model parameter was varied across its broadest operational range within the literature, while all other parameters were held at their base case values. The reader is referred to Farid (2017) for a detailed development and testing of the model.

RESULTS

The model results showed that long nurse shifts and work weeks double the nursing fatigue level, while increasing burnout by up to 6 times, absenteeism by up to 5 times, and medical errors for the patients increasing by up to 150%. In addition to the work hours, restrictions on burnout-related absence and shortening the duration of absence also affected the model output, where fewer nurse absences and early return to work increased burnout and medical errors by up to 200%.

DISCUSSION

The modelling process demonstrates the feasibility of using System Dynamics to understand the effect of HF on quality of care. The model results show the effect of two important policies – overtime and early return-to-work – on not only nurses' health, but also the patient safety and quality of care.

The model uses previously validated data for most of the model inputs, combined with estimates from an experienced patient care manager and a subject matter expert. It is important to note that the focus of the current modelling is not to predict quality outcomes, but rather to understand some of the factors that lead to HF-related problems. Further validation of the model is needed, including testing the model outputs against quantitative data from a hospital nursing unit.

The current model only focuses on nursing workload as the main burnout risk factor. However, literature has shown that other physical and psychosocial factors also affect the health and performance of nurses and care providers (Daynard et al., 2001; Trinkoff, Storr, & Lipscomb, 2001). Hence, it can be expected that the current model results capture only part of the effect of HF on quality of patient care. Future models may need to include a comprehensive set of HF factors that affect nurses for a more complete analysis of the effect of HF on the quality of patient care and patient safety.

CONCLUSIONS

The model demonstrates a novel application of SD for healthcare to examine the impact of management strategies on nurses' wellbeing and on care quality. Results illustrate the potentially counterproductive effects of early return to work and restrictive absence policies, as well as the hidden costs of prolonged work days and work weeks, with burnout and medical errors increasing by up to 150% for the former and up to 6 times for the latter. This research sets the foundation for future models to use SD in healthcare to understand the effect of other HF-related design and policy issues on employee wellbeing and quality of patient care.

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SIMULATING THE DYNAMIC EFFECT OF PHARMACY STAFF WORKLOAD ON SAFETY AND PERFORMANCE

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KEYWORDS
Systems Analysis, Simulation, Pharmacy Dispensary

SUMMATIVE STATEMENT

Increasing number of accidents caused by the complex interactions of socio, technical and environmental factors have shown the limitations of traditional safety techniques. System dynamics simulation modelling is a powerful approach for addressing complex non-linear issues. We utilised system dynamics approach to model and simulate dynamic factors contributing to dispensing errors and backlog in a hospital pharmacy to facilitate holistic comprehension of factors impacting system performance and effects of system changes

Simulation des effets dynamiques de la charge de travail du personnel de pharmacie sur la sécurité et le rendement

MOTS-CLÉS
Analyse des systèmes, simulation, pharmacie

SOMMAIRE
Le nombre grandissant d'accidents causés par les interactions complexes entre les facteurs sociaux, techniques et environnementaux a démontré que les techniques de sécurité traditionnelles ont des limites. La modélisation de la dynamique des systèmes est une approche efficace pour résoudre les enjeux complexes et non linéaires. Dans le cadre de cette recherche, nous avons utilisé une approche axée sur la dynamique des systèmes pour modéliser et simuler des facteurs dynamiques, qui contribuent à signaler les erreurs et les retards dans une pharmacie en milieu hospitalier, afin de faciliter la compréhension holistique des facteurs ayant une incidence sur le rendement du système et des répercussions des changements apportés au système.

PROBLEM STATEMENT

High-pressure workload is currently a serious problem to many hospital pharmacy staff. Changes to the pharmacy staff's role, pressures to meet targets, staff shortages and long working days with no opportunities for rest breaks have led to pharmacy staff with a high workload and increasing dispensing errors. This led to concerns that patient safety is being compromised. Berwick's review into patient safety (Berwick, 2013) crucially highlighted the urgent need for developing methods and guidance for staffing ratios based on a dynamic understanding of staff workload and systematic approach.

RESEARCH OBJECTIVE/QUESTION

This project aims to model the dynamic effect of pharmacy staff workload on safety and efficiency allowing us to simulate/test various scenarios and optimise staffing ratio considering safety and performance.

METHODOLOGY

System dynamics is an analytical modelling methodology, its origins of which are attributed to Forrester (1961) in his pioneering work on "industrial dynamics" in the 1960s. Today, SD methodology is used beyond the industrial setting and has been applied in many different fields of study including healthcare. SD combines both qualitative and quantitative aspects and aims to enhance understanding of complex systems, to gain insights into system behaviour. The qualitative aspect entails the construction of "causal maps" or "influence diagrams" in which the system structure and the interrelations between the components of a system are explored. The quantitative aspect entails the development of a computer model in which flows of material or information around the system are modelled and bottlenecks identified. Such models can then be used in a "what if" mode to experiment with alternative configurations, flows, and resources

We developed a conceptual model (causal loop diagram) of the relationship amongst staff ratio, interruption and fatigue over a period of 24 hours. This development commenced with a systematic review of the literature, then involved a series of semi-structured interviews. The final qualitative model was finally developed using a group model building session and was articulated in terms of a causal loop diagram. Its mathematical representation was constructed in Vensim (simulation software for system dynamics modelling).

The mathematical expression of the causal loop diagram was a system dynamic model structured as 13 stocks and flows modules connected by auxiliary information to form an interdependent set of co-flows. The main outcomes of the model that were of interest in this study were the workload, interruption and fatigue trade-off impacting system performance and effects of system changes. We calculated measure output in terms of backlog and dispensing errors where backlog is the number of incoming prescriptions waiting to be labelled and dispensed and dispensing errors is the number of detected and undetected errors made by the staff.

The three main loops can be summarised as follows:

- Loop 1: Increase in workload, decrease time to self-check for errors, increase in dispensing errors, increase in rework done, increase in backlog, increase in workload (reinforcing loop)
- Loop 2: Decrease in qualified staff, increase in questions from trainees, increase in interruptions, decrease in time available to dispense prescription, increase in dispensing errors, increase in undetected errors, increase in patient harm, increase in qualified staff (balancing loop)
- Loop 3: Increase in workload, increase in stress, increase in fatigue, increase in dispensing errors, increase in undetected errors, increase in patient harm, increase in staff, decrease in workload (balancing loop)

We developed the base model using exogenous inputs for the model parameters extracted from a series of interviews with practitioners, pharmacy databases and literature. Verification performed included logical tests, sensitivity analysis, and sense checking from the stakeholders. Validation of the model was undertaken for each three scenarios for which sufficient quality data were available from the hospital dispensaries. We created variants of the base model for the scenarios based on a generic hospital dispensary. We customised the model to each hospital pharmacy dispensary allowing them to change the model's baseline values to match their respective hospital pharmacy dispensary such as the number of incoming prescriptions per hour, the number of staff and the number of prescriptions queried. Once the base model and variants were developed, we performed a simulation for each dispensary to establish outcomes for the simulation period and how this affects system performance. For all simulations, the dispensary boundary was considered the scope of the model.

The simulation modelled three different scenarios.

Scenario 1: effect of staff ratio and skill-mix on workload and errors. The objective of scenario 1 was to examine the trade-off between efficiency (production) and thoroughness (safety) by analysing staff levels (resources) and their impact on performance. Analyse how number of labellers and checkers can have an impact on production and errors (safety).
Scenario 2: effect of interruptions on performance and errors. The objective of scenario 2 was to achieve a trade-off by examining the effect interruptions (questions from co-workers and trainees) can have an effect on efficiency.
Scenario 3: effect of high workload on fatigue and errors. The objective of scenario 3 was to examine and analyse how the level of workload has an effect on fatigue and eventual burnout which in turn has an on capacity and errors.

Inputs into the model were from the stakeholders and healthcare databases data in 3 main categories. First were the incoming urgent and non-urgent prescriptions received per hour by each hospital pharmacy dispensary. The urgent prescriptions have priority over the non-urgent, and this is simulated in the model. Second were the number of staff required to effectively (lean) run a hospital dispensary depending on the number of machines available. This includes the maximum capacity of each staff group when it comes to dispensing the prescriptions. This was obtained from the hospital pharmacy dispensaries. Third were the errors data showcasing the number of errors committed by each practitioner allowing us to fine tune the model.

RESULTS

The simulation results demonstrated the trade-off between efficiency and safety. The results revealed how the level staffing ratio, interruptions, workload and subsequent fatigue have an impact on safety and performance of the pharmacy dispensary as a whole. The results were presented to pharmacy managers/staff using learning based interactive dashboard. The dashboard presents three scenarios, allowing pharmacy staff to interactively change inputs to see how it impacts the performance and proactively interpret the results

Scenario 1

Scenario 1 examines the trade-off between efficiency (production) and thoroughness (safety) by analysing staff levels (resources) and their impact on performance. It analyses how a number of different types of staff can have an impact on production and errors (safety). This is presented in Figure 1 where four different graphs are displayed based on data obtained from a Leicester-based hospital pharmacy dispensary. They are compartmentalised in four different sections: incoming prescriptions received by the dispensary per hour, outgoing dispensed prescriptions per hour, the workload of the staff, the backlog generated and how that impacts the number of errors committed. The graphs show the default baseline obtained from the dispensary which is based on a ratio of five labellers and two checkers.

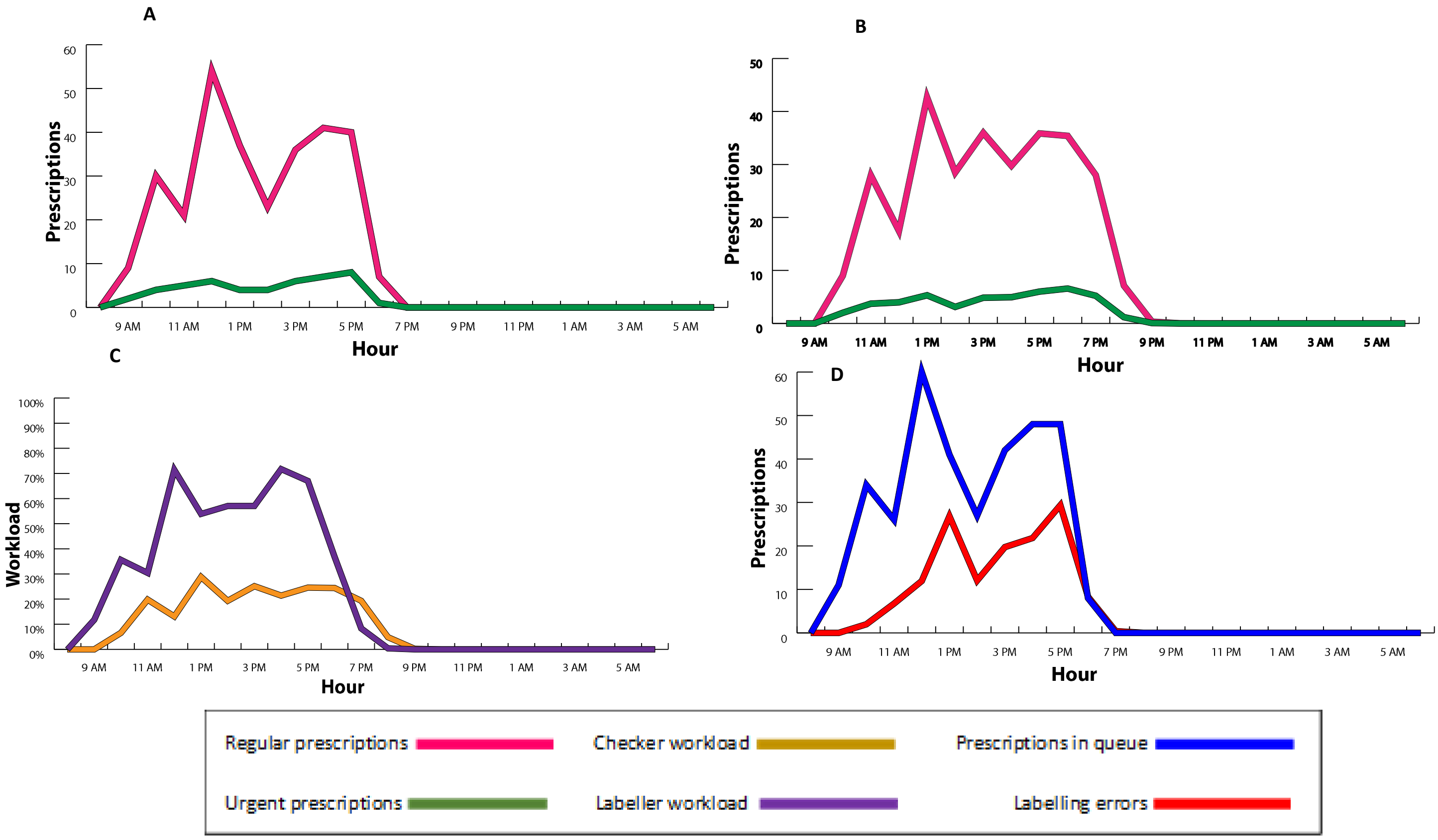

Figure 8: Scenario 1 for (a) incoming prescriptions; (b) outgoing prescriptions; (c) staff workload; and (d) backlog metrics

Scenario 2

Scenario 2 examines the balance by examining the effect interruptions (questions from co-workers and trainees) have an effect on the level of efficiency. Interruption is calculated on the percentage of incoming prescriptions that are queried by trainees and co-workers. Every query is equivalent to one prescription that could have been dispensed. Figure 2 shows the baseline data obtained from the Leicester-based dispensary revealing that around 20% of prescriptions are questioned. This is equivalent to an average of 10% efficiency performance lost by labellers and 5% by checkers. However, at times, when the incoming prescriptions double and the staff levels stay the same, the number is much higher can be off-set by increasing the number of qualified staff. This scenario allows staff to find a balance in the number of staff available and the number of incoming prescriptions that are queried so as to balance the performance of the system.

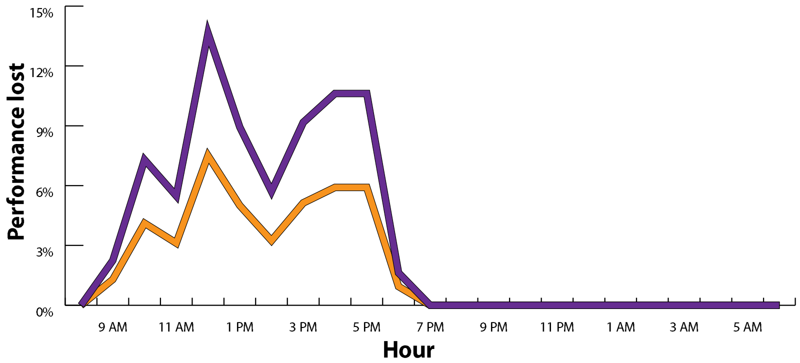

Figure 9: Scenario 2 for efficiency loss depending on the number of questions asked (interruptions)

Scenario 3

Scenario 3 examines and analyse how the level of workload has an effect on fatigue and eventual burnout which in turn has on capacity and errors. The model takes into account that 85% and above workload can be maintained for a number of hours before fatigue kicks in, this has been validated through interviews and is illustrated in Figure 3. Once the continuous high workload is maintained over a number of hours, fatigue kicks in and an hourly reduction of capacity by 5% is applied until the workload downsizes to below 85%. Once that happens, an hourly restoration rate of 10% is applied. The graphs reveals that once fatigue kicks in, the number of errors committed shoots up exponentially until it stabilises.

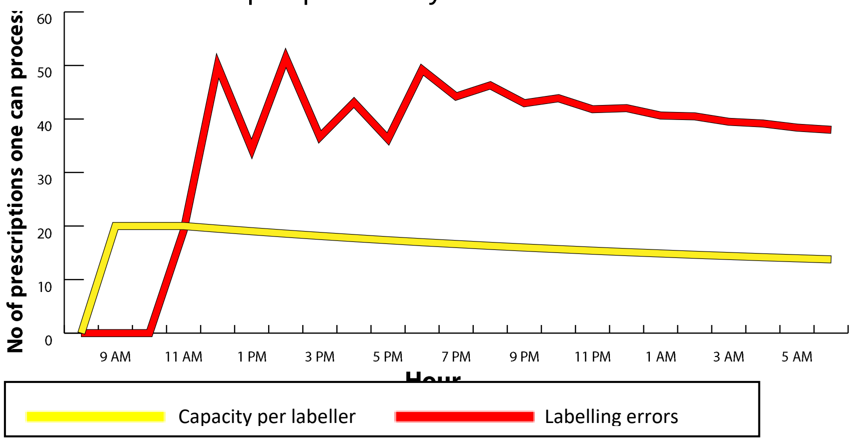

Figure 10: Scenario 3 for capacity loss due to high workload

DISCUSSION

We developed and applied a quantitative system dynamics model to show the potential consequences of factors that impact hospital pharmacy dispensary safety such as workload and staff ratios, interruption and fatigue whilst providing settings to intervene to ameliorate the worst-case scenarios using backdrop metrics of backlog and dispensing errors. This is coupled with effective forecasting of how different decision-making policies lead to different kinds of system behaviour. To be useful, a model needs to include only a necessary and sufficient number of components (Sterman, 2004).We tested the validity of the model based on the data that we received and group discussions that we conducted. The evidence has suggested that the model is a sufficiently accurate account of reality to provide lessons on safety performance within the dispensary.

The model reveals how well-intended efforts prove to be disastrous after passing of time. The staffing ratio management in the dispensaries that the model has been tested recruits a large number of trainees in order to keep the costs down and perform the same level of work as a qualified staff. The model reveals that whilst in the short term, the backlog is reduced to a minimum, in the long run, the number of detected errors kept increasing exponentially as the number of rework done to correct the errors contributed to the backlog. Furthermore, since the trainees had a reduced capacity in comparison with the more qualified staff, they were more prone to burnout which again contributed to the number of errors committed. The model forced the stakeholders to take into the account a varied skill-mix of various capacities to counteract growing backlog and errors and keep the workload to an acceptable standard.

Because we focused on the dispensary system, only the task flow of labellers and checkers were developed in detail, and we reported only the performance indicators of these two groups. The model could be further refined by adding the task flow of administrators (receptionists), and several subsystems that have a clear impact on the safety performance of the dispensary such as (automatic) robots, staff on the wards, the types of prescriptions and the role of clinical checkers which is performed before labellers label the prescriptions.

CONCLUSIONS

This paper presents that under-performance of dispensary system can be tracked down to the inadequacy of the tools and methods currently used to analyse them. Whilst the dispensary system is dynamic and complex in nature, the methods and heuristics guiding decision-making in the system do not capture adequately the effects of the most important elements in the system and their interconnections resulting in their observed poor performance. The remedy to this situation is to adopt principles of system dynamics to formulate, model, and analyse the system.

In conclusion, we offer three recommendations where system dynamics approach can address complex non-linear issues in dispensary system:

- Backlog can be prevented or significantly minimised with the right set of staff and skill-mix, taking into account the respective capacity of each staff group including trainees.
- Increasing number of qualified of staff reduces questions from trainees/co-workers but trade-off needs to be applied to what is an acceptable number of loss of efficiency.
- Introducing a five-minute break every three hours prevents build of fatigue and eventual capacity depletion leading to more dispensing errors committed.

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SIMULATING THE IMPACT OF PATIENT ACUITY ON NURSE WORKLOAD AND CARE QUALITY

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KEYWORDS
Virtual Nursing Unit, Discrete Event Simulation, Human Factors, Healthcare ergonomics

SUMMATIVE STATEMENT
Given the trend for higher acuity levels among hospitalized patients, Discrete Event Simulation (DES) was used to predict the effects of increasing patient acuity on nurse workload and care quality by means of a Virtual Nursing Unit (VNU) model. As patient acuity increases, nurse workload was also increased, an 8% increase in 'Tasks in queue' and 6% increase in 'distance walked by Nurse', and a decrease in care quality was also recorded, 13% increase in 'missed care' and -5% 'task in queue time', when staffing remained constant.

Simulation de l'incidence de l'acuité des besoins du patient sur la charge de travail et le rendement du personnel infirmier

MOTS-CLÉS
Unité virtuelle de soins infirmiers, simulation d'événements discrets, facteurs humains, ergonomie des soins

SOMMAIRE
Étant donné que les niveaux d'acuité des besoins ont tendance à être plus élevés chez les patients hospitalisés, on a utilisé la simulation d'événements discrets (DES) pour prédire les conséquences d'une augmentation de l'acuité des besoins du patient sur la charge de travail et la qualité des soins au moyen d'un modèle d'unité virtuelle de soins infirmiers (VNU). À mesure que l'acuité des besoins du patient augmentait, la charge de travail du personnel infirmier augmentait aussi. Les résultats révèlent une augmentation de 8 % liée à la « file d'attente des tâches » et de 6 % quant à la « distance parcourue par une infirmière »; une diminution de la qualité des soins a également été observée ainsi qu'une augmentation de 13 % liée aux « soins négligés » et une diminution de 5 % liée à la « file d'attente des tâches » lorsque les effectifs demeuraient constants.

PROBLEM STATEMENT

Given the increasing demands of healthcare (HC) for an aging population, policies have been implemented to improve system throughput by discharging patients earlier than previously. This leads to increased acuity levels for patients remaining in the hospital thus, increasing workload for nurses. Continuous exposure to increased workload levels leads to deterioration in the health for nurses that further leads to a drop in the quality of care delivery (Moraros et.al., 2016). Patient acuity is defined as the level of illness of the patient and is associated with the intensity of care required by a patient. Therefore, nurses who provide care for patients with higher levels of acuity report increased levels of fatigue as compared to other nurses

(Barker & Nussbaum, 2011). A tool is needed to test combinations of policy and technical design aspects to predict the impact of acuity on nurse workload and care quality (quality of care being delivered) – DES is a potential solution.

RESEARCH OBJECTIVE/QUESTION
How can patient acuity be modelled using Discrete Event Simulation (DES) to quantify the possible impacts on nurse workload (WL) and care quality?

METHODOLOGY
The VNU model is created using Rockwell ARENA, a type of DES environment software. The VNU imitates the nurses' work environment of an inpatient unit of a hospital. The example VNU model was created after extensive consultation with the subject matter expert (a Registered Nurse (RN) with years of practical and research experience).

Figure 1 represents the main inputs and outputs of the model. The main inputs are Virtual layout (physical layout of the inpatient unit), patient care data (essential details of the daily patient care tasks that a nurse performs) and operating logic (nurse working logic and task priorities). In this study, the outputs are recorded separately for nurse workload and care quality. Nurse workload is assessed by 'task queue' (the number of pending tasks) and distance walked by nurse (the amount of distance walked by the nurse during a shift). Care quality is assessed by calculating the amount of 'missed care' (pending tasks that were not started by the nurse before the end of the shift), and 'task in queue time' (the amount of time a task is spent in queue waiting to be completed).

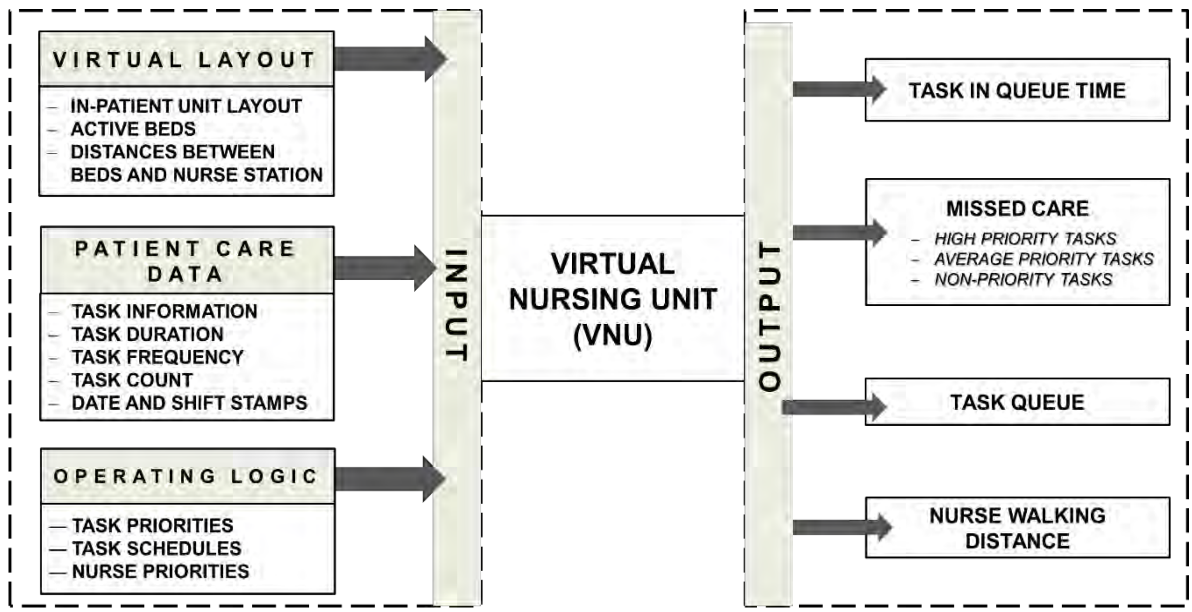


Figure 1 illustrates the Inputs programmed in the VNU model and the outputs being recorded

Virtual layout
The virtual layout was developed using Microsoft Visio software to program the overall floor plan details of an inpatient unit such as nurse station location, total beds, active beds, type of beds either single, double or both, and the distances reflecting the simulated unit layout in the DES model. The virtual layout is also used for visual verification while running the simulation. It helps one visualize the nurse's movement that helps to visually verify nurse priorities (programmed into the model) as care is delivered during the shift.

Patient Care Data

As illustrated in Figure 1, patient care data entails essential details of the daily patient care tasks that a nurse performs. Task data comprises of *task information, task frequency* and *task duration.* **Task information** includes basic task information i.e. task group (e.g. nutrition), assigned identification number, sub-tasks within this category (e.g. feeding with minimal assistance), shift and date stamp. This was obtained from a large urban academic health centre in Toronto, Canada, for a period of one month. The data was part of a workload report generated from GRASP software system (Grace Reynolds Application of the Study of PETO)**.** GRASP is a proprietary management information-processing system (MIS) used to collect data for analysis of the nursing workload (Farrington et al. 2000). **Task frequency** entails how frequent a certain task is completed along with the day and time stamps. Task frequency is calculated using an average of task count for each task group across all patients per day for a period of one month. **Task duration** is the amount of time required by the nurse to complete the task. Task duration for each of the task group is calculated using a frequency-weighted average of the sub-tasks for each group.

Task Name	Priority level (rank)	Task distribution type	Task delivery location	Time Duration (min)	Task Priority Category	Acuity Sensitive Task?
Medication	1	Random intervals	Bed side	6.51	High Priority	Yes
Vital Signs	2	Random intervals	Bed side	5.26	High Priority	Yes
Assesment and Planning	3	Random intervals	Bed side + Nurse Station	6.93	High Priority	-
Evaluation	3	Random intervals	Nurse Station	3.00	High Priority	Yes
Vascular Access	4	Random intervals	Bed side	31.50	High Priority	Yes
Treatments	5	Random intervals	Bed side	9.50	High Priority	Yes
Activity	6	Random intervals	Bed side	26.10	Average Priority	-
Consultation	6	Random intervals	Bed side	6.00	Average Priority	Yes
Hygiene	6	Scheduled (8:00AM) + Random intervals	Bed side	13.32	Average Priority	-
Nutrition	6	Scheduled (8:00AM, 12:00PM, 5:00PM) + Random intervals	Bed side	17.05	Average Priority	-
Other Direct Nursing Care	6	Random intervals	Bed side	25.65	Average Priority	Yes
Admission	6	Scheduled intervals (7:30AM)	Bed side	32.10	Average Priority	-
Discharge	6	Scheduled intervals (7:30AM)	Bed side	21.40	Average Priority	-
Non-patient care	6	Random intervals	Nurse Station	13.79	Average Priority	-
Elimination	16	Random intervals	Bed side	19.91	Non-Priority	-
Teaching and Emotional Support	17	Random intervals	Bed side	19.68	Non-Priority	-

Table 1 represents List of tasks programmed in the VNU model along with their task distribution type, task delivery location, task duration, task priority level and acuity sensitive tasks

Operating Logic

As illustrated in Figure 1, operating logic consists of *task priorities, task schedules, nurse priorities, task location* and *call tasks*. **Task priorities** indicate which tasks have an increased priority for completion over other tasks. **Task schedule** refers to tasks that follow an established *schedule* and those that occur *randomly* throughout the shift. For example: hygiene is scheduled for once a day at 8am. However, the hygiene task can happen at any time (randomly) as well. In the case of random task schedule, for example: bed linens are changed as per schedule but may need to be changed again due to unexpected soiling late in the day. In this model, nutrition, hygiene, admission and discharge are identified as both, scheduled and random tasks. Within the simulated environment, there are also **'call' tasks** that are called directly by the patient at random intervals. In the case of Vascular access, for example: if a patient's IV needle becomes displaced, the nurse performs IV maintenance which is a task that was not scheduled or at a random interval. Instead, this task was called directly from the patient's bedside. The **task location** was determined for each task i.e. occurring at the nurses' station or patient bedside. Table 1 represents *task location*, *task priority level* and *task scheduling type*. In this model, the nurse is programmed or simulated to do the highest priority task first. There may be occasions where more than one task bears the same priority. For instance, a medication task is assigned the highest priority (priority 1) and this task could be generated from a patient with the greatest distance to the nurse and at the same time the same task (bearing same priority) from a patient with least distance to the nurse. In this case, the task logic was built to simulate the nurse performing the task at the least distance.

Outputs

In this study, the outputs were recorded separately for nurse workload and care quality. Nurse workload is assessed by '**task queue**' and '**distance walked by nurse**'. Care quality is assessed by calculating the amount of '**missed care**' and '**task in queue time**'. As illustrated in Figure 1, nurse workload outcome: missed care, is further categorized as **priority tasks** *(bearing task priority 1 – 5)*, **average priority** *(bearing task priority 6)* and **non-priority tasks** *(bearing task priority >6).*

Model Testing

Patient acuity is defined as the level of illness of the patient and is associated with the intensity of care required by a patient. In the model, patient acuity is operationalized as task frequency. As illustrated in Table 1, tasks such as Medication, Vital signs, Evaluation, Vascular Access, Treatments and Consultation were only classified as acuity sensitive i.e. when acuity level increases so does the task frequency.

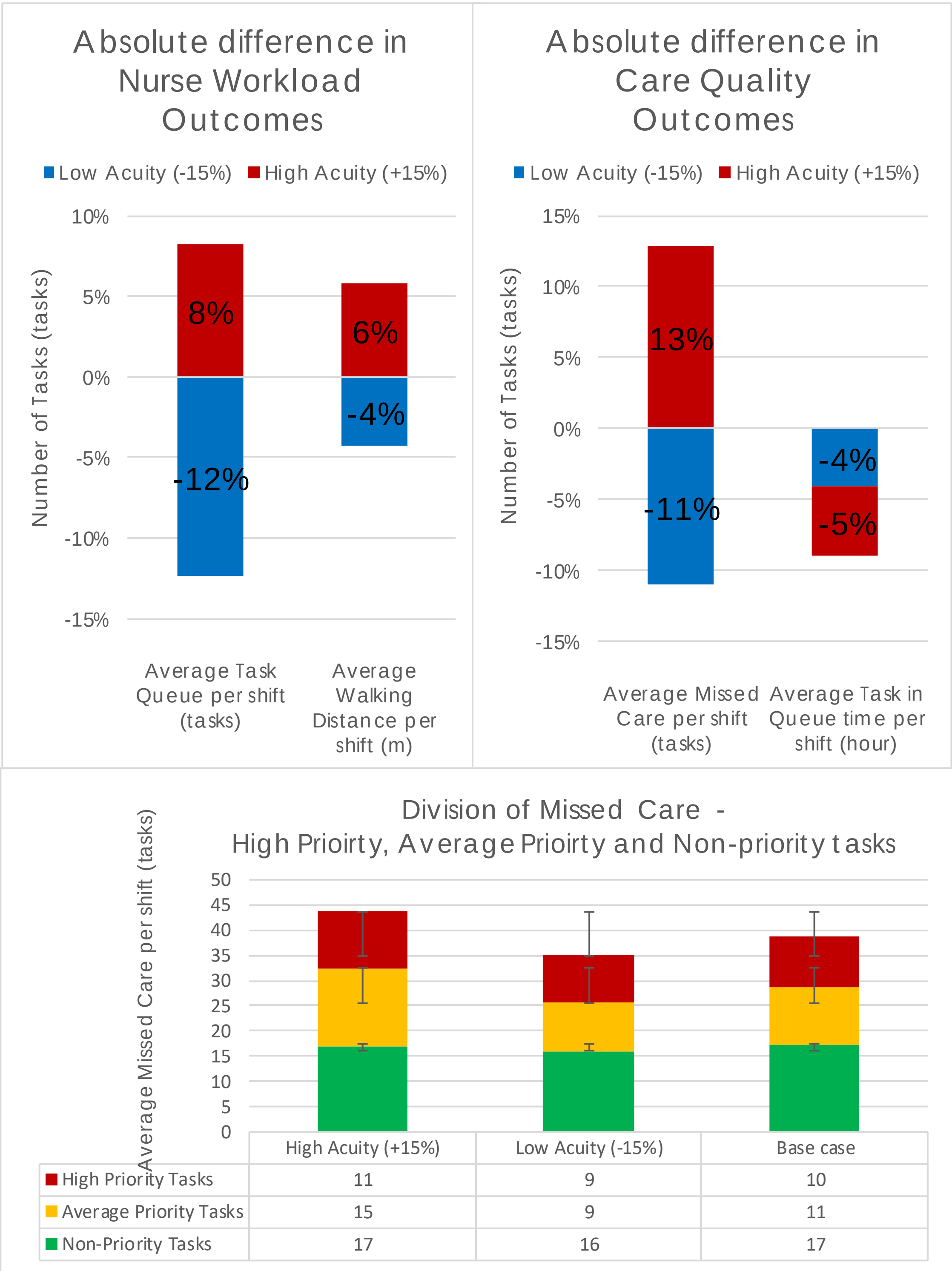
The model is run on three acuity levels: Low (-15% of the Base case), Medium (Base case) and High (+15% of the Base case) acuity levels, for 252 shifts, which is approximately the total working days in an year where each shift consists of 12 hours with 1 nurse assigned to 5 patients. Data for 10 replications were recorded for each operating condition.

A warm up period of 41 days was established using Welch's method (Hoad et.al., 2010). Excluding the 10 replications of 41 warm up days, Averages across 2110 shifts were taken for Missed care, Task in Queue time, Task Queue and Distance walked. Recorded Missed care was further divided into High priority, Average priority and Non-priority tasks by means of percentage calculation.

RESULTS

With the increase in acuity level, Missed care, Task in Queue and Walking distance all increased with the exception of Task in Queue time. For High Acuity, there was a 13% increase for Missed care, -5% decrease in Task in Queue time, 8% increase for Task in Queue and 6% increase for Walking distance. For Low Acuity, there was a decrease of -11% for Missed Care, -4% for Task in Queue time, -12% for Task in Queue and -4% for Walking distance. By comparing the effect of Low and High acuity levels on 'Task in Queue time', an effect of only 1% was recorded, which illustrates that acuity has almost no effect on 'Task in Queue time'.

In the case of Missed care, for High acuity: on average 44 tasks were recorded in which 11, 15 and 17 tasks were recorded as High priority, Average priority and Non-priority tasks respectively. For Low acuity level: 35 tasks were recorded, in which 9, 9 and 16 tasks were recorded as High priority, Average priority and Non-priority tasks respectively.



Outcomes	High Acuity (+15%)	Low Acuity (-15%)	Base case
Average Task Queue per shift (tasks)	27	22	25
Average Walking Distance per shift (m)	481	436	456
Average Missed Care per shift (tasks)	44	35	39
Average Task in Queue time per shift (hour)	1.16	1.17	1.22

Figure 2 illustrates Absolute Differences in Nurse workload and Care Quality indicators; Division of Missed care, for Low & High Acuity levels and Base case

DISCUSSION

Using DES to examine nursing workload is a novel approach of using DES methodology as previous studies only focused on patient flow (e.g. Casier, et.al., 2012; Mohammadi & Shamohammadi, 2012; Günal & Pidd, 2010). This approach helps hospital administrators understand and predict the effects of change in healthcare system policy and technical decisions in terms of nurse workload and care quality.

As illustrated in Figure 2, With the increase in patient acuity, an increase in all outcomes was noted with the exception of 'Tasks in Queue' time because acuity in the model is defined as the inter-arrival times between tasks. If acuity increases, the inter-arrival time between tasks would decrease which would lead to the operator (nurse) getting busier. Since the programming logic states that the nurse will always do the highest priority task at the least distance; therefore, minimal nurse walking activity was observed (6%) for high acuity. Consequently, more tasks were completed in a lesser waiting time. This explains the slight decrease in Task in Queue time (-5%). In the model, the distance from one bed to the other is shorter as compared to the beds to nurse station tasks. By comparing the effect of Low and High acuity levels on 'Task in Queue time', an effect of only 1% was recorded, which illustrates that acuity has almost no effect on 'Task in Queue time'.

The VNU model predicts missed care levels, and also quantifies them in-terms of high priority, average priority and non-priority tasks. The model can quantify specific workload and care quality indicators. In this example we looked at "patient acuity" only, although a broad range of system design and patient characteristics might be examined in the future using this approach. Limitations to the VNU model includes using frequency weighted standardized task duration time from GRASP data that are not acuity sensitive, a hypothetical floor layout with scaled drawings of patient bedrooms and the nurse\ing station and using the nurse operating logic for a general in-patient unit ward. Future work includes exploring newer indicators for workload and care quality, such as fatigue and error rates, testing new design factors, a field-validation study, using a floor plan from an existing hospital, and using acuity sensitive time duration inputs. A scarcity of published work suggests research is needed in this domain.

CONCLUSIONS

In this paper, Patient Acuity is modelled using DES to predict and quantify its effect on Nurse workload and Care Quality. The demonstrator model reports: as *patient acuity increases*, *nurse workload increases*, 8% for 'Tasks in queue' and 6% 'Distance walked by Nurse', and *Care quality decreases*, 13% increase in 'Missed care' and -5% 'Task in queue time'.

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INTEGRATING FATIGUE MODELLING INTO APPLIED ERGONOMICS

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Summative Statement: Fatigue modelling typically requires expensive computer programs, and high levels of technical experience. This work presents a simple to use method for understanding fatigue accumulation in repetitive tasks, and proposes an interpretation for fatigue metrics in ergonomics.

Intégration de la modélisation de la fatigue en Ergonomie appliquée

Sommaire : En général, la modélisation de la fatigue nécessite l'utilisation de programmes informatiques coûteux et un haut degré d'expérience technique. Cette étude présente une méthode simple à mettre en place pour comprendre l'accumulation de la fatigue dans les tâches répétitives, et propose une démarche pour interpréter les paramètres de la fatigue en ergonomie.

Problem statement: Muscle fatigue has been identified as a precursor for musculoskeletal injury, as well as decreases in worker productivity and work quality. Tools capable of evaluating the acceptability of tasks with complex force-time histories typically require expensive computer programs, technical experience, or are mathematically complex (Rashedi & Nussbaum, 2015).

Research Objective / Question: The purpose of this study was to develop an easy to use, practical tool for evaluating fatiguing work. This would result in a metric that could be used to evaluate ergonomic changes to repetitive, assembly line type work.

Methodology: A series of 70 randomly generated force-time histories were created, with varying duty cycles between 16% and 83%. The individual force levels ranged between 1, and 60% MVC, with an average force level of 30% MVC. Each force time history cycle was 60 seconds in length, and the rest length was determined by the duty cycle (DC) (ex. DC = 83%, rest time = 10 seconds). A 2-hour simulation of each effort was run through the Three Compartment Model with Graded Motor Units (Sonne & Potvin, 2016) in MATLAB. During each two-hour window for each time history the integrated, maximum, and average fatigue (Figure 1A) was calculated.

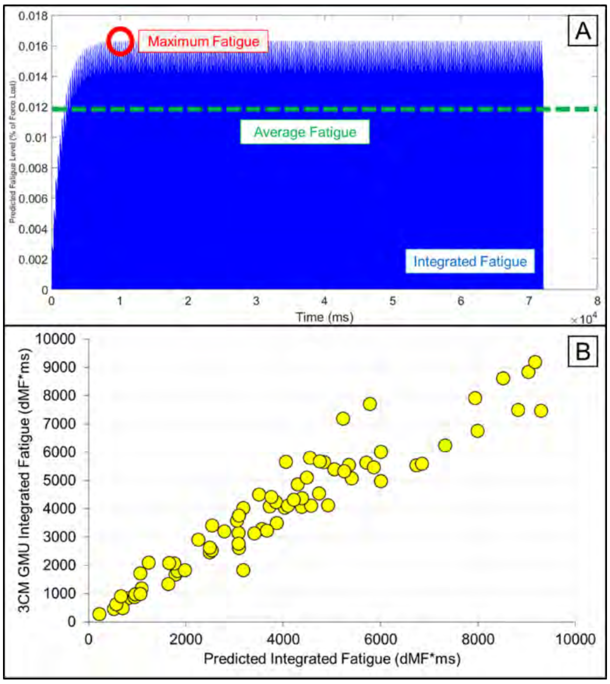

Figure 11. Description of fatigue metrics (A), and Evaluation of Predictive Model (B)

To make this fatigue modeling approach applicable for web-application, a non-linear regression equation was developed. Input variables of root mean quartic weighted average force, and cycle rest time were used to predict integrated fatigue (%MVC•s), maximum fatigue (% MVC lost), and average fatigue levels (% MVC lost)(Figure 1A). A non-linear, machine learning program (Eureqa, Nutonian, Boston, USA) was used to fit the data. Goodness of fit was determined using r^2.

Model Testing: Subjective effort levels for hand and forearm exertions were collected at a Hydro Coil building facility. Time histories, and frequencies of jobs were collected, along with sequencing of tasks within individual jobs. In total, there were 4 cells examined, with between 6 and 8 tasks required to complete each job. The effort frequencies and durations were calculated with respect to a 60 second cycle time. The root mean quartic (RMQ) of each effort was calculated, and produced a weighted average for the forces used in each job, as per Vandergreindt & Potvin (2016). The composite maximum acceptable effort level was also calculated. Job acceptability was determined by the ratio of RMQ to Maximum Acceptable Effort (MAE) – with, a ratio of greater than 1 being unacceptable, and less than 1, being acceptable.

Results:
Development of a Model: The regression approach explained 95.5%, 88.2%, and 87.2% of the variance in integrated (Figure 1B), average, and maximum fatigue. The regression equations created were then exported to Microsoft Excel for further analysis.

Testing the Model: Based on the RMQ approach, of the 4 jobs analyzed, two were calculated to be acceptable (risk scores of 0.93, and 0.87), and two were unacceptable (2.30, and 2.26). The acceptable jobs had peak maximum fatigue levels of 3.5, and 2.1%, compared to 25.4, and 14.9% for the unacceptable jobs. The integrated fatigue levels indicate significantly more accumulated fatigue over the course of a work week in the unacceptable jobs.

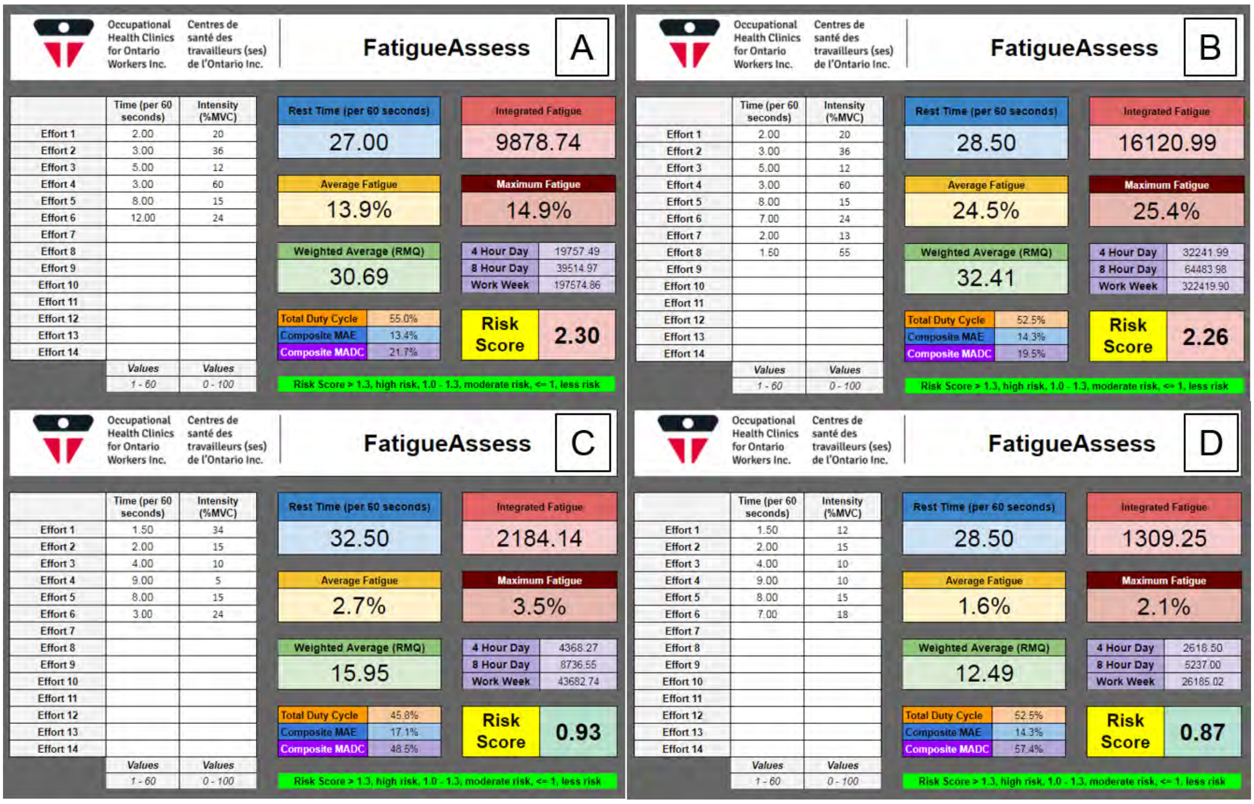

Figure 12. Job demands and cycle times for tasks required to complete 4 separate (A-D) jobs in a hydro coil manufacturing facility. Average, maximum, and integrated fatigue are calculated, along with RMQ weighted averages, and composite MAE values.

Application for Ergonomic Interventions: To examine the impact of an intervention which simulated the use of a tool to reduce effort demands and time of contact in one of the unacceptable jobs, task element 4 in job 1 was replaced with an effort of 15%, and an effort duration of 1.5 seconds. This reduced the integrated fatigue in an 8 hour day from 39519.97 %MVC•s to 15952.55 %MVC•s – a reduction of 60% from the current state (without a tool).

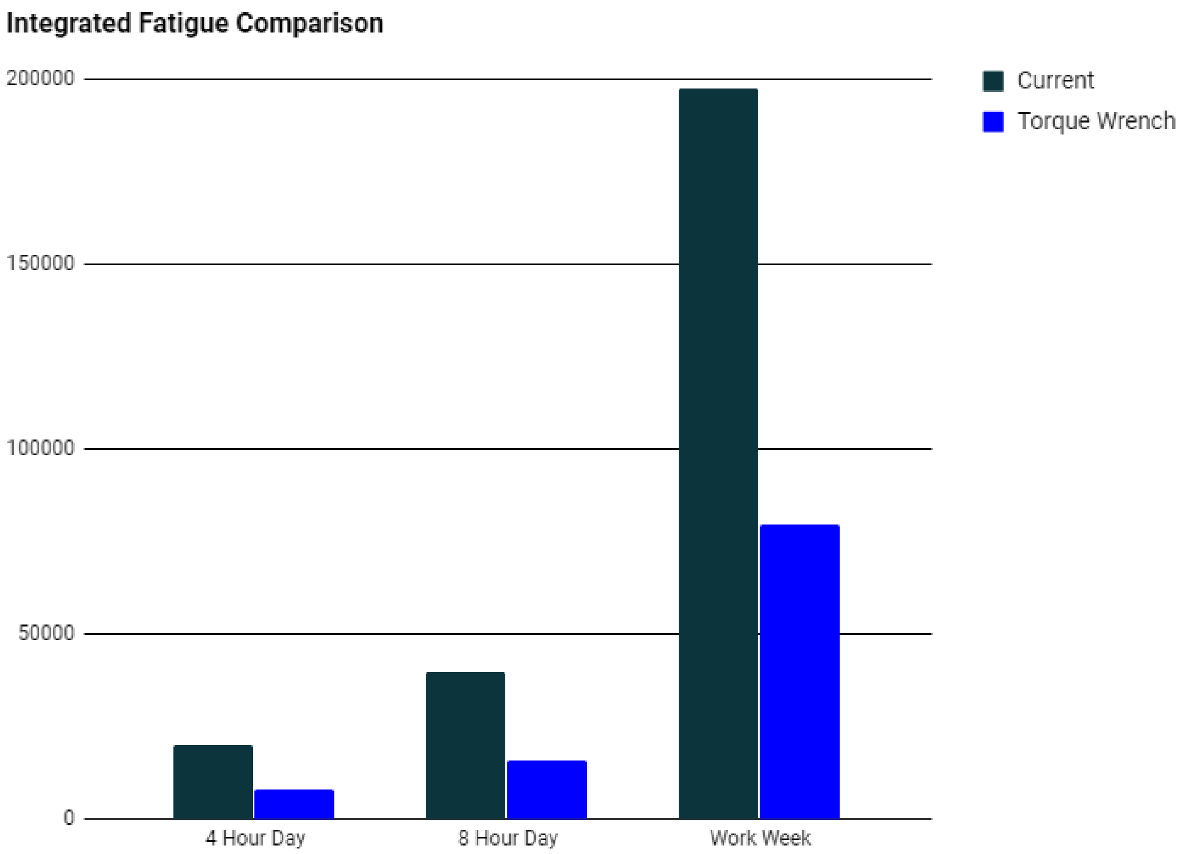

Figure 13. Integrated fatigue levels for a job (Figure 3A), with a high intensity hand exertion, compared to a reduced demand/time exertion reflective of using a torque wrench in place of a manual exertion.

Discussion and Conclusions: Theoretically, integrated fatigue can be used to represent the amount of fatigue accumulated over the course of a day, week, or month. This can be used to compare interventions on their fatigue reductions. This analysis may be used for determining acceptable fatigue levels in workplaces. Further research is still required to determine if there is an association between different fatigue metrics, and outcome measures like discomfort or injury.

Additionally, Potvin & Fuglevand (2017), have produced a more sophisticated fatigue model than the Three Compartment model with Graded Motor Units (Sonne & Potvin, 2016), which posits fatigue levels may be more than just the amount of force generating capacity lost. It would be beneficial to incorporate the findings from this model for greater inference on the fatigue process, and how it may impact worker comfort, injury risk, as well as productivity and quality measures. OHCOW is currently producing a web app to be used by ergonomists for applying fatigue modelling to their analyses.

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COMPARATIVE ANALYSIS OF THREE HUMAN MODELING SOFTWARE PACKAGES DURING THE ANALYSIS OF LOW BACK LOADING IN STATIC POSTURES

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KEYWORDS
Tecnomatix Jack, Santos, 3D Match, Digital Human Modeling

SUMMATIVE STATEMENT
Low back loading was calculated for static postures in 3D Match, Tecnomatix Jack, and Santos® Lite, in order to compare the results from the three methods. Jack calculated significantly different, and larger moments and forces at the L4/L5 joint compared to either Santos® Lite or 3D Match. Santos® Lite calculated significantly different anterior-posterior shear compared to 3D Match.

Analyse comparative de trois logiciels de modélisation humaine au cours d’analyses de charge exercée sur le bas du dos en postures statiques

MOTS-CLÉS
Tecnomatix Jack, Santos, 3D Match, Digital Human Modeling

SOMMAIRE
La charge exercée sur le bas du bas a été calculée pour les postures statiques en utilisant les logiciels de simulation 3D Match, Tecnomatix Jack et Santos® Lite afin de comparer les résultats des trois méthodes. La méthode Jack a calculé les moments de force à L4/L5 d’une façon considérablement différente et élevée comparativement aux méthodes Santos® Lite ou 3D Match. La méthode Santos® Lite a calculé d’une manière considérablement différente le cisaillement antérieur et postérieur comparativement à la méthode 3D Match.

PROBLEM STATEMENT
In the marketplace of biomechanical analysis software, there are many options to choose from, ranging in cost and capability. Each software package relies on a proprietary model based on specific assumptions in order to calculate joint moments, and forces. However, it is useful to know how model outputs may differ between software packages to inform end-user decision based on these outputs.

RESEARCH OBJECTIVE/QUESTION
Do moment and force outputs differ when utilizing 3D Match, Tecnomatix Jack, and Santos® software packages to analyze low back biomechanics during an occupational lifting scenario? If so, can differences be explained by modeling assumptions stated within each software?

METHODOLOGY

Video data from 34 trials of paramedics performing stretcher related lifting tasks were analyzed using 3D Match, Tecnomatix Jack, and Santos® to calculate compression, shear and net joint moments at the L4/L5 joint. Video data were posture matched and supplemented with hand force data to support analysis in 3D Match. Kinovea was used to estimate the joint angles for the frames of video where 3DMatch indicated peak shear, compression and net joint moment. After posturing the mannequin in Tecnomatix Jack, and Santos®, hand force data was included and biomechanical analysis were performed. A repeated measures ANOVA was computed to detect for a main effect of software in output compression, shear and net joint moments. Bonferroni-corrected post hoc analyses were applied to determine the location of any main effects.

RESULTS

Tecnomatix Jack calculated significantly different results when compared to both Santos® Lite, and 3D Match for all measures of interest in this investigation (Compression – Santos 1555±363 N, Jack 2241±580 N, 3D Match 1556±300 N; AP Shear - Santos 148±132 N, Jack 492±270 N 3D Match 31±160 N; Moment - Santos 75±24 Nm, Jack 99±34 Nm, 3D Match 69±28 Nm). The only significant difference between Santos® Lite and 3D Match was shown in the analysis of anterior/posterior shear (p=0.0072).

DISCUSSION

In general, Technomatix Jack output higher estimates of spine loading for the occupational lifting task relative to the other software's. Santos® Lite and 3D Match utilize the same McGill polynomial-based approach to estimate low back loading explaining why these software output similar values. It is interesting that the net joint moment estimates differed between Technomatix Jack and the other software's. This may be due to difference in assumption related to anthropometry.

CONCLUSIONS

Technomatix Jack generated higher spine loading exposures. We do not know if this is more or less accurate than the other two software's. However, it is useful for practitioners utilizing these tools to understand the underlying assumptions and their effect on final outputs.

Technical Session 8: Healthcare and Macroergonomics Systems Approaches

Séance technique 8: Approches liées aux systèmes de santé et à la macroergonomie

THE CHARACTERISTICS OF INTERRUPTIONS FOLLOWING TRAUMA ACTIVATIONS

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KEYWORDS
Interruptions, trauma care, trauma activations

SUMMATIVE STATEMENT
While clinicians can benefit from interruptions and some interruptions are necessary, many interruptions can be deleterious to patients' and providers' safety. Interruptions are perceived to increase the risk for errors by disrupting clinicians' cognitive and physical processes and increasing cognitive demand. The purpose of this study is to examine the characteristics of interruptions following trauma activation in the emergency department to understand potential impact on clinicians' workflow.

Les caractéristiques liées aux interruptions après les niveaux d'activation en trauma

MOTS-CLÉS
Interruptions, soins en traumatologie, activations en traumatologie

SOMMAIRE
Même si certaines interruptions peuvent être avantageuses pour les cliniciens, et parfois même nécessaires, un grand nombre d'interruptions peuvent être néfastes pour la sécurité des patients et des fournisseurs de soins. Les interruptions semblent augmenter les risques d'erreurs en perturbant les processus cognitifs et physiques des cliniciens et en augmentant les exigences cognitives. La présente étude a pour but d'examiner les caractéristiques des interruptions après l'activation en traumatologie dans un service d'urgence afin de comprendre les répercussions potentielles sur le déroulement du travail des cliniciens.

PROBLEM STATEMENT
Clinicians have anecdotally indicated that interruptions increase following trauma activations and have provided various reasons for such increase; however, prior literature has not examined interruptions pre and post trauma activations. The study seeks to understand interruptions following trauma activations.

RESEARCH OBJECTIVE/QUESTION
Do interruption characteristics change following trauma activations?

METHODOLOGY
Observers shadowed ED clinicians across entire shifts and logged interruptions that affected clinicians in a tablet PC-based tool. Interruption characteristics captured included duration, nature, location, and task priority. Trauma activations lasting more than five minutes were also recorded. Only interruptions occurring within one-hour of trauma activations were

included in the analysis. Descriptive statistics, a chi-square analysis, paired t-test, and Mann-Whitney U test were performed to evaluate whether the nature of interruptions changed following trauma activations.

RESULTS

Eleven shifts met the inclusion criteria. Clinicians were interrupted a mean (M) 105.2 times per shift (SD=75.8). Traumas lasted 19.9 minutes on average (SD=7.8 min). A paired t-test revealed no significant difference in interruption occurrence pre- and post-trauma activations (p>.2; M= 8.6, SD=4.5; M=8.2, SD=4.9, respectively). Interruption duration was also not statistically significantly different pre (*Mdn*=13.0) and post trauma activation (*Mdn*=17.0). There was a statistically significant association between patient-related interruptions and trauma activations, $\chi^2(1)=4.807$, p=.028, where patient-related interruptions were more frequent following the end of trauma activations.

DISCUSSION

The results from this study suggest that interruptions behaviors are different following trauma activation. This provides new knowledge regarding interruptions and warrants further investigation into the phenomena. There are many reasons for the surge in patient-related interruptions following a trauma and one can postulate causes to be related to increase in patient demand and/or temporary shortage of staff that creates a backlog in completing patient related tasks.

CONCLUSIONS

Patient-related interruptions were more frequent following the end of trauma activations. This study indicates that there need to be more comprehensive studies that examine the impact of trauma activation on interruptions and emergency care team's stability.

ACKNOWLEDGEMENTS

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A COST-BENEFIT ANALYSIS OF A POWERED STRETCHER AND LOAD SYSTEM INTERVENTION IN A PARAMEDIC SERVICE

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KEYWORDS
Cost-benefit, Economics, MSD Prevention, Ergonomic Intervention

SUMMATIVE STATEMENT
Powered stretcher and load systems are being considered as an intervention by paramedic services but potential effectiveness and capital cost are noted as barriers preventing implementation. This study shows that a powered stretcher and load system intervention significantly reduced the incidence of stretcher-related musculoskeletal disorders compared to a control service. Cost-benefit analysis suggests that capital costs can be recovered in 5.8 years, less than the expected 7-year service life of the powered stretcher and load system.

Une analyse coût-avantage des interventions liées à l'utilisation de civières motorisées dotées de système de chargement dans un service ambulancier

MOTS-CLÉS
Coût-avantage, économie, prévention des TMS, intervention ergonomique

SOMMAIRE
L'utilisation de civières motorisées dotées de système de chargement est envisagée par un service ambulancier, mais l'efficacité possible et l'investissement en capital sont considérés comme des obstacles qui empêchent la mise en œuvre du projet. Cette étude montre que l'utilisation de civières motorisées dotées de système de chargement avait considérablement réduit l'incidence des troubles musculosquelettiques liés aux civières par rapport à un groupe témoin. L'analyse coût-avantage indique que l'investissement peut être récupéré en 5,8 ans, ce qui est inférieur à la durée de vie de 7 ans qui est envisagée pour les civières motorisées dotées de système de chargement.

PROBLEM STATEMENT

Paramedics are exposed to high physical demands in their day-to-day work including lifting, carrying and transporting both patients and equipment (Coffey, 2016). The high physical demands of work puts paramedics at a greater risk of musculoskeletal disorders (MSD) and in fact, paramedics have the greatest prevalence of MSDs by sector (Maguire et al., 2005, 2014).

To combat this high prevalence of MSDs different interventions have been developed and implemented in various paramedic services. One such intervention is powered stretcher and load systems. The stretcher is used by paramedics in almost every emergency call response regardless of the patient's level of acuity for patient transfer (Morales et al., 2016; Prairie and Corbeil, 2014). Historically, stretchers used have been manual and required physical exertions for raising/lowering the stretcher height, loading/unloading from the ambulance and pushing/pulling for patient transportation. To eliminate the need for physical raising/lowering powered stretcher designs come equipped with a motor that can raise and lower the cot at the touch of a button. Lab-based studies have demonstrated that a powered stretcher required less muscle activation compared to a manual stretcher design during raising/lowering tasks (Sommerich et al., 2013). Power load systems are an accessory feature installed in the back of an ambulance to automatically load or unload the stretcher using a robotic arm, further reducing the physical demands on paramedics. Lad et al. (2016) showed that the power load functionality significantly reduced peak low back compression compared to loading a manual stretcher.

Powered stretcher and load system technologies are effective in reducing loads on the body compared to manual stretchers, but do they reduce injury rates? Studnek et al. (2012) and Fredericks et al. (2009) investigated injury trends following full implementation of powered stretchers into a paramedic service. Both showed that the intervention was successful. Studnek et al. (2012) found a reduction in injury incidence rates from 61.1 to 28.8 per 100 full-time equivalents following the intervention. Fredericks et al. (2009) reported a 41% reduction in claims costs and a 68% reduction in days lost to injury after full implementation of powered stretchers. Both studies provide evidence supporting powered stretchers as an effective MSD control. However, there are three limitations that may limit the applicability of these findings to services looking to invest in the technology.

Previous research has not considered the added power load system, included a control group in the experimental design, or considered the cost-benefit. Not including a power load system may lead to an underestimation of potential MSD reduction benefits. Although the powered stretchers were shown to be effective, the addition of a power-load system may further reduce injury incidence following implementation as this technology reduces the demands of loading a stretcher in addition to lifting the stretcher. A second limitation of these studies is that neither included a control group, which was identified by Studnek et al. (2012) as an important consideration for future research. Injury rates may fluctuate and change in a workplace and so it is difficult to attribute reductions in injury rates solely to the intervention without comparing them to a control that may be exposed to many similar factors over time. A final limitation to previous research is that the economic feasibility of these technologies has not been considered. Investing in this technology comes with a high price tag and even though injury incidence will likely be reduced, services need to consider cost effectiveness of these technologies to secure investment funds.

RESEARCH OBJECTIVE/QUESTION

To address these limitations our primary objective was to analyze reported injury data in both a service that fully implemented powered stretcher and load systems and a control of similar size and location over a period of 4 years pre-intervention and 1 year post-intervention. We hypothesized that powered stretcher and load systems would reduce the incidence of stretcher-related MSDs both within the intervention service and compared to a control service following intervention. We believed that cost savings from these injury reductions would result in powered stretcher and load systems being economically viable as determined by a cost-benefit calculation.

METHODOLOGY

A retrospective cohort study was conducted using injury incidence, claims cost data and call responses over a 6-year period (2010-2015) from the Niagara Emergency Medical Service (NEMS) and the Hamilton Paramedic Service (HPS). NEMS fully implemented Stryker Power-PRO™XT and Power-LOAD™systems (Portage, MI) in all ambulances over a period of January to April in 2014. HPS used manual stretchers for the entire 6-year collection period and served as a control service that had similar coverage area, number of employed paramedics and number ambulances in service to NEMS while bordering the NEMS coverage area geographically. No other major MSD prevention programs were introduced in either service over the course of the study.
Injury data from both services was extracted from their respective injury reporting software for analysis. The services had consistent injury reporting processes that resulted in similar data outputs for analysis. Injury data from 2010-2013 in both services was taken as pre-intervention measures while injury data from 2015 was used as the post-intervention measure. The year 2014 was not included in pre-post analysis since the intervention took place over 4 months of this year. To identify injuries classified as stretcher-related MSDs the data set was first reduced to only injuries classified in the reporting software as an MSD. The injury description field, where a supervisor can provide context on how an injury occurred, was then used to determine whether the injury was stretcher-related. If a stretcher was mentioned in any capacity in this field then the injury was classified as a stretcher-related MSD.

For statistical analysis, all stretcher-related MSDs were normalized to number of call responses. Call response types are variable so we specifically considered any calls where the ambulance was mobile (referred to as a T3 time) as our number of call responses. One-tailed binomial proportion tests were used to determine if proportions of stretcher-related MSDs to call responses were lower within each service post intervention and to determine if proportions were lower year by year in the intervention service compared to the control. A z-score of ≥ 1.65 defined a significant reduction in injury incidence. All statistical calculations were performed using Excel (Microsoft, Redmond, Washington).

For the cost-benefit calculation, the Washington State Ergonomics Cost Benefit Calculator was modified to give an estimate on the payback period of the powered stretcher and load system intervention. This calculator uses standardized estimated injury costs, actual injury incidence and intervention costs as inputs for calculation (Goggins et al., 2008), but we modified the calculator to use actual annual injury costs to provide a more accurate estimate of payback period. The intervention cost was calculated as the sum of the cost of the powered stretcher and load systems, including an estimate of the one-time training cost. The cost of the powered stretcher and load systems was determined as the difference between the cost of the powered stretcher and load systems and the cost of manual stretchers. Training costs were calculated as the average paramedic wage, multiplied by the total number of NEMS paramedics, multiplied by 5 hours of training per paramedic. Annual recurring costs (e.g., equipment maintenance) were conservatively estimated as the cost to replace four powered stretcher and load systems over the payback period, which represents approximately 10% of the fleet. With these inputs, Equation 1 was used to calculate the payback period in years, which is represented by the variable *x.*

$$\mathbf{0} = \boldsymbol{Intervention\ Cost} - \big((\boldsymbol{Annual\ Cost\ Benefit} - \boldsymbol{Annual\ Recurring\ Costs})\boldsymbol{x}\big) \qquad \textbf{(1)}$$

RESULTS

Within NEMS the implementation of powered stretcher and load systems significantly reduced the incidence of stretcher-related MSDs from 7.09 to 1.46 injuries per 10,000 call responses following intervention ($z=4.93$, $p<0.001$). Meanwhile, there was a modest increase in stretcher-related MSD incidence from 4.59 to 6.96 injuries per 10,000 calls post intervention in the HPS. Changes in injury incidence pre to post-intervention are pictured in Figure 1.

Comparing incidence of stretcher-related MSDs between the two services, NEMS had significantly lower incidence in both 2014 ($z=2.93$, $p=0.002$) and 2015 ($z=4.76$, $p<0.001$). Prior to powered stretcher and load system intervention (2010-2013) NEMS had higher incidence of stretcher-related MSDs than HPS across all years (Figure 2).

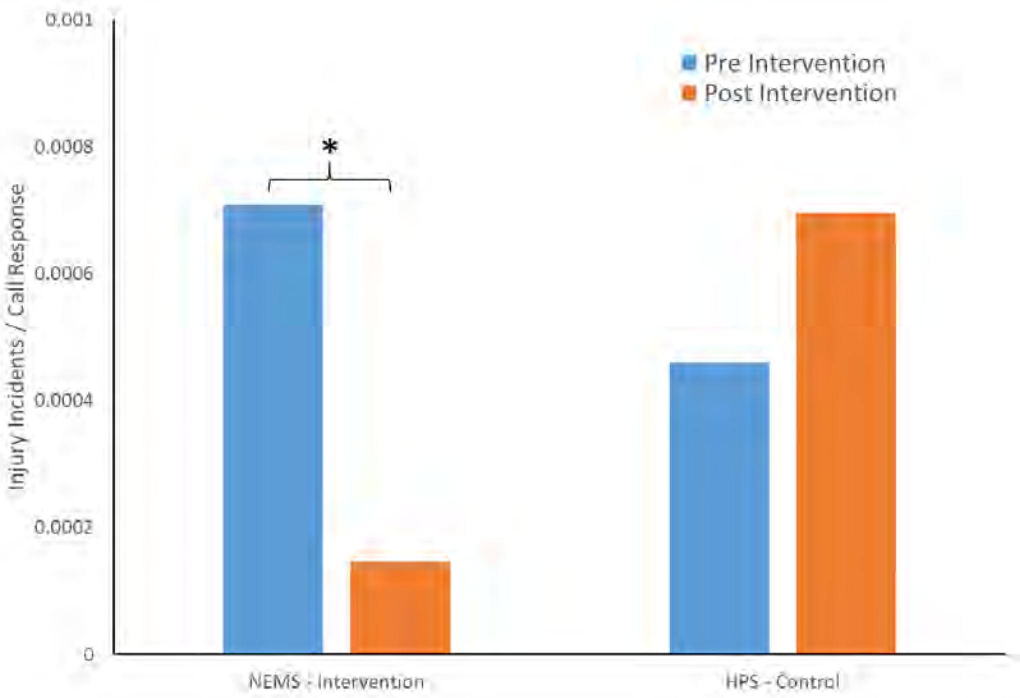

Figure 1 – Incidence of stretcher-related MSDs per call response in NEMS and HPS pre (2010-2013) and post (2015) powered stretcher and load system intervention. An asterisk (*) is used to indicate where the proportion of stretcher-related MSD incidence was significantly lower in the post intervention period.

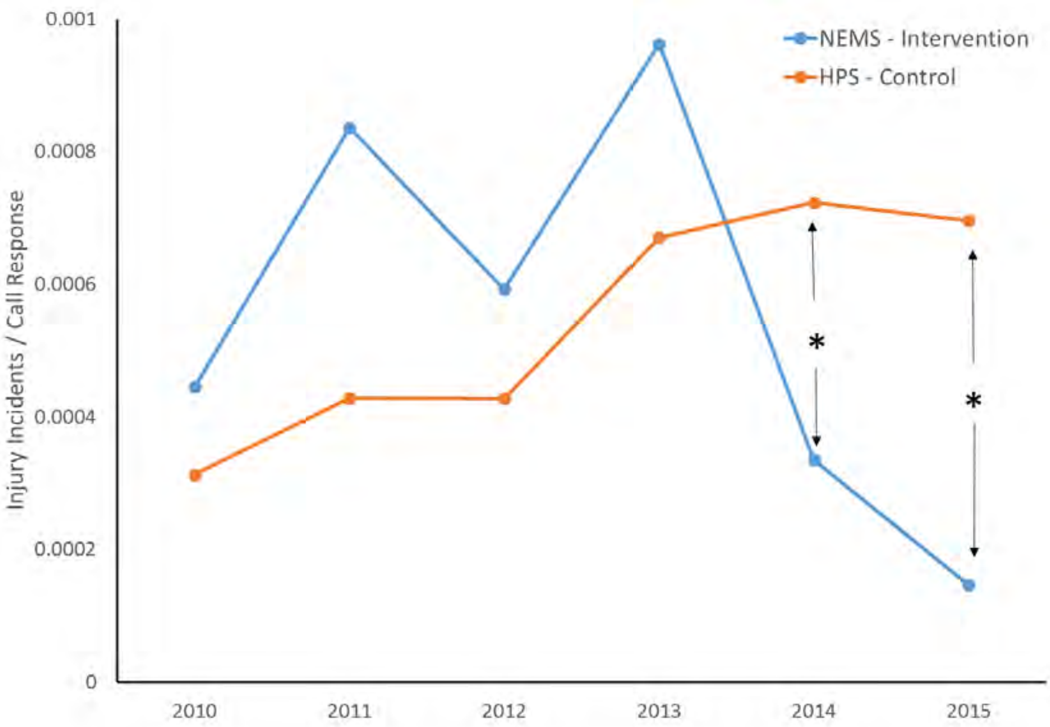

Figure 2 – Incidence of stretcher-related MSDs per call response in NEMS and HPS from 2010 to 2015. An asterisk (*) is used to indicate where the proportion of stretcher-related MSD incidence was significantly lower in NEMS

Using the modified Washington State Ergonomics Cost Benefit calculator to determine the economic feasibility of the powered stretcher and load system intervention a payback period of 5.8 years was calculated. The estimated service life of the powered stretcher and load systems is 7 years meaning that it is anticipated that all implementation costs including equipment purchase, maintenance and training will be recaptured 1.2 years prior to the end of the normal service life of the equipment.

DISCUSSION

Our primary hypothesis that incidence of stretcher-related MSDs would be lower within NEMS following intervention was supported as rates decreased by 78%. The hypothesis that NEMS would have significantly lower injury incidence than HPS after the intervention was also supported. The similarities in stretcher-related MSD incidence between the two services prior to intervention, and significantly lower incidence in NEMS compared to HPS the year of, and the year after intervention provide compelling evidence that the powered stretcher and load system technologies are a viable intervention to reduce stretcher-related MSD incidence.

Our secondary hypothesis that this intervention would be economically viable was supported by the results of the cost benefit analysis. Paramedic services face barriers, such as yearly operating budgets, which make it difficult to invest in expensive controls to reduce the incidence of MSDs. The results of the cost-benefit show that even though there is a high price tag associated with the initial purchase of these systems, costs can be recaptured within the service life of the product making the initial investment more palatable. Over time services may begin to see greater financial gains as training will no longer be required as the equipment reaches the end of its service life. We believe that these findings can help inform decision makers who may be considering powered stretcher and load interventions.

Although this study has found that powered stretcher and load systems are an effective intervention, there are some limitations to note. Since this data was retrospective, there may be concerns with the rigor of the injury reporting data that was used to inform this study. Although between the two services there may be some differences in how injury events were described we believe these differences would not be large enough to affect our results. Secondly, we assume that HPS was an appropriate control for NEMS. Although the two services are separate entities we believe the similarities in size, call volume and geography strongly support the assumption that HPS is representative of NEMS. Finally, the Washington State Ergonomics Benefit Calculator provides a simple cost-benefit estimate that does not account for the time value of money, inflation or other economic factors. Although an analysis including some of the aforementioned factors could influence the result of the cost-benefit calculation doing so would require making other assumptions, which could influence outputs and associated error. For these reasons, we are confident in the efficacy of our cost-benefit calculation approach.

CONCLUSIONS

This study provides evidence supporting the effectiveness of powered stretcher and load system intervention to reduce incidence of stretcher-related MSDs in a paramedic service. The reduction in injuries coupled with the predicted payback period being less than the life expectancy of the equipment support that powered stretcher and load systems are a cost-effective strategy to reduce MSDs. We recommend that paramedic services consider the benefits of adopting powered stretcher and load systems moving forward.

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DEALING WITH NEAR MISS EVENTS IN HEALTH CARE: CHALLENGES IN THE DESIGN OF SOCIO-TECHNICAL SYSTEMS

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KEYWORDS
Patient safety; socio-technical systems; early warnings; near miss events; systems design

MAIN MESSAGE
Organisations often fail to act on early warnings, largely because they do not challenge their perceptions of management control. The paper sets out a framework for considering the nature of early warnings and their relationships to management and the notion of a designed-for systems state.

S'attaquer aux incidents évités de justesse dans les soins de santé: les défis en matière de conception de systèmes sociotechniques

MOTS-CLÉS
Sécurité des patients, systèmes sociotechniques, signes avant-coureurs, incidents évités de justesse, conception de systèmes

MESSAGE PRINCIPAL
Souvent, les entreprises ne tiennent pas compte des signes avant-coureurs, principalement parce qu'ils ne remettent pas en question leurs perceptions du contrôle de gestion. Cette communication définit un cadre pour prendre en considération la nature des signes avant-coureurs et leurs liens avec la gestion et la notion de concevoir en fonction de l'état des systèmes.

PROBLEM

> "No one likes to deal with uncertainty in any aspect of life, let alone those aspects having to do with possible threats to health. …..risk assessors have a technique for dealing with these uncertainties, but the technique does not make them vanish" - (Rodricks, 1992), p. 186-187.

Risk and uncertainty could be seen to sit at the core of the provision of health care services and especially within an acute setting. The opening quote by Rodricks, whilst describing the risk of chemical exposure within a public health setting, could also be clearly applied to acute care. The argument about managing risk relates to the understanding that we have about the relative risks associated with a particular exposure, process, or intervention and the specific assumptions that are made about the nature of the probabilities of that risk and the consequences associated with it (Rodricks, 1992). This paper is a theoretical consideration of the issues associated with early warnings. It was prompted by a series of observations within a number of UK hospitals in which nursing staff appeared to ignore the warnings that were generated. These observations prompted a consideration of the ways in which organisations could consider enhancing its abilities around such processes and what the likely challenges would be in terms of implementation.

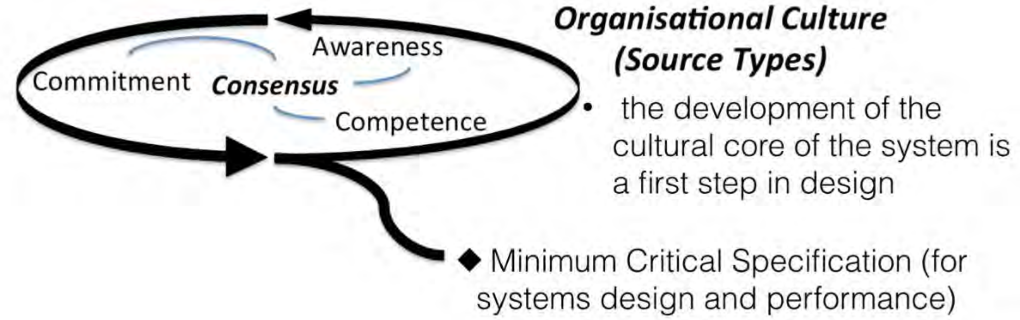
The starting point for a consideration of early warnings within health care involved a series of observations within a hospital and the processes through which the hospital board were told of the problems that occurred at the operational level. The first of these observations involved a critical care ward where it was observed that one of the monitors was showing a 'flat line' for a patient. Local staff on the ward commented that there was a fault on the machine and that the patient was being observed. However, there was no line of sight between the monitoring station and the patient and so it was clearly not possible to see the patient. Added to this, the design of the ward meant that the nursing station did not allow for line of sight observations that were possible in the older Nightingale wards in which the nursing station was located at the centre of two 'wings' of beds, each of which could be observed from the central point. A second observation was undertaken on an elderly medicine ward in which the four occupants had all recently suffered from a stroke. The alarm on one of the patient's monitors was activated and yet no one from the nurses' station responded. On this occasion, the observer raised concerns about the patient's well-being with the nurse – stating that the patient seemed to be in distress and that the alarm was clearly activated. The response of the nurse was that there was a problem associated with the patient's alarm and that was the reason that it kept tripping. However, when the nurse examined the patient, it was clear that they had suffered from a cardiac arrest and that the alarm had been triggered as a result of that rather than a malfunction. The nurse urgently requested the crash team. These incidents highlighted both the reliance of nursing staff on monitors for patient well-being and also the vulnerability of that technology to fail to danger with the result that harm could be generated for the patient as a consequence. From a management perspective, these incidents should trigger a root cause analysis investigation and be reported to senior management as both represent a failure of the system to function as designed. In both cases, local adaptations were made that had the potential to impact upon patient safety and yet the adaptations appeared to have been seen as routine forms of adjustment.

Within an acute care setting, the issues of early warnings and near miss events provide important information for management about the performance of systems controls under a range of operating conditions. Many of these control systems are designed for a particular systems state (the designed-for state) but they are often not adapted to cope with the processes of emergence within organisational operating practices and local conditions. As an organisation moves from its designed-for state to an emergent-state, then a gap is created that allows gaps to be created within controls. Reason (1997; Reason, 1987, 1990a, b) has likened the gaps in controls to the holes in Swiss Cheese and the model has been used extensively within health care to illustrate the ways in which accident pathways can by-pass controls that were assumed to be in place. One of the challenges facing patient safety, is to ensure that systems controls match the task demands that are generated by the dynamic nature of health care interventions. Given that most patients interaction with the health care system when they are in a vulnerable state, and given the emergent and complex nature of many health-related problems, then the task demands that are created are both complex and multi-layered. The challenge of designing a set of controls to cope with these issues is, therefore, extremely complex and dynamic. Those involved in the management of patients at the sharp end will invariably be required to adapt to the emergence that exists in the patient-clinician interactions. One of the demands placed upon such a socio-technical system is learning from such adaptations and, in particular, the near miss and early warning events that will naturally occur within the system (DoH, 2000).

In order to deal with these questions, this paper will consider the issues from the perspective of the literature on systems design and ergonomics in an attempt to ensure that the discussion is based on a robust theoretical platform. Two main theoretical perspectives will shape this discussion. The first concerns the nature of the design of socio-technical systems and draws on the work of Cherns (1976, 1987). The second deals with the processes around the development of organisational cultures and has a focus on the ways that the 'source types' of commitment, competence, and awareness impact on the development of that culture (Reason, 1990b, 1993, 1995). The paper is largely theoretical, although it is based upon a series of observations made in acute care hospitals in the UK. These observations were used as a basis for assessing the theoretical challenges that exist in the design of a system that meets the requirements of patients for privacy, patient safety, and an effective process for the capture of early warning and near-miss data. These challenges will be framed using the lens provided by Cherns' work on socio-technical systems and the work on safety culture developed by Reason.

The first stage in the Cherns' framework concerns the building of consensus within the organisation around the nature and importance of the main elements of that system and its goal state. In part, this relates to the development of the organisational culture in which these activities occur and the potential that exists for ensuring that conflict between organisational objectives is minimised. Against this broad background, it is important to identify the main aspects of the organisation's culture that contribute to this issue. In discussing the nature of organisational culture, Reason outlines three elements that can be seen as being important in shaping consensus (or lack thereof) here in relation to teaching. These are the ***awareness*** of the importance of capturing early warnings, the ***commitment*** towards delivering high quality patient care by acting upon those warnings, and the ***competence*** that people have to deliver improvements in organisational controls and to communicate those changes to those who manage the overall performance of the organisation. These issues are shown in figure 1.

Figure 14: Reason's source types

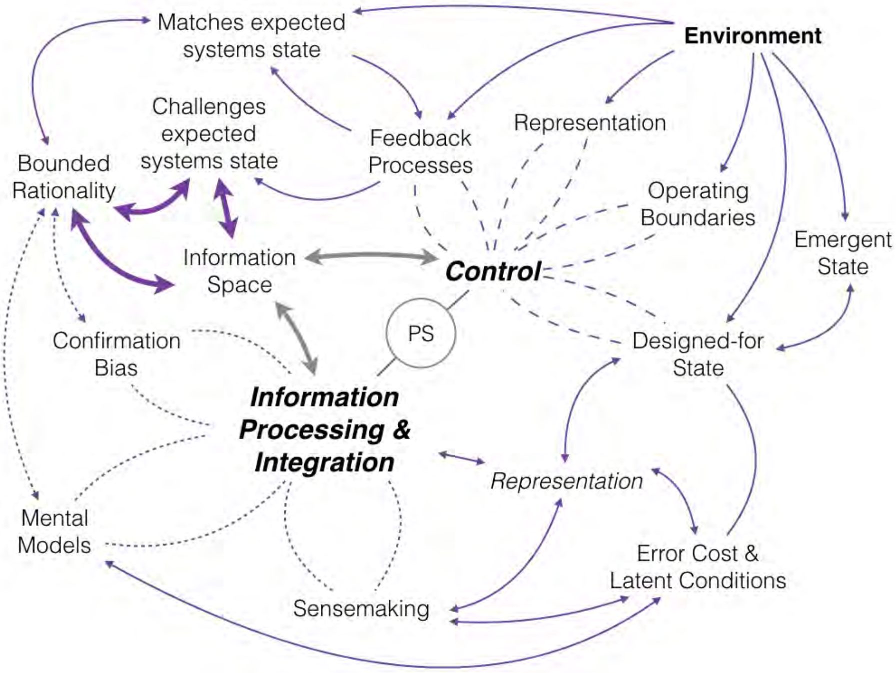


Adapted from Reason (1993) and Cherns (1976, 1987)

The challenge for healthcare organisations in terms of developing a near miss or early warning capability is in terms of ensuring that there is sufficient commitment to addressing the task demands associated with the implementation of such a system, awareness of the limitations associated with it, and the development of the capabilities and competencies needed to address the task demands that arise from it. It is only then that the organisation can hope to develop the core specification that is needed.

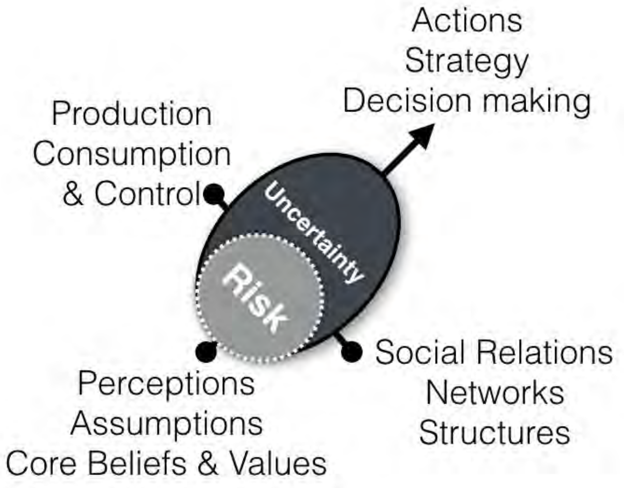
A central element of this process relates to the management of information flows around the near miss process. Figure 2 sets out some of the parameters of the relationships that exist between the control processes that sit at the core of patient safety and the information processing demands associated with an early warning provision. The environmental context within which patient safety is contextualised will, by definition, generate a set of operational conditions that will reflect both the designed-for systems state and its emergent nature. The key to an effective early warning process will necessitate the effective representation of the gap between these two systems states and the effective feedback to those who manage the system. This process feeds into the development of an accurate level of awareness associated with the performance of the patient safety sub-system. A central element of this relationship concerns the ways in which those actors within the system make sense of the critical gaps that exist within the different systems states and their associated processes. It is these elements of organisational performance that can be seen to shape the effectiveness of information gathering around early warnings.

Figure 15: elements of the information processing requirements



One issue that emerges from an assessment of the literature around emergence within organisational controls, relates to the importance of information flows as an element in the provision of control, especially within a context of multi-team/agency working (Fischbacher-Smith, 2015; Preece, Shaw, & Hayashi, 2013). The processes by which knowledge is managed has been seen as a critical issue within organisations, and in particular the ways in which weak signals are identified and acted upon (Seidl, 2004, 2007; Tsoukas, 2005). This is particularly problematic as the organisation moves away its designed for state to another (emergent) equilibrium state (Hodge & Coronado, 2007; Tsoukas, 1999). Figure 3 shows an adapted form of the processes that are set out by Tsoukas and Hodge and Coronado. Here the issues of risk and uncertainty are seen to be important drivers that shape decision-making processes around patient safety but uncertainty has a more significant role to play in the process than is normally acknowledged by managers. The perceptions and world-views held by managers about the nature of systems performance will be largely a function of their understanding of the designed-for state, whereas the emergent state will shift the balance from a risk-based approach towards one in which uncertainty plays a more significant role in the overall decision-making process. A potential mediating factor here is the ways in which information is collected about performance (through the production and consumption of health care services) and the adequacy or otherwise of controls. The success of attempts to collect data on early warnings and near-miss events will be a function of the performance of the networks, formal and informal social relations that exist for the transmission of information, and the governance structures that exist within the organisation.

Figure 16: Risk, uncertainty and the move away from the designed-for state



Adapted from information in (Hodge & Coronado, 2007; Tsoukas, 1999)

It is within the relationships that exist between the processes of production and control and the networks through which information is transmitted through a range of social networks and formal organisational structures and processes. A central element in the processes around early warnings concerns the relationships between the perceptions that managers have about the risks that they face and the decisions that are made as a consequence. Thus, the issue of early warnings sits at the core of the relationships set out in figure 3 and, in particular, the relationships between the operating core of the organisation and the networks and structures that facilitate communication.

DISCUSSION

> "*the mechanism driving people's behavioural choice is their perception of their danger, which stems directly from the near-miss influence on the hazard category in memory*" - Tinsley et al, p. 1609

One of the principal challenges around the collection of information around near miss and early warning data relates to the reluctance of staff to report errors. This issue was recognised in the UK's Department of Health (2000) report into patient safety and the example of the aviation industry's reporting system was used as a benchmark for considering what an effective system should look like. However, unlike aviation, healthcare is a more 'personal' system in which many of the interactions are between the clinical staff and the patient and so near miss events are often not observed or monitored. A key element in the rejection of information concerns the abilities of individuals to perceive the threat as real rather than theoretical. Tinsley et al (2012) argue that

> "near misses, have an undue influence on how people evaluate risk and can lead to questionable choices when people face an impending hazard with which they have had prior near-miss experience.…. this near-miss effect is robust because it seems to implicitly influence the thoughts people use as inputs to their decision making" - (Tinsley et al., 2012), p. 1597.

Thus, within the context of figure 3, the central spine of the process relates to the ways in which core beliefs, values and assumptions interact with risk and uncertainty and shape decision making in the process. For low-probability, high-consequence events for which there is no a priori experience, this is a double-edged problem. On the one hand, individuals may have no experience of a particular hazard and therefore either assume that it is unlikely to happen or they are not certain what the pre-cursors of the hazard are, if any. On the other hand, the consequences of the hazard may be potential so high that individuals at the sharp end of organisational activities do not think that their actions may have knock-on effects and may result in an escalation of the problem. Tinsley et al (2012) also differentiate between resilient and vulnerable near miss events. Where an organisation has experience of dealing with the task demands generated by an adverse event, it may lead to a false sense of capability around those problems. For vulnerable near miss events, the sense of harm ensures that there is sufficient information about the nature of the problem and the vulnerabilities that it generates.

Nashef (2003) outlines three types of near miss event and these are shown in figure 4. Type I events are characterised as those failures that occur and for which no harm is caused. The control systems that are in place to deal with any failure are adequate to deal with the task demands of the event, which are almost by definition within the normal parameters set for the activity. These events can, however, provide some insights into the failure modes and vulnerable pathways that exist within the system (Smith, 2005a) and, as such, provide important information on the nature and configuration of perturbations that could escalate into more serious failures (Smith, 2005b). Type II events are those where elements of the controls in place failed or operated in a degraded mode. These failures are akin to the holes in Reason's (1990b, 1993) Swiss Cheese model. Whilst no harm is caused by these failures, the fact that the controls do not work as designed should lead the organisation to reconsider its contingency plans and assess the viability of its controls. For type III failures, the controls also fail but on this occasion some harm is caused.

Figure 17: the nature of near miss events

Near Miss Events	Characteristics (assumes an adverse event)
Type I:	• Systems in place to detect and correct the failure work as planned • No harm caused
Type II:	• Some control (detection/mitigation) processes fail to operate as planned • control systems operate in a degraded mode • No harm caused
Type III:	• Some control (detection/mitigation) processes fail to operate as planned • Harm is caused but falls short of catastrophic failure

Source: Adapted from information in (Nashef, 2003)

For each of the three types, there is considerable potential for the organisation to learn. By framing these near miss types within the axis of core beliefs and assumptions and the processes around decision-making. Each of these new miss types will also challenge the relationships between the calculated risks (as known forms of event) and the uncertainty (as the known unknowns) within the threat matrix for the organisation. If we add to this to the impact that the perception of resilience has upon the response of organisations to particular threats, and the accounts that management provide of the significance of those near miss events (as counterfactuals), then the resultant matrix highlights the complex context in which near miss events are framed. The counterfactuals can take the form of denial, a reconstruction of an alternative narrative, or the maintenance of a paradigmatic view of the ways in which the system functions and operates which results in managers being 'blind' to the threats that exist (Fischbacher-Smith, 2012; Turner, 1976, 1994).

Figure 5 sets out these interconnected issues as a matrix in which the early warnings and near-miss events occur and are managed by organisations. The shifting boundaries between the three main elements will change the landscape in which the information needed to make early warnings effective will be distorted, constrained, or viable. The ways in which that information is codified will also be important in shaping the ways in which it is decoded and interpreted by those need to act upon it (Boisot, 1995, 1998; Boisot, MacMillan, & Han, 2007). These information-related challenges are significant within organisations – a lesson so vividly illustrated by the British Airways crisis in May 2017 (Fischbacher-Smith, 2017) – as they can serve to mask much of the information that is available around early-stage problems (Brookfield & Smith, 2007; Fischbacher-Smith & Fischbacher-Smith, 2014). Within organisational settings, there is inevitably a process through which information is filtered out within an organisation setting and does not reach those managers who are in a position to take corrective actions around near miss events (Fischbacher-Smith & Fischbacher-Smith, 2014; Fischbacher-Smith, Irwin, & Fischbacher-Smith, 2010). In some cases, this filtering of information is a function of the trust that exists within networks (and by definition the distrust that might exist around management) and the tendency for some issues to remain undisclosed as a function of the culture within the organisation or the profession (Costas & Grey, 2016)

Figure 18: The managerial space for near miss events

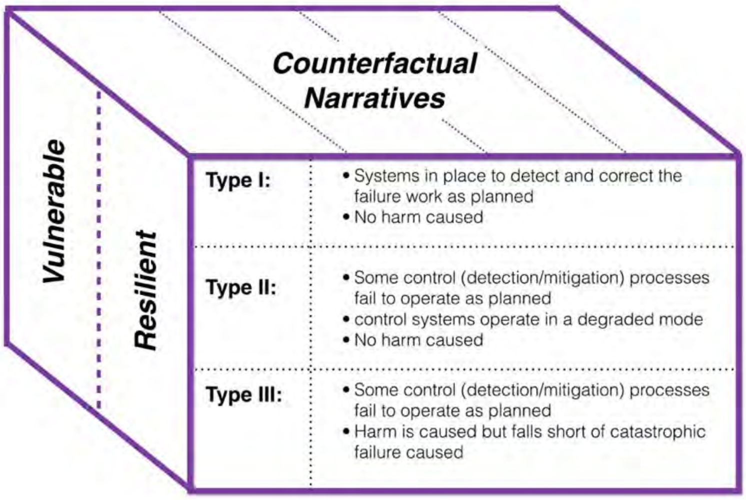
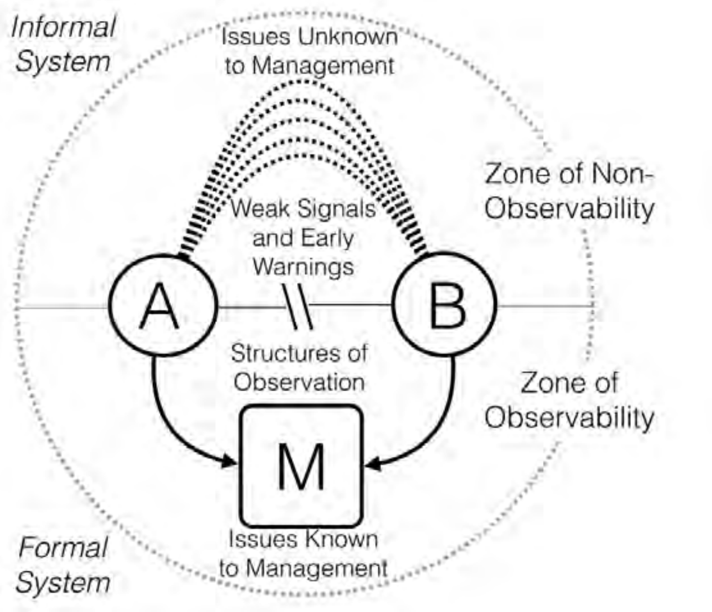


Figure 6 seeks to conceptualise the processes by which information fails to reach those managers who can take action on the issues. In essence, organisations only formally observe a relatively small amount of the transactions that take place within their boundaries. Therefore, if A and B are organisational members, then the managers (shown as M) will only be made aware of the information that flows to them via the various structures of observation (Seidl, 2004, 2007). As a consequence, the weak signals don't get identified as they often sit outside of these structures and are not captured by formal processes. So, whilst there are rumours and early warnings present within the information flows within the organisation, they are not captured and acted upon. In the aftermath of an adverse events, these 'warnings' are often surfaced.

Figure 19: the zones of observability and non-observability



There are, therefore, a number of structural barriers that exist within organisations and which mitigate the collection of data around near miss events and other sources of early warning about the potential for failure. If organisations are to address these issues, then there is a need to consider the barriers to information flows and the commitment and competences needed to ensure that weak signals and early warnings are both identified and acted upon.

CONCLUSION

> "Secrecy is endemic within work organizations. It is not an anomaly nor is it only found in unusual or special organizations, but rather it is woven into the fabric of all organizations in a multitude of ways" - (Costas & Grey, 2016), p.1.

This paper has set out a theoretical framework within which the processes around early warnings and near-miss events can be contextualised. The collection of data on early warnings and near misses in health care remains a key managerial challenge that relates to systems design and monitoring. Ergonomics and human factors research has a key role to play in this regard and practitioners need to have a robust theoretical framework on which to develop practice-based interventions.

This paper represents an attempt to frame the issues in relation to acute care and contextualises it within the wider body of work on socio-technical systems design. The paper is based upon a set of questions and theoretical challenges that emerged out of both observations in health care settings and the discussion of the main challenges with practicing managers and other health care professionals.

It could be argued that most organisations are structured in such a way that information flows within them are constrained by design. This, combined with the cultural constraints that often exist around admitting mistakes, will ensure that the problems around near miss detection will remain challenging for managers and other organisational members alike. One possible solution is to take a more holistic approach to dealing with the issues and adopt a systems ergonomics perspective on the challenges. However, further research is needed to verify the frameworks set out in this paper before they can be used to improve the reporting processes.

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DEVELOPMENT OF A FRAMEWORK FOR THE ANALYSIS OF WEAK SIGNALS WITHIN A HEALTHCARE ENVIRONMENT

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KEYWORDS
Weak signals, Healthcare, Patient Safety, Safety-II

SUMMATIVE STATEMENT
Weak signals provide an opportunity for pro-activeness that can assist in improving safety. Through a review of literature and evaluated with three different case studies, this study proposed a framework for the analysis of weak signals in the healthcare environment.

Élaboration d'un cadre de travail pour analyser les signaux de faiblesse dans un établissement de santé

MOTS-CLÉS
Signaux de faiblesse, soins de santé, sécurité des patients, sécurité II

SUMMATIVE STATEMENT
Les signaux de faiblesse offrent une occasion de démarche proactive pour améliorer la sécurité. Au terme d'un examen de la littérature et d'une analyse de trois études de cas, la présente étude propose un cadre pour analyser les signaux de faiblesse dans les milieux de la santé.

INTRODUCTION

Due to the complexity of the system (Carayon & Friesdorf, 2006) and dual nature of safety in healthcare research, both the staff's and the patients', this field will benefit from adopting not only the traditional definition of safety, whereby the number of adverse events are as low as possible but also the more recently developed definition of Safety-II, whereby the ability to succeed under varying conditions is promoted (Hollnagel, 2014). To adjust performance to ensure success of the task anticipating, identifying and responding to signals indicating changes in the system is required (Hollnagel, 2014). Signals are sensed information regarding emerging events (Ansoff & Mcdonnell, 1990), and include indicators or cues from the environment (Rasmussen, 1983) which require interpretation and sense-making (Weick, 1995). The strength of these signals can vary resulting in different requirements regarding interpretation and abilities of sense-making. Often these signals are weak and resultantly vague in nature (Ansoff & Mcdonnell, 1990). They need to be actively sought out and created by processing interrelated existing events, prior knowledge and future expectations in order to understand the information they provide (Macrae, 2014a).

Weak signals may provide an opportunity to achieve pro-activeness and promote effective risk management, in that through the continuous identification and addressing of problems that threaten safety (Macrae, 2014b) unexpected events may be addressed in a more cost-effective and timely manner (Vogus & Sutcliffe, 2007). Despite accident reports increasingly stating signals which indicate missed opportunities were present prior to adverse events, research exploring weak signals and the role they may play in safety, especially in healthcare, is limited. The aim of this research was to develop a conceptual framework for the investigation of weak signals in the healthcare environment and to explore the framework elements in three different healthcare case studies using qualitative methods.

METHODOLOGY

Through a review of literature on weak signals from the field of human factors, strategic management theory, systems ergonomics, natural decision making theory as well as literature on safety, a list of possible theories and models was compiled and a preliminary framework was developed. The framework aimed to provide a structure for identifying sources of signals, an understanding of how signals are manifested in the work environment and a process for the classification of these signals.

An explorative qualitative method was adopted to investigate aspects relating to weak signals within the healthcare environment due to the fuzzy nature of weak signals. Three different case studies in healthcare were used to test and evaluate the framework. The three case studies included cases from patient handling, patient discharge from acute care to community-based care and the treatment of sepsis. The patient handling case study consisted of 2 focus groups, the patient discharge case study consisted of 348 incident reports, 1 ombudsman report, and data collected from 9 focus groups, and the sepsis case study consisted of 2 ombudsman reports and 99 survivor and tribute stories.

The same focus group method was applied for the patient handling and patient discharge case studies. The focus groups consisted of a 45-minute session and focused on investigating the signals present when tasks go wrong and how task failure could be prevented. The questions used to guide the discussion in the focus groups were developed based on the literature on Safety-II (Hollnagel, 2014). Examples of the questions asked included: “What could go wrong with this task?”, “How do you know the task is going wrong?”, and “When you know it is going wrong, how do you correct yourself?”. The discussions of the focus groups were recorded using two audio recorders and one researcher recording field notes. The focus groups were transcribed and together with the field notes, Ombudsman reports, survivor and tribute stories, and the incident reports, were analysed using thematic analysis using QSR International’s NVivo 10 qualitative data analysis software.

Sample Characteristics

For the patient handling case study, 2 focus groups with a total of 17 participants were conducted. The mean age of the participants was 50.29 years (±8.64). The mean total number of years involved in patient care across the focus groups was 28.00 years (±10.59). The current positions held by the participants included manual handling advisors, back care advisors or managers, manual handling area leads, one head of manual handling and one director manual handling consultant.

The data sources for the patient discharge case study consisted of 9 focus groups with a total of 53 participants, one Ombudsman report and 348 incident reports. The mean age of the participants in the focus groups was 40.89 years (±10.23). The mean total number of years involved in patient care across all nine focus groups was 15.50 years (±10.75). The current positions held by the participants in the focus groups included community, district and acute staff nurses, locality managers, physiotherapists and occupational therapists, discharge coordinators, ward managers, a hospital consultant and a team leader of a care home team. The report analysed was titled “A report of investigations into unsafe discharge from hospital” (2016) and included nine cases which illustrate problems with the discharge process. The incident reports analysed included all “Third Party Incidents” reported by adult integrated teams across three directorates in Nottinghamshire (UK) for the financial years 2014 – 2015 and 2015 – 2016.

The sepsis case study consisted of 99 survivor and tribute stories from the sepsis UK trust website and two Parliamentary and Health Service Ombudsman Reports. The 99 stories from the sepsis trust website analysed consisted of 55 survivor stories and 44 tribute stories. The reports analysed included the report “Time to act. Severe sepsis: Rapid diagnosis and treatment saves lives” (2013) and the report “An avoidable death of a three-year-old child from sepsis” (2014) which focused on one case. The “Time to Act” report was a clinical report that focused on ten cases in which the patients died of sepsis. The stories and reports analysed included cases that cover a wide age range from new-born babies to 90 years of age.

RESULTS

Framework

The preliminary framework drew upon research from numerous fields, including strategic management theory (Ansoff & Mcdonnell, 1990), systems ergonomics (Holden et al., 2013; Karsh et al., 2006), and the work on weak signals by Macrae (2014a), as well as the work on error by Reason (1991).The aim of the framework was to provide a structure for the analysis of weak signals in the context of the work, actions and events in the system in which they occur specific for the healthcare context and is depicted in Figure 1.

The work by Ansoff (1975) on weak signals in strategic management theory and the work by Macrae (2014a) on weak signals in aviation were used to provide the basic definition and premise for the conceptual framework. The left aspect of the framework included elements from the second version of the Systems Engineering Initiative for Patient Safety (SEIPS) model (Holden et al., 2013). The SEIPS 2.0 model was selected as it provides a framework for the analysis of processes and the relationship of various elements that occur in healthcare specifically (Carayon et al., 2006) and was selected to provide a structure for the identification of the sources of the signals. Furthermore, this model was selected as it provides a general multi-level model of a work system.

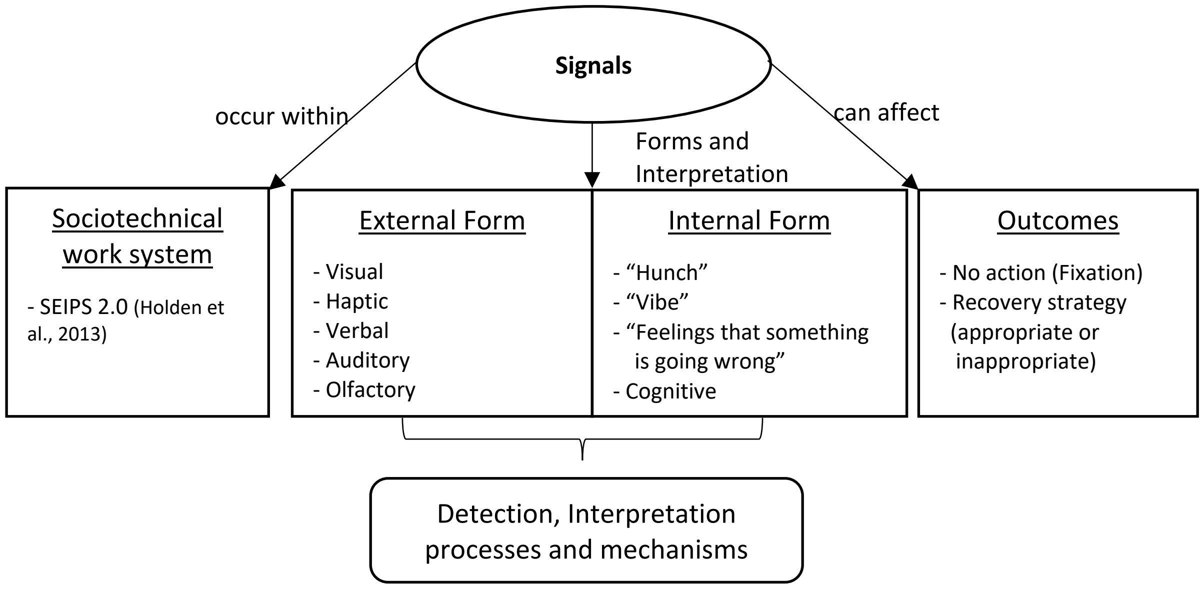

Figure 1: A conceptual framework for the investigation of weak signals within the healthcare context.

The forms of the signals have been described in the framework as either being internal or external. An external signal may also generate an internal signal, but the external source or signal that causes the experience of an internal signal may not always be present or known. The external signals include visual, haptic, verbal, auditory or olfactory cues. The internal signals include the experience of a “hunch”, “vibe” or a general sense of “something going wrong”. Signals can affect outcomes in that, as a result of fixation (Reason, 1991), no action may be taken or alternatively a recovery strategy is implemented which may either result in an appropriate or inappropriate outcome. By considering the source and type of information these signals provide, insight regarding the status of the system and areas of risk may be revealed (Macrae, 2014a).

Signals were identified in the three case studies and were grouped according to the elements in the sociotechnical work system, as described in the SEIPS 2.0 model, from which they originated, the forms, either internal or external, and interpretation of the signals as well as the outcomes or actions that resulted due to these signals.

Case Study 1 – Patient Handling
From the two focus groups conducted with experts in patient handling, the signals that assisted in detecting that an error may occur were identified as originating from the work system elements of the “person(s)” and “tasks”. Examples of signals originating from “person(s)” included trained memory cues, individual checks, the patient’s physical state and feedback from the patient. Examples of signals originating from “task” in the system included heightened awareness due to an unfamiliar aspect or element of the task.

The forms or manifestations of the signals included either external (from the environment) or internal forms. The signals identified as internal consisted of trained memory cues, for example a rhyme to ensure all safety aspects of the task were completed, individual checks such as those developed through personal experience, being less task orientated and more situation aware, and questioning actions. The signals identified as external consisted of visual or sensory signals such as seeing or feeling that the brakes on the bed were not activated prior to the patient being transferred and feedback from the patient. In addition to these, participants also mentioned different sensory signals as well as feelings that could not be describe in more detail other than the experience of intuition. These forms included heightened awareness due to an unfamiliar aspect or element of the task, as well as visual or sensory signals.

Case Study 2 – Patient Discharge
The sources of the signals identified in the patient discharge case study included the following elements from the work system: “person(s)”, “tasks”, and “internal environment”. Examples of signals originating from “person(s)” in the system included the patient’s physical state and feedback from the patient and their family. Furthermore, the experience of the interaction with the patient’s family was also identified as a source. Examples of this included if the family was continuously contacting health services for support, as well as the behaviour of the families such as becoming intense or disengaged during interactions with community staff. Examples of signals originating from “tasks” included information contained in the patient documentation and key aspects of the patient history, for example the history regarding readmissions. Signals originating from the “internal environment” included the state of the patient’s home, which may indicate that the patient is not coping following the discharge from acute care.

The external forms of the signals included sensory signals such as visual, auditory and olfactory cues. Visual cues included the patient not looking well, auditory cues included feedback from the patient and their family, and olfactory cues that provided an indication that possibly the patient was not coping with tasks related to activities of daily living. The internal forms of signals included cognitive signals, for example, awareness of a patient's history and current health status. An additional cognitive signal included a mismatch between the patient's expected state and their actual state. Similarly, to the patient handling case study, the signal generated by an unfamiliar aspect or element of the task that results in heightened awareness was also found in this case study.

Specifically, from the results of the focus groups, participants felt that the identification of these signals is a necessary component of their current work as they felt their work requires them to adapt the patient's treatment plan accordingly so that a readmission would not occur. The outcomes, as a result of identifying signals described in most of the cases analysed in this case study, included action in order to prevent the patient being readmitted to acute care.

Case Study 3 – Sepsis
The work system elements of the SEIPS 2.0 model identified as being sources for signals in this case study included "person(s)", "tool" and "task" elements. The person-related source identified included signals originating from the patient. The signals originating from the patient included the physiological indicators of sepsis (e.g. fever, vomiting, fast and shallow respiratory rate, elevated heart rate, rash, pain), behaviour-related (e.g. unusual response to illness) as well as unusual general behaviour (e.g. agitation, loss of appetite, not their "usual" self). Additional patient-related signals identified included patient history (e.g. immunosuppressed), and a change in the patient's condition or rapid unexpected deterioration the patients' health. Tool and task elements that were a source of signals relating to sepsis included the paediatric early warning score and the blood tests that may indicate sepsis even if the patient appears more health than they are.

The interpretation of these signals manifested themselves as "hunches" or "feeling something was wrong" to different persons in the system, these included the patient themselves, family members of the patients suffering from sepsis and the staff members treating them. In some cases, the patient identified and interpreted these signals and these would have been most likely in the form of a cognitive cues, in that the symptoms and severity experienced were unusual and not fitting the expected preliminary suspected diagnosis. In the majority of cases, the family identified and interpreted these signals. These included external forms such as visual cues (e.g. patient looked very unwell) and internal forms such as cognitive indicators. An example of cognitive indicators included identifying that the patient's behaviour was very different and unique to other instances where they had been ill and possible registering the subtle indicators such a change in the patient's awareness, mental state (e.g. slurring words) and consciousness. An additional example of the family interpreting signals included questioning the diagnosis when made by medical staff as they felt that the patient's symptoms and behaviours did not align with the proposed diagnosis. In the examples of signals identified by staff, sepsis was not always immediately recognized but the seriousness of the situation was, which resulted in prompting action.

The outcomes initiated, as a result of identified signals, included the signals being rationalised away, the signals being misinterpreted so no action was taken, and seeking medical assistance. In many of the examples analysed the physiological signs and indicators of sepsis were attributed to other potential causes and rationalised away, for example "I am sure it is just flu, since it is flu season".

DISCUSSION AND CONCLUSION
Weak signals may aid in rendering a system more resilient by improving the ability to succeed under varying conditions (Hollnagel, 2014) as they provide insight regarding the status of the system and areas of risk (Macrae, 2014a). As a result, weak signals may also provide a means for effective risk management (Macrae, 2014a). By identifying where these

signals originate from and understanding how weak signals are identified and interpreted, possible changes to work structure and management could be developed to encourage signal identification for promoting patient safety. By identifying and interpreting signals as they arise, one may be able to detect unexpected or negative events earlier, which then could be addressed in a more timely manner. In healthcare, this could result in significant benefits particularly with regards to patient health.

The proposed framework provided a structure for the investigation and understanding of how weak signals are experienced within the healthcare environment. In all three case studies, sources were identified where these signals may originate from. The more systems spanned in the case studies, the more elements of the work system produced signals. Examples of the forms of signals as well as the types of outcomes that occur once signals have been identified were identified and collated across the three case studies.

Though the framework provided a structure for the investigation of weak signals, it is currently undergoing further evaluation and expansion to include theories and models that best assist in understanding how weak signals within the healthcare environment are identified and interpreted. Possible theories that will be evaluated in relation to weak signal identification and interpretation include the signal detection theory (Green and Swets, 1966), the concepts of situation awareness (Endsley, 1995), sensemaking (Weick, 1995), naturalistic decision making (Zsambok & Klein, 1997), emotional attunement (Benner, Tanner, & Chesla, 1996) and the skill-rule-knowledge model of behaviour (Rasmussen, 1983).

The proposed framework provides a preliminary basis for the investigation of signals and may assist in the development of a possible tool and means to incorporate signals in promoting patient safety and task success. Further investigations are required to identify additional elements that aid in task success as well as the factors that promote or inhibit signal identification.

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USING A PARTICIPATORY ERGONOMICS APPROACH TO IMPROVE PATIENT ROOM CLEANING AND PREVENT HEALTHCARE-ASSOCIATED INFECTIONS

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KEYWORDS
Participatory ergonomics, patient room cleaning, hospital-associated infections, environmental care associates, process redesign

SUMMATIVE STATEMENT
To improve daily patient room cleaning and prevent healthcare-associated infections, we apply a participatory ergonomics approach to redesign the cleaning process and associated work system. We collaborate with environmental care (EVC) associates, supervisors, and managers, as well as other stakeholders (e.g., nurses), and applied human factors principles and tools to facilitate the participatory ergonomics process.

Utilisation d’une démarche d’ergonomie participative afin d’améliorer les pratiques de nettoyage dans les chambres des patients et de prévenir les infections nosocomiales

MOTS-CLÉS
Ergonomie participative, nettoyage des chambres de patients, infections nosocomiales, préposés à l'entretien ménager, révision des processus

SOMMAIRE
Afin d’améliorer le nettoyage quotidien des chambres de patients et de prévenir les infections nosocomiales, nous avons appliqué une démarche d’ergonomie participative pour revoir les méthodes de nettoyage et le système de travail connexe. Nous avons collaboré avec des préposés, des superviseurs et des gestionnaires à l’entretien ménager ainsi qu'avec d'autres intervenants (p. ex., des infirmières), et avons appliqué les principes et les outils ergonomiques pour faciliter le processus d'ergonomie participative.

PROBLEM STATEMENT

Participatory ergonomics is a macroergonomic approach to work system design emphasizing the active participation of people in "planning and controlling a significant amount of their own work activities, with sufficient knowledge and power to influence both processes and outcomes in order to achieve desirable goals" (Wilson, Haines, and Morris 2005). An increasing number of studies have applied participatory ergnomics in healthcare (Bohr, Evanoff, & Wolf, 1997; Evanoff, Bohr, & Wolf, 1999; Fragala & Santamaria, 1997; Jun, et al., 2017; Udo, et al., 2006; Xie, Carayon, Cox, et al., 2015). While most of these studies were focused on clinicians (e.g., physicians, nurses) and patients and families, few participatory ergonomics studies have been conducted with other healthcare workers who are usually placed in a subsidiary position. This paper describes an ongoing participatory ergonomics study, in which we collaborate with environmental care (EVC) associates and other healthcare stakeholders to redesign the daily patient room cleaning process.

Patient room cleaning plays an important role in preventing pathogen transmission in the hospital and reducing healthcare-associated infections (Carling, 2016; Drees, et al., 2008). Driven by EVC management, efforts to improve patient room cleaning have been focused on monitoring cleaning performance and providing feedback and training to EVC associates (Han et al., 2015). While the effectiveness of these efforts has been documented (Carling, et al., 2010; Munoz-Price, et al., 2011), researchers argued that to develop effective and sustainable interventions for improving patient room cleaning, we need to understand the complex patient room cleaning process and associated work system from the perspectives of EVC associates and other stakeholders and actively involve them in intervention development and implementation to secure buy-in (Rock, et al., 2016). In this paper, we describe a participatory ergonomics process, in which EVC associates and other stakeholders are involved in the development and implementation of a system-based intervention for improving daily patient room cleaning. Challenges to involving EVC associates in the participatory ergonomcis process are discussed.

METHODOLOGY

This study is conducted at a large urban teaching hospital in the Northeastern US. The participatory ergonomics process includes three phases: (1) assessment of the cleaning process, (2) intervention development, and (3) intervention implementation. A trans-disciplinary study team consisting of infectious disease specialist, infection preventionist, and human factors engineers has been convened to facilitate the participatory ergonomcis process. Frontline EVC associates and EVC supervisors and managers participate in the participatory ergonomics process through "direct representative participation" (Haines et al., 2002). Other stakeholders, such as nurses, hospital facilities, and union, are kept informed through the participatory ergonomics process. We use the systems engineering initiative for patient safety model (Carayon et al., 2006) and the model of multi-stakeholder collaboration in healthcare system redesign (Xie, Carayon, Cartmill, et al., 2015) to guide the participatory ergonomcis process.

RESULTS

Assessment of the Cleaning Process

To assess the daily patient room cleaning process, we observed 10 EVC associates cleaning 89 patient rooms. The observation data showed that a number of high touch surfaces (e.g., bedrails, patient chair, family and visitor chairs, callbox, cabinet) were frequently missed during daily cleaning (Rock, et al., 2016). In addition, we conducted semi-structured interviews with 12 EVC associates to examine work system factors influencing daily cleaning. Interview data indicated that daily patient room cleaning could be influenced by various work system factors, including people (e.g., knowledge, skills, experience, and physical limitations of EVC associates), tasks (e.g., tasks of EVC associates and other healthcare workers), teamwork (e.g., mutual help between EVC associates, responsibility of other healthcare workers), tools and technologies (e.g., availability, usability, and usefulness of cleaning tools and supplies), physical environment (e.g., patient room layout, environment occupied by patients, families, and other healthcare workers), and organization (e.g., staffing levels, safety culture, leadership) (Xie, et al., 2017).

Based on the observation and interview data, we identified 11 areas for improvement, including four areas related to the cleaning process (i.e., EVC morning huddle, cart preparation, patient room cleaning, common areas cleaning) and seven areas related to the work system (i.e., safety culture, teamwork among EVC associates, teamwork between EVC associates and nurses, EVC leadership, EVC checklist and documentation system, training, performance evaluation).

Intervention Development

We are currently in the phase of intervention development and have conducted six one-hour focus groups with EVC associates, supervisors, and managers to prioritize areas for improvement, brainstorm ideas for intervention, and discuss details of each intervention idea (Table 1). Four areas for improvement that were selected to focus on were (1) cart preparation (process), (2) safety culture (work system), (3) teamwork between EVC associates and nurses (work system), and (4) EVC leadership (work system). Five EVC associates who actively participated in the focus groups volunteered to work with the study team and facilitate the development of the intervention: two focusing on cart preparation, two focusing on safety culture and teamwork between EVC associates and nurses, and one focusing on EVC leadership. A number of intervention ideas have been created and discussed for each of the prioritized areas.

Table 1 Summary of focus groups

Timeline	Participants	Objectives
Focus group 1 (Feb. 16, 2017)	- 4 EVC associates - 4 study team members	- Introduce the study to EVC associates - Review of observation and interview data - Discuss and prioritize areas for improvement
Focus group 2 (Mar. 2, 2017)	- 7 EVC associates - 4 study team members	- Review prioritized areas for improvement - Brainstorm intervention ideas
Focus group 3 (Mar. 16, 2017)	- 5 EVC associates - 5 study team members	- Review and finalize intervention ideas
Focus group 4 (Apr. 6, 2017)	- 4 EVC associates - 2 EVC managers - 5 study team members	- Communicate challenges of EVC work with EVC management - Discuss feasibility of intervention ideas
Focus group 5 (Apr. 12, 2017)	- 2 EVC managers - 3 EVC supervisors - 3 study team members	- Discuss detailed design of the intervention
Focus group 6 (May 11, 2017)	- 4 EVC associates - 1 EVC managers - 2 EVC supervisors - 5 study team members	- Discuss and finalize the design of the intervention

<u>Cart preparation</u>

One of the main challenges that EVC associates encountered was cart preparation. At the beginning of their shift, EVC associates spent a great amount of their time locating carts and preparing cleaning tools and supplies. To improve the cart preparation process, a number of intervention ideas were proposed to address different work system elements:

- Tools and technology
    - o Purchasing additional carts to ensure every unit/shift has its own cart

    - Labeling carts for each unit/shift
    - Installing global positioning system on carts for tracking
- Environment
    - Having a designated area in the basement for cart storage
    - Matching floor marking and wall signs with labels on carts
    - Installing wall cameras to monitor cart storage area
- Organization
    - Recruiting a night shift inventory clerk to prepare carts for EVC associates
- Tasks
    - Inventory clerk handing off prepared carts to first shift EVC supervisor
    - EVC associates getting carts from the designated area at the beginning of the shift and returning carts to the designated area at the end of the shift
    - EVC supervisors ensuring EVC associates returning carts to the designated area at the end of the shift and handing off carts to the next shift
    - Supervisors rounding on units and monitoring the use of carts

Safety culture and teamwork between EVC associates and nurses

Two related areas that were prioritized for improvement were safety culture and teamwork between EVC associates and nurses. EVC associates expressed the feeling of being excluded from the healthcare team (e.g., not being invited to attend unit events) and not being respected by nurses and other healthcare workers (e.g., not being allowed to use the workroom). To improve the unit safety culture and teamwork between EVC associates and nurses, a multi-level communication structure between EVC and nursing was proposed. According to this structure, EVC associates communicate ongoing or major issues (e.g., dispute with other healthcare workers) with the nurse manager of the unit and immediate or minor issues (e.g., access to supplies) with the charge nurse of the day. A new role, i.e., nurse champion, will be introduced on each unit to engage EVC associates in, for example, nursing huddles and unit events (e.g., birthday party, potluck). In addition, EVC associates are expected to be involved in the comprehensive unit-based safety program (CUSP) team of each unit, an infrastructure developed to facilitate the collaboration of all healthcare team members in addressing safety issues on a unit (Pronovost, et al., 2005). We have communicated these intervention ideas with both nurse managers and bedside nurses to secure their buy-in. Nurse champions have been identified on some units.

EVC leadership

The last area that was prioritized for improvement was EVC leadership. EVC associates indicated that they had limited face-to-face communication with their supervisor, that their supervisors did not understand their work and challenges very well, and that they did not receive strong support from their supervisor. One of the proposed intervention ideas for improving EVC leadership was to have EVC supervisors shadow EVC associates using the Shadowing Another Provider tool (Thompson, et al., 2008), which is a structured tool developed to help healthcare providers identify teamwork, communication, and collaboration issues affecting the quality and safety of care from the perspective of other professional disciplines. In addition, during the participatory ergonomics process, two joint focus groups were held for EVC associates, supervisors, and managers to share their opinions (Table 1). It was proposed to routinize this process and have regular meetings between EVC associates and their supervisors and managers to continuously address challenges faced by EVC associates.

Intervention Implementation

Additional focus groups have been scheduled with EVC associates and managers to finalize the intervention package and develop an implementation plan. The implementation plan will be guided by human factors implementation principles (e.g., top management commitment, stakeholder participation, communication and feedback, learning and training, project management) (Carayon, et al., 2012; Karsh, 2004). The intervention package will be pilot tested on the participating units. A one-minute video will be developed to introduce EVC associates to the intervention ideas addressing each prioritized area. The five EVC associates who volunteered to facilitate the development of the intervention have also agreed to serve as liaisons and communicate the intervention implementation plan with their colleagues. We will continuously collect feedback from EVC associates and other stakeholders to strengthen the intervention package and its implementation.

DISCUSSION AND CONCLUSION

In this study, we apply a participatory ergonomics approach to improve the daily patient room cleaning process. EVC associates, supervisor, and managers, as well as other stakeholders (e.g., nurses), are involved in the participatory ergonomics process. A number of intervention ideas have been created. Previous studies have documented challenges to the application of participatory ergonomcis in healthcare (Bohr, Evanoff, & Wolf, 1997; Xie, Carayon, Cox, et al., 2015). Given the literacy level and workload of EVC associates, as well as the power distance between EVC associates and other healthcare workers, our study faces unique challenges.

First, as compared to other healthcare workers, EVC associates are more conservative about participating in research activities, such as observations, interviews, and focus groups. Many EVC associates worried about their data being shared with their supervisors and managers. To address this concern, we used different strategies (e.g., attending EVC huddles, distributing posters and handouts, inviting EVC associates to participate in study team meetings) to communicate study objectives and procedures with EVC associates. We also scheduled separate focus groups with EVC associates and EVC supervisors and managers to encourage open discussion. After a few focus groups, EVC associates became more familiar with the process and expressed the willingness to communicate and share their opinions with therefore supervisors and managers. Follow-up focus groups then were scheduled jointly with EVC associates, supervisors, and managers.

Second, because of EVC work schedule, interviews and focus groups had to be conducted during their lunch break. Compared to interviews, conducting multiple one-hour focus groups over a four-month period (intervention development) was challenging. Consistent attendance of EVC associates was critical to cutting the “setup” time spent on introduction and recap and saving time for discussion. Four EVC associates were able to attend all focus groups. In addition, we prepared each focus group by confirming the time and location with participants and setting up the conference room beforehand and providing lunch for participants at the focus group.

Last but not least, to fully engage EVC associates in the participatory ergonomics process, we needed to consider the literacy level of EVC associates and use lay language in all materials shared with EVC associates (e.g., consent form, presentation slides).

This study is conducted at a single academic hospital, which limits the generalizability of the results to other settings. More empirical studies are needed to illustrate the application of participatory ergonomics to healthcare system work system and process redesign.

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Technical Session 9: Healthcare And Macroergonomics

Séance technique 9: Soins de santé et macroergonomie

HOW DO CALL CHARACTERISTICS AND PARAMEDICS' PERCEPTIONS OF PHYSICALLY DEMANDING TASKS CHANGE AFTER IMPLEMENTING POWERED STRETCHERS?

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KEYWORDS
Powered stretchers, paramedics, physical demands, musculoskeletal disorder, intervention

SUMMATIVE STATEMENT
A participatory approach was used to gather physical demands description data and to record paramedics' perceptions of physically demanding task within each call before and after implementing the Stryker Power-Pro XT™ with Power-Load™ system within the services. Although the powered stretcher takes longer to use than a manual stretcher, call characteristics (e.g., time-on-scene) were unchanged. Stretcher related physical demands and the perception of those demands were greatly reduced following implementation, where paramedics' now perceive patient handling (e.g., lateral transfer) and carrying equipment bags as the most physically demanding.

Caractéristiques liées aux appels et perceptions des ambulanciers par rapport aux tâches physiquement exigeantes : les changements constatés après la mise en place de civières motorisées

MOTS CLÉS
Civières motorisées, ambulanciers, exigences physiques, trouble musculosquelettique, intervention

SOMMAIRE
Une approche participative a été utilisée pour recueillir des données sur la description des exigences physiques et pour enregistrer les perceptions des ambulanciers liées aux tâches physiquement exigeantes au cours de chaque appel avant et après la mise en place des civières Stryker Power-Pro XT™, dotées du système Power-Load ™, dans les services. Même si la civière motorisée prend plus de temps à manipuler qu'une civière manuelle, les caractéristiques d'appel (p. ex., le temps pour arriver sur les lieux) sont restées les mêmes. Toutefois, les exigences physiques liées à la civière et à la perception de ces exigences ont considérablement diminué après la mise en œuvre des nouvelles civières de sorte que les ambulanciers perçoivent maintenant la manipulation des patients (p. ex., le transfert latéral) et le transport de sacs d'équipement comme étant les tâches les plus exigeantes sur le plan physique.

PROBLEM STATEMENT
Paramedics are exposed to musculoskeletal disorder (MSD) hazards when performing lifting, carrying, pushing and pulling tasks while providing pre-hospital patient care. Exposure to MSD hazards increases the risk of developing an MSD. This includes high forces, poor

postures and the repetition of stretcher handling tasks. Presently, MSDs are the number one type of lost-time injury reported to the Workplace Safety and Insurance Board (WSIB) in Ontario, where the paramedic sector has traditionally reported more MSDs than any other work sector (Wells, 2015). Powered stretcher and load systems are beginning to emerge as a control to mitigate stretcher-handling related exposures, but we know little about how they might influence the normal work of paramedics.

RESEARCH OBJECTIVE/QUESTION

To determine if the implementation of the Stryker Power-Pro XT™ with Power-Load™ system altered call response characteristics, physical demands exposures or paramedics' perception of physical demands relative to when using a manual stretcher.

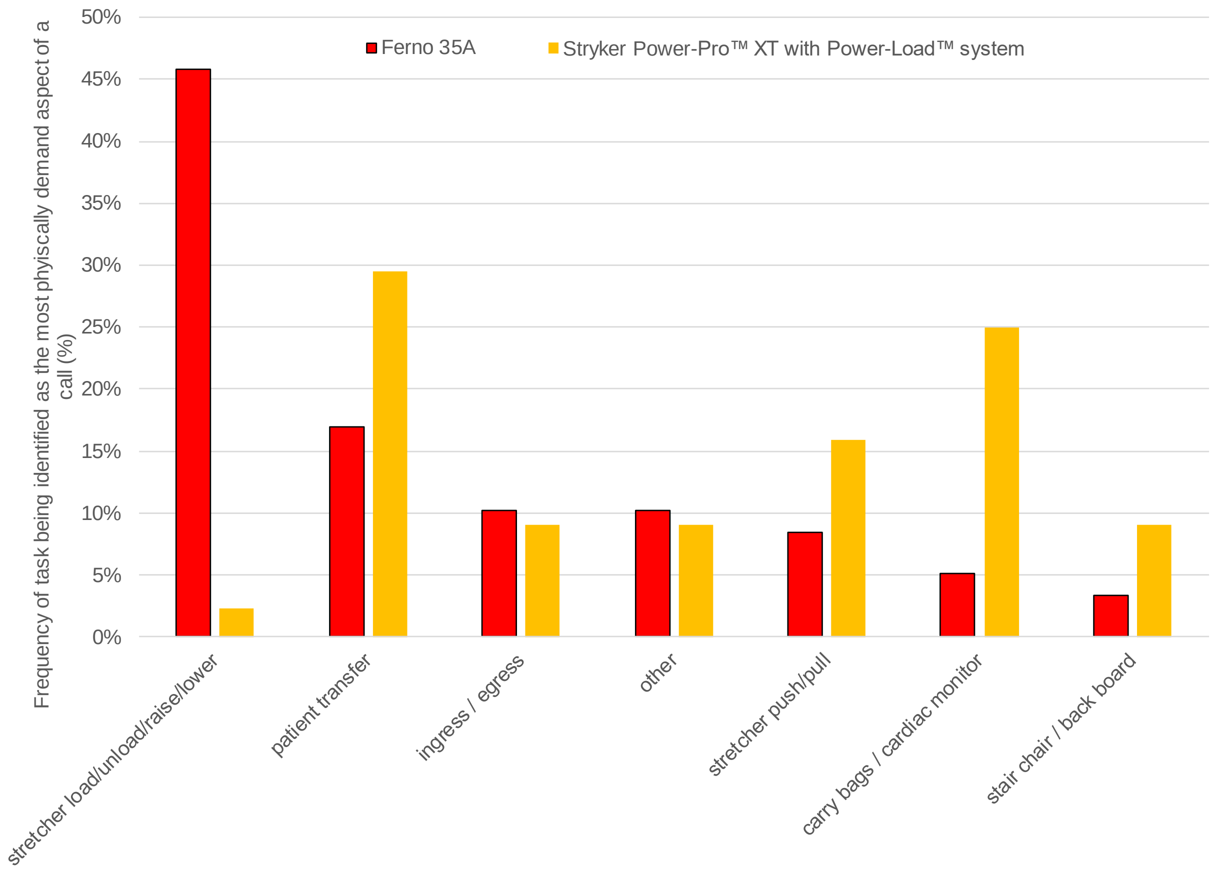
METHODOLOGY

A direct observation-based task analysis approach was used to assess the physical demand exposures and perceptions of physical demands after implementation of the Stryker Power-Pro XT™ with Power-Load™ system (Power). Six paramedics were trained to identify physical demands and quantify relevant aspects of each demand during a Physical Demands Description (PDD) workshop. Following the training, observers gathered PDD data from 38 full 12-hour shift calls. This included 70 calls where the Ferno 35A manual stretcher (Manual) was used and 55 calls where the Powered system was used. During each call, observations were focused on the non-attending paramedic; the paramedic more likely to be handling equipment. A standardized recording booklet was provided to the observers to record details about specific physical demand elements including: stretcher handling, patient handling, patient assessment, equipment handling, etc. As well, observers were required to document quantifiable measures associated with each physical demand element (i.e., distance travelled while carrying equipment) and call information (time of call, patient demographics, etc.). Paramedics also indicated their overall perceived ratings of clinical, physical and emotional demand associated with the call using a 0-10 visual analog scale.

Data from each booklet was transcribed and descriptive statistics were computed. Statistical tests were applied to detect for differences in dependent variables pertaining to call response characteristics, physical demands and perception of physical demands.

RESULTS

Call characteristics did not differ between the Manual and Power. The exposure associated with stretcher handling did change, where the total weight handled decreased by 800kg per shift when using Power. Paramedic's perception of physically demanding tasks also changed where stretcher handling tasks were identified as the most demanding aspect of a call (46% of the time) when using Manual, whereas, patient transfer tasks (29% of the time) and equipment handling (25%



of the time) were identified as the most physically demanding when using Power (Figure 1).

Figure 20. The frequency (expressed as a percentage) for which tasks were identified as the most physically demanding when using the Ferno 35A (red bars) and Stryker Power-Pro™ XT with Power-Load™ system (yellow bars).

DISCUSSION

This study evaluated how call responses characteristics, physical demand exposures and paramedics' perception of physical demands may be affected by the implementation of a powered stretcher intervention. Powered stretchers with load systems reduce the high force exposure associated with lifting/lowering and loading/unloading of the stretcher. While biomechanical (Sommerich et al., 2015) and epidemiological (Armstrong et al., 2017; Fredericks, Butt, & Hovenkamp, 2009; Studnek, Crawford, & Fernandez, 2012) evidence supports the effectiveness of powered stretchers as an engineering control to reduce MSDs, we still do not understand potential long term consequences of the intervention. Data from this study revealed potential future areas for MSD concerns associated with the implementation of powered stretchers including: physical capabilities, patient transfers and equipment handling.

Adopting a powered stretcher with a load system reduced the high force exposure associated with MSD hazards during stretcher handling tasks; however, this reduction in mass lifted could result in a “de-training” effect, posing a risk to paramedics’ ability to perform non-stretcher-related physically demanding tasks.

While the benefit of reduced exposure far outweighs the threat of de-training, services should consider supplementing powered stretcher implementation with fitness-based resources to mitigate any potential adverse effects. Following powered stretcher implementation, patient transfers and equipment handling have emerged as the most demanding tasks, as perceived by paramedics. Improving controls to these new perceived high demand activities provides a future opportunity to maximize the long- term benefits of this intervention.

CONCLUSIONS

The implementation of the Stryker Power-Pro XT™ with Power-Load™ system has substantially reduced the physical demands associated with stretcher handling tasks; however, physical capabilities of paramedics should be monitored post implementation to mitigate any threats of de-conditioning that may result from the substantial reduction in lifting afforded by Power.

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MSD PREVENTION STRATEGIES FOR THE PARAMEDIC SECTOR: A REVIEW OF CURRENT EVIDENCE

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SUMMATIVE STATEMENT: Work-related MSDs pose a significant challenge for the paramedic sector. Several studies provide evidence supporting engineering and administrative-based control options that can help reduce and mitigate MSD risks for paramedics.

Les stratégies de prévention des TMS dans le secteur ambulancier : un examen des connaissances actuelles

SOMMAIRE : Les troubles musculosquelettiques (TMS) constituent un défi de taille dans le secteur ambulancier. Plusieurs études fournissent des éléments probants qui appuient les mesures de contrôles techniques et administratifs afin de réduire et d'atténuer les risques de TMS chez les ambulanciers.

PROBLEM STATEMENT: Individual research studies describe prospective benefits and limitations associated with interventions that could help mitigate and reduce MSD risks in the paramedic sector. However, there is no single review or compilation of research summarizing available evidence-based interventions.

RESEARCH OBJECTIVE / QUESTION: To review and synthesize peer-reviewed and grey literature reporting on interventions to reduce or mitigate work-related MSDs within the paramedic sector.

METHODOLOGY: An exploratory literature review was conducted to identify and synthesize research describing MSD prevention related interventions targeted to the paramedic sector. Databases including PubMed, Web of Science and Google Scholar were searched using terms including: paramedic, MSD, prevention, intervention, etc., to generate a list of relevant articles. Article titles and abstracts were reviewed to identify papers that described primary research targeting MSD prevention in the paramedic sector. Papers were reviewed and data were extracted including: the type of intervention, the type of control, outcome measures, and effect of intervention on the outcome measures. This exploratory review was not a systematic review and the research quality of each paper was not considered. This is a noted limitation of this study.

RESULTS: Thirty-two primary research studies were identified and reviewed, 14 reporting on engineering controls, 14 reporting on administrative controls and 4 using a combined approach. Engineering controls included: powered stretchers, lateral transfer devices, adjustable stair chairs, medical bag weight reductions (where permitted), and revised layout of the patient compartment. Administrative controls included: performing all lifts with a minimum of two persons, alternating roles between leader and follower during lift, carry and lower tasks, engaging in exercise training, and avoiding manual lifting when and where possible through the use of assistive devices.

DISCUSSION: Paramedics are consistently exposed to MSD hazards due to the nature of their job. As a result MSDs are a significant concern. Primary research identifies engineering and administrative controls that reduce exposures to MSD hazards (e.g., using a lateral transfer device), increase paramedic capacity to withstand MSD hazard exposures (e.g., exercise), and in can effectively reduce the incidence of MSD within a paramedic service (e.g., powered stretchers).

CONCLUSIONS: Paramedic services may realize a reduction in MSDs by implementing evidence-informed MSD prevention strategies. This review identified several options, ranging in cost and complexity. To facilitate knowledge transfer, the list of potential MSD prevention strategies is presented in an EMS Section 21 Guidance Note made available through the Public Services Health & Safety Association in Ontario (http://www.pshsa.ca/ems-section-21-guidance-notes/).

USING A SYSTEMS FRAMEWORK AND METHODOLOGY FOR OBSERVING BEHAVIOR IN OPERATING ROOM ENVIRONMENTS

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KEY WORDS

Operating room design, systems approach, observation framework

SUMMATIVE STATEMENT

Operating room (OR) environments are complex systems with dynamic interactions between people, equipment, tools and built environment. A systems approach and an observation methodology is presented for observing and analyzing behaviours in the OR for patient safety outcomes.

Utilisation de cadre et de méthodologie des systèmes pour observer les comportements dans les salles d'opération

MOTS-CLÉS

Aménagement de salles d'opération, approche systématique, cadre d'observation

SOMMAIRE

Les salles d'opération représentent des systèmes complexes nécessitant des interactions dynamiques entre les personnes, l'équipement, les outils et l'environnement bâti. Une approche systématique et une méthodologie d'observation sont présentées afin d'observer et d'analyser les comportements dans les salles d'opération qui pourraient entraîner des conséquences pour la sécurité des patients.

PROBLEM STATEMENT

The incidence of adverse events such as surgical site infections and surgical errors are an increasing problem in the operating room (OR) due to the highly vulnerable state of the patient and the complex interactions required between providers of different disciplines and a range of equipment, technology and the physical space where care is provided (Owens et al., 2014; World Alliance for Patient Safety, 2008). While innovations in technology and medical practice are radically impacting how surgeries are being performed today, the physical design of ORs has lagged behind, resulting in environmental latent conditions that can often impact patient safety in the OR (Rostenberg & Barach, 2011; Weerakody et al., 2013). A systems approach is required for understanding the complex interactions in the OR and for developing sustainable design solutions that may improve patient safety outcomes in the OR.

RESEARCH OBJECTIVE

The research team has been awarded a 4-year grant from the Agency for Healthcare Research and Quality (AHRQ) to develop a learning lab focused on patient safety in the OR. This is a multidisciplinary initiative involving architects, human factors experts, industrial engineers, nurses and anesthesiologists. The first year of the project focused on developing an understanding of the safety issues in the OR through in-depth observations and analysis of behavior during surgery. As such, the research for the first phase of this study sought to develop a method to observe and analyze behaviors in an operating room environment and understand key environmental factors that may impact safety and efficiency outcomes in the OR.

STUDY FRAMEWORK

For this study, the extended Systems Engineering Initiative for Patient Safety (SEIPS 2.0) was utilized to provide a framework for understand the dynamic exchange between the sociotechnical system, the individuals within the system and the outcomes which provide feedback into the system (Holden et al., 2013). Within this framework, an individual or a group of individuals is placed in the center of the work system, acknowledging that the work system should support each individual’s performance needs, capabilities and limitations. The physical environment is one component of the work system that can be leveraged to support individuals within the system to facilitate effective work processes that lead to desired outcomes. This framework supports a paradigm shift from traditional OR design strategies, which placed the tools and technology central to the design instead of the individual.

RESEARCH QUESTIONS

Utilizing this systems approach, the research team developed an observational protocol to address the following two questions:

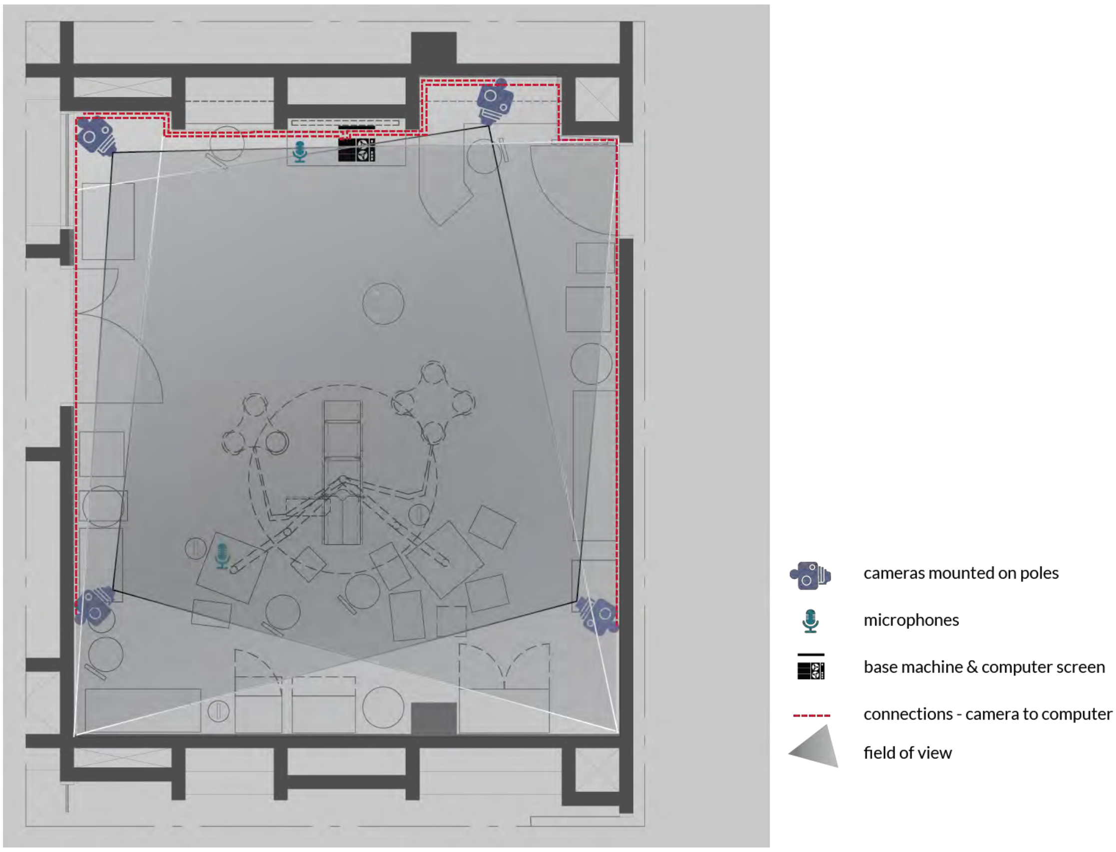
RQ1: Who is doing what activity and where are they located at different times of the surgery?

RQ2: What types of disruptions are happening during the surgery and who and what are involved?

METHODOLOGY

Video Observation Lab Development

A mobile video observation lab consisting of four video cameras on retractable poles, two wireless microphones and one laptop computer was designed to provide video capture of 35 surgeries in five distinct ORs within two buildings on the medical campus. Both the video capture and coding platform utilized Noldus Observer XT software to provide 78 hours of video observations, of which 59 hours were coded using the below protocol. The video data was coded from the time of patient entry into the room to the time of patient exit from the OR. The video data related to the turnaround phase was not coded. Figure 1 shows the



setup of the mobile video observation lab in an OR.

Figure 1: video capture

Coding Protocol Development

Prior to developing the behavioral observation protocol, an in-depth literature review of existing taxonomies was conducted. From this review of the literature, Palmer's (2013) taxonomy for surgical flow disruptions was chosen to examine types of disruptions and the individuals involved in those disruptions. To test this existing taxonomy and determine the inclusion of the remaining variables of interest, on-site observations were conducted. Following the on-site observations, a multidisciplinary team consisting of faculty and students from architecture, industrial engineering, operations research and surgical team members from the participating healthcare organization participated in two rounds of consensus building to develop the coding protocol framework. The types of tasks and activities being performed by the surgical team members were categorized as patient related, equipment related, materials and supplies related and information related.

Once the framework was established, pilot coding was conducted on three videotaped surgeries to determine missing variables, solidify variable definitions, as well as determine categories and subcategories of variables. Refinements were then made to the coding protocol, and pilot coding was conducted on one surgery to establish inter-rater reliability of 0.8 and higher. The final coding protocol consisted of: five surgical phases, seven primary subjects, eight objects, 13 primary locations, 26 behaviors, five types of surgical flow disruptions, door openings and lighting condition.

This framework provided a structured approach to analyzing where people and objects were located in the OR, the activities people were performing and the objects they were interacting with. Additionally, surgical flow disruptions were identified including the duration of those disruptions and their perceived level of impact on the surgery.

RESULTS

The detailed analysis framework based on a systems approach yielded rich insights about the tasks and activities of key stakeholders, the locations of people, objects and equipment, space needs during different phases of surgery and also the inter-dependencies and relationships between key players in the OR. This approach yielded rich data that supports an evidence based approach to designing the OR. From this data set, several types of analyses have been conducted. For example, one line of questioning has focused on understanding the movement patterns of the circulating nurse during the surgery in order to understand the impacts of different design factors such as size of room, crowdedness on the circulating nurses' movements in the OR and the relationship with disruptions. The data also allows us to conduct similar explorations for other team members in order to understand how different system factors impact safety outcomes such as disruptions in the OR. Additionally, statistical analysis has been conducted to understand the impact of door openings on bacterial load in the OR, surgical team members work patterns and the impact of environmental conditions on the type and duration of surgical flow disruptions, as well as their perceived level of impact on the surgery.

This data set has also been used to develop playback models of staff movement within the existing ORs using simulation software. These observed behavior patterns can also be used to evaluate new or proposed designs using the simulation models. The simulation modeling has been utilized to support the visualization and identification of areas in the OR of high use, congestion, as well as underutilized areas and barriers to flow within the observed surgeries. Figure 2 shows and image of the simulation modeling.

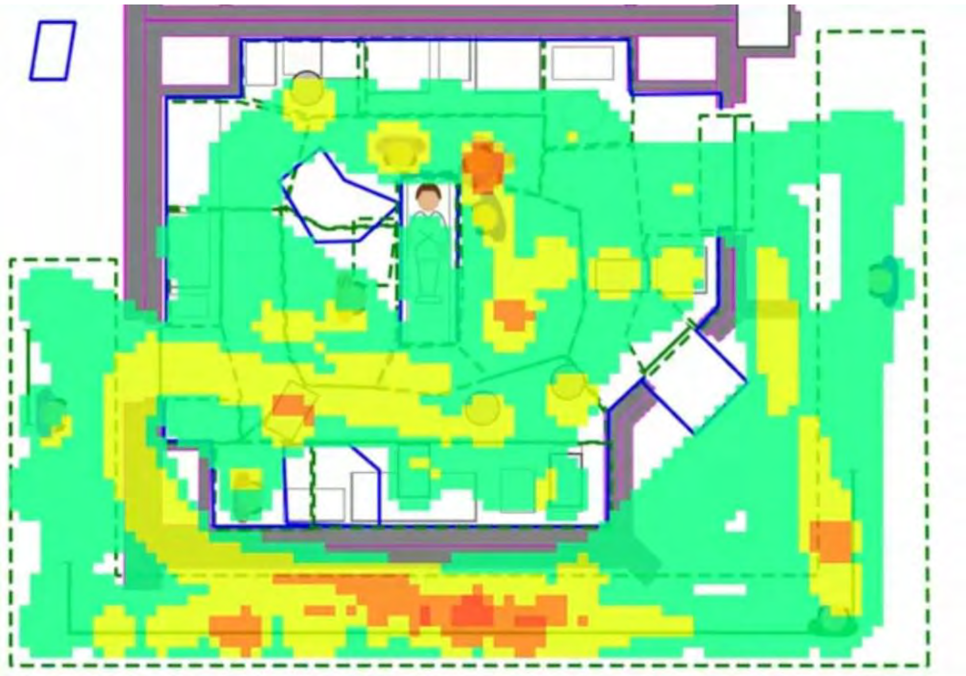


Figure 2: simulation modeling image

DISCUSSION

A systems framework provides a rigorous multi-dimensional approach for researching and designing a dynamic environment such as an OR. This is a more holistic approach to designing healthcare facilities that allows for a deep understanding of the complex interplay between people, tasks, processes, technology and the built environment. While there are several benefits to video observation such as less intrusive and time intensive data capture, reduced Hawthorn effect and reliance on observer memory and the opportunity for fine-grained analysis and understanding with greater accuracy, several challenges exist. Observing human behavior through video inherently lacks contextual clues that would otherwise be picked up during in-person observations. Additionally, verbal behaviors can be difficult to evaluate due to reduced audio quality of individual conversations. Furthermore, coding of the videos can be incredibly time consuming depending on the coding protocol developed. However, the large amounts of data that are able to be produced, allow for a wide variety of analysis to be conducted, providing for a more robust understanding of the phenomena being studied.

CONCLUSIONS

The development of a detailed observation framework was crucial for gaining deep insight into a dynamic environment such as the OR. There is potential to use the observation methodology and analytical framework in a range of different healthcare environments for studying complex problems and providing design solutions that may impact patient safety outcomes.

ACKNOWLEDGEMENTS

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PROMISING PRACTICE: PARTNERSHIPS IN PERSON-CENTERED APPROACH (PPCA)

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KEYWORDS
Quality of Health Care, Organizational Culture, Long-Term Care, Ergonomics

MAIN MESSAGE
To highlight the role of teamwork, communication, organizational or work culture and work environment in the prevention of patient handling injuries in a residential care setting

Une pratique prometteuse : partenariats dans l’approche centrée sur la personne

MOTS-CLÉS
Qualité des soins, culture organisationnelle, soins de longue durée, ergonomie

MESSAGE PRINCIPAL
Mettre en évidence le rôle du travail d'équipe, de la communication, de la culture organisationnelle ou du travail, et du milieu de travail dans la prévention des blessures liées à la manipulation des patients.

PROBLEM

The underlying philosophy of the Partnerships in Person-Centred Approach (PPCA) is that the conditions of work are the conditions of care, and considers the relationships, people, practices and physical environments. The health care industry is a complex one with constantly evolving competing priorities and diverse occupations working to provide quality care within the system. In the midst of this complexity is the person receiving care.

In 2015 in BC, the health care and social services sub-sector had an injury rate of 4, higher than the overall rate of 2.2, only Forestry and Warehousing industries had higher rates. Five industries had rates of 4, including health care, construction and transportation (WSBC, 2015). There are 14 owned and operated residential care and 12 acute care hospital sites in Fraser Health. Injuries to staff from patient handling activities continue to be the top driver of injuries and costs, annually accounting for about 25% of WorkSafeBC claims and 35% of claims costs.

CONTEXT

The opportunity to formally explore the concept of PPCA was presented in 2011 when a provincial team in conjunction with WorkSafeBC worked to develop safe resident handling standards in residential care. The goal then was to develop standards aimed at reducing injury rates to health care workers in residential care.

The foundation for the concept was laid in 2007, when our Health and Safety team began to investigate the high injury rates and associated time loss at some residential care facilities. It was noted by the team and communicated by the frontline staff themselves that there were barriers to optimising the safety culture at the facilities.

The impetus for further exploring this approach was driven by the need to address concerns related to injury rates at our residential care sites given that the elements of the Provincial Safe Resident Handling Standards (WSBC, 2011) were met including having 100% coverage of ceiling lifts and a Safe Client Handling Policy (Fraser Health, 2016) in place. As a setting, residential care historically had higher injury rates than other health care areas. The Ergonomics team was the health authority representative in the project.

ACTIONS

Implementation of PPCA at each site was preceded by meetings with the site manager to discuss the concept. The goal of the meetings was to highlight the interdependencies that come into play when seeking to provide “excellent care”, and illustrate how teamwork, communication, worker injury, and working conditions/environment impact the provision of quality care to the resident.

Implementation of PPCA is built around four key elements: Innovation Survey, weekly meetings, PPCA team meetings, and safety huddles. Together, these draw on concepts associated with safety culture, systems theory, and human factors. The overarching aim of the PPCA is “provision of excellent care for residents” (Taylor, 2012), by optimizing interactions between the diverse range of people who work in a residential care facility.

The first step in implementing this approach is the establishment of weekly meetings. These meetings are short meetings led at first by a facilitator (Ergonomist), then later by the department leadership (manager or care coordinator). At these meetings, staff are encouraged to give voice to concerns which impede the provision of excellent care, they are also encouraged to identify possible resolutions. A strict time limit of 10 – 15 minutes is enforced. These initial weekly meetings feature direct care staff, along with nursing and management.

The innovation survey usually follows after the weekly meetings are well established, and is administered by the Ergonomics team. The Innovation Survey instrument measures staff perception of elements considered essential to safe client handling and safety climate, with the safety climate components based on two validated safety culture instruments (Sexton et al, 2006; Thomas et al, 2005). The survey is delivered in a structured interview format.

The larger bi-monthly meetings follow the initial innovation survey. This meeting brings together a larger group of people reflecting the diverse roles involved in the provision of excellent care. At these meetings the team reflects on the common goal of excellent care and the issues that undermine the goal. The meeting builds on the opportunity provided by the weekly meetings to enhance working practices and promotes lateral dialogue between the diverse staff .The meeting format allows opportunities for feedback on ideas with regards to how proposed solutions will impact other members of the diverse teams and how they in turn work to provide excellent care. During larger meetings the injury data for a specified period is reviewed.

Safety huddles are established as another method of learning, and are encouraged to be documented. They fall into two categories, "in the moment" huddles (when any staff member can call a huddle at any time to discuss and troubleshoot an issue) and "scripted" huddles. The scripted huddles are determined at the bi-monthly meeting based on training and education needs identified by staff, following review of the injury data.

The ergonomist's role is to facilitate the establishment of a PPCA team, a process which unfolds over several months. Initial meetings are set up with the manager to discuss the PPCA and processes. These meetings are essential in establishing the stages, and introducing the idea of reducing the traditional hierarchical distances between the leadership and care staff. During these initial meetings with the manager, the four key elements of the PPCA are discussed, as well as the interdependencies that come into play when seeking to provide "excellent care", illustrating how teamwork, communication, worker injury and work environment impact the provision of quality care to the resident.

OUTCOMES

One of the key goals when implementing PPCA was to reduce injuries to staff from patient handling activities as a way to facilitate excellent care for residents. PPCA uses a participatory approach to address musculoskeletal injury (MSI) prevention and increase safety culture.

Our findings indicate that sites with PPCA teams continue to have lower claim rates and lower claims costs rates than sites without PPCA teams. In 2016, PPCA sites had a 28% lower claim rate (Figure 1) and 34% lower rate of claims costs (Figure 2) than non-PPCA sites. PPCA sites also demonstrated a 12% lower rate of absence (Figure 3) than other sites.

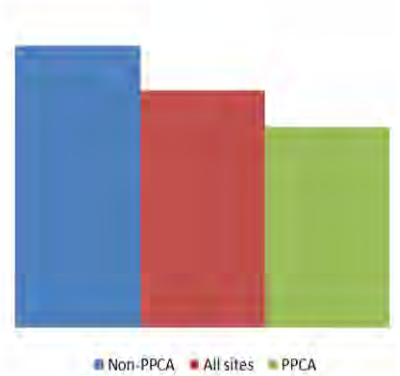

Figure 1: Rate of Claims

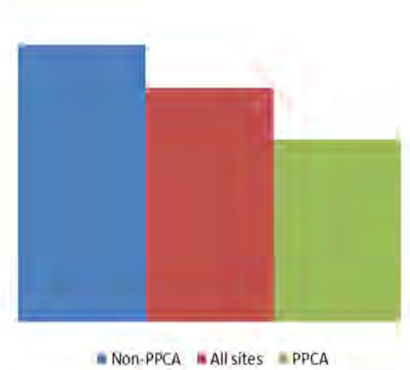

Figure 2: Rate of Claims Costs

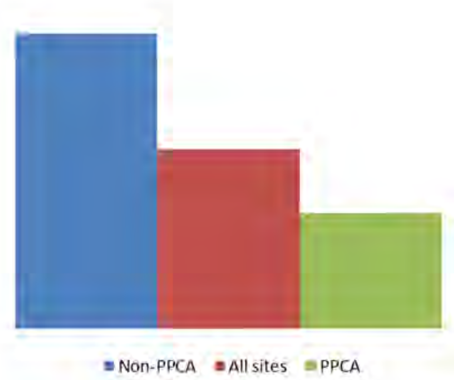

Figure 3: Percent of Absence

The Innovation survey results at PPCA sites (Figure 4), taken as a measure of key elements associated with safety climate, show increases in the range of 5 – 17% when comparing start up to one year after PPCA start up.

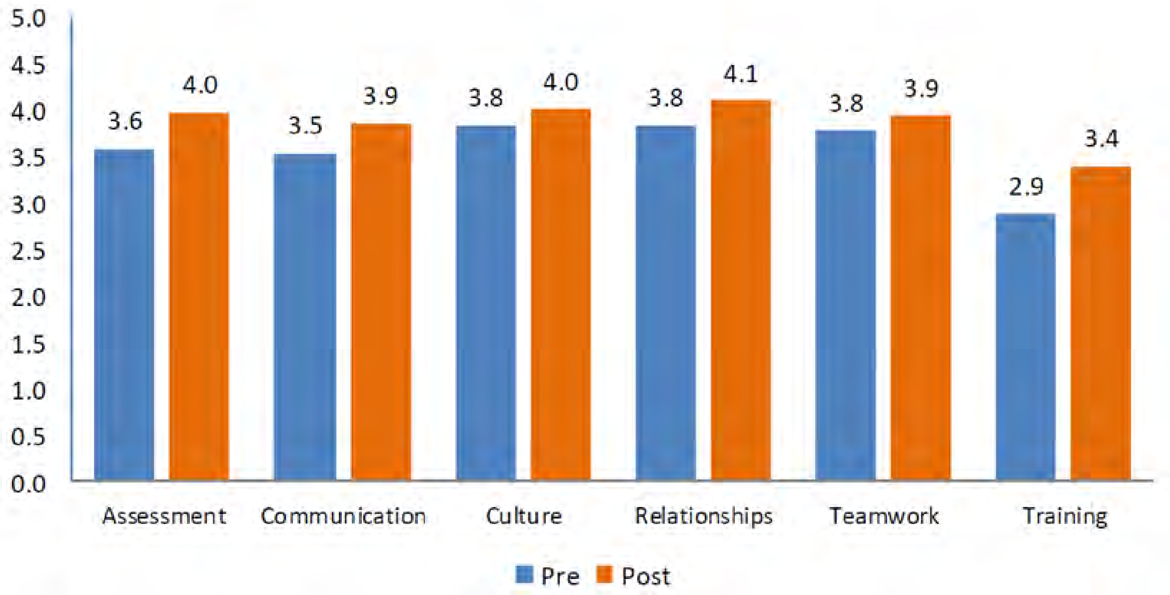

Figure 21: Innovation survey results

Staff responses to the questions on the Innovations Survey provide valuable information. When asked “what contributes to the safe work environment here?”, responses refer to good communication, cooperation, everyone working together, and the ability to bring issues forward in a timely manner. When asked “what makes this a great place to work?” employees cited examples such as the residents, other staff being like family, and feelings of safety.

Barriers to implementation of PPCA include changes in organizational structure at sites that are new to implementation. Ongoing competing priorities also limit the opportunities to engage with leadership.

DISCUSSION

Health care is a traditionally hierarchical environment with inherent power distances, which can be a potential barrier to communication and teamwork. Teaching people how to speak up and creating the dynamic where they will express their concern is a key factor in safety (Leonard et al, 2004). In residential care, this hierarchy usually means that Health Care Aides who spend the most time with the residents may not be frequently consulted about care decisions (Caspar & O’Rourke, 2008). Staff access to information makes person-centred care possible (Kolanowski, Van Haitsma, Penrod, Hill & Yevchak, 2015).

Teamwork has long been regarded as important in the provision of quality care; each member of the team brings something different to the table (Lockhart, 2015). The value of leveraging the knowledge and expertise of the direct care staff cannot be overstated, identifying problems as they occur helps enhance patient safety (Luther & Resar, 2013). Within the team, direct care staff spend the most amount of time with the individual residents and are therefore well placed to identify problems as they occur and facilitate better processes.

Communication is essential to workplace efficiency and for the delivery of high quality and safe work. It provides knowledge, institutes relationships, establishes predictable behaviour patterns and is vital for leadership and team coordination (WHO, 2009). More than 60% of the events reported to the Joint Commission responsible for the Institute of Medicine Report "To Err is Human" were attributable to communication failures (Tija et al, 2009). The Canadian Patient Safety Institute (2011) recommends that organizations should embrace teamwork and communication as a "must have" rather than a "nice to have". The elements of PPCA contribute to both by creating a forum for lateral dialogue and feedback through the avenue of the weekly meetings, larger team meetings and Innovation Survey.

There are associations to be made between working conditions, staff injury and resident care. Nurse working conditions have been shown to affect patient outcomes (Maiden, 2010). Intimidating behaviour and deficient interpersonal relationships can lead to mistrust, chronic stress and dissatisfaction among nurses (AACN, 2005).

PPCA sites are continuing with all the key elements, the meetings are run by the sites with the Ergonomists participating in a consulting role. There is continued participation of diverse unit staff. The team meetings generate ideas which are directly related to ways to improve the quality of care for the resident. The meetings also serve as forum to plan for dissemination of new policies at a site level.

CONCLUSION

The overwhelming literature evidence suggests that it is necessary to provide opportunities for groups of health care workers to come together and develop their team working practices. Good teamwork can help reduce patient safety problems and improve team members' morale and wellbeing (WHO, 2009). Teaching people how to speak up and creating the dynamic where they will express their concerns is a key factor in safety (Leonard et al, 2004). PPCA considers the relationships, people, practices and physical environments that may have an influence on the residents (Taylor, 2012). This approach embodies human factors principles to enhance clinical performance through an understanding of the effects of teamwork, tasks, equipment, workspace, culture and organization on human behaviour and abilities, and the application of that knowledge in clinical settings (NHS, 2013).

In implementing the PPCA, we found it essential to establish connections and strong communication with the staff and management. We built on the connections by establishing a link between resident and staff safety; everyone is motivated to provide the best care for their residents.

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Technical Session 10: Macroergonomics & Organisational Change

Séance technique 10: Macroergonomie et changement organisationnel

HISTORICAL ANALYSIS AS A KEY TOOL FOR SEEING ALTERNATIVES FOR FUTURE: A CHANGE LABORATORY EXPERIENCE

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Symposium: HFE interventions in organizational design

SUMMATIVE STATEMENT: We present contributions of historical analysis applied in the methodology of the Change Laboratory for interventions in organizational projects. Apart from theoretical concepts, we also present the procedures used in the case of a formative intervention, which sought to understand and overcome the crisis in the relationship between a Public Health School and a School Health Centre (SHC).

L'analyse historique comme principal outil en vue d'envisager des solutions de rechange pour l'avenir : une expérience en laboratoire sur le changement

SOMMAIRE : Cette étude présente des contributions d'analyse historique appliquées dans la méthodologie du laboratoire sur les changements en matière d'interventions dans le cadre de projets organisationnels. Outre les concepts théoriques, nous présentons également les procédures utilisées lors d'une intervention formative qui visait à comprendre et à surmonter la crise qui existe dans les relations entre une école de santé publique et un centre de santé scolaire.

PROBLEM STATEMENT: The analyses of organizations using the Work Ergonomic Analysis methodology make an important contribution to the understanding of present-day situations and serve as a basis for ergonomists' recommendations for the transformations and innovations of organizational projects. However, this approach does not contemplate or does not give the necessary emphasis to the historical analysis of the activity system, having as its presupposition that the understanding of the present is sufficient to reflect on and foresee the future.

RESEARCH QUESTIONS: Of what does the system or the activity network under analysis consist? What are its elements today and how and when were they modified in the past? What historical events favored the changes made in the activity? What contradictions led to the development of the activity and in what direction?

OBJECTIVES: To highlight, based on an empirical case of formative intervention using the Change Laboratory, the specific contribution of the historical analysis for the redesigning of the organization of a SHC in its relationship with a Public Health School.

METHODOLOGY: Case Study using the data and results obtained from the CL intervention occurred in the SHC which is part of a Public Health School in the State of São Paulo, in 2015. The tools and strategies used were revisited as questions, mirror data, change matrix, system of activity and time line which served as first and second stimuli and produced concrete results and learning.

RESULTS: A time line was constructed anticipatively, which made it possible to visualize which the historical events involved were and how they contributed to creating the contradictions, which led to the crisis in the relationship between the two institutions in their present activity. In 1925, the Health Service was the field of learning for the students of the School. Changes in curricula and a greater emphasis on research led to the distancing of the School from the Service. This process of estrangement was aggravated by financial difficulties. During the collective analysis of the historical development of the activity system, both the participants and the researchers expanded the way in which they understood the moments of crisis and their possible solutions, identifying the sources of the conflicts lived by the players involved. The CL made the understanding of how the problematic context generated the request for intervention possible, as also of the changes which occurred in the system over time. Historical Analysis made it possible to create a proximal development zone, which has helped in the construction of sustainable solutions for the future. The researchers learned as they changed their understanding of the relation between the two systems of activity.

Conclusions: In order to understand and intervene in this present activity it was necessary to become acquainted with its past development, that is to say, with how and why the system of activity developed and arrived at its present situation. This is a starting point to learning how to manage the dynamic of a situation rather than to permit oneself to be driven by it. The participants from SHC and faculty were able to better understand the reasons for the present situation, and based on this understanding to be able to imagine alternatives for the future. The knowledge of alternatives, for both employers and employees, is of strategic importance for organizational design and transformations. A lack of understanding of the past can harm the construction of sustainable solutions for the future. Despite this being a specific case study the CL methodology demonstrates the value of historical analysis as a potential tool for redesigning the future.

BREAKING ORGANIZATIONAL SILENCE BY IMPLEMENTING WORK DISCUSSION SPACES

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KEYWORDS
Work Discussion Spaces, Organizational Silence

SUMMATIVE STATEMENT
"Organizational silence" – i.e. the tendency not to report about factors that negatively affects performance – is a widespread phenomenon. This paper presents a "work discussion space" (WDS) methodology experimented in order to break organizational silence.

Briser le silence organisationnel en mettant en place des espaces de discussion sur le travail

MOTS-CLÉS
Espaces de discussion sur le travail, silence organisationnel

SOMMAIRE
Le « silence organisationnel » – c'est-à-dire la tendance à ne pas signaler les facteurs qui ont une incidence néfaste sur le rendement – est un phénomène très répandu. Cette communication présente une méthodologie axée sur les « espaces de discussion sur le travail » (EDT) qui a été expérimentée dans le but de briser le silence organisationnel.

PROBLEM STATEMENT

According to Morrison & Milliken (2000), "powerful games and norms prevent employees from saying what they know about technical and policy issues" (p.706). Fearing negative repercussions or not believing that speaking would make a difference, the employees do not enough share information, offer critical analyses of ideas, report problems or suggest new perspectives. This "organizational silence" compromises the effectiveness and quality of both decision making and change processes.

Facing this extending phenomenon, different authors advocate systems that enable employees to voice work concerns, such as a management "of labour" (Conjard and Journoud, 2013), "by labour" (Bonnin, 2013) or "by discussion" (Detchessahar, 2013), that aims to make visible "actual work" and better take it into account in decision-making and organizational processes.
It implies to design both:

- *An "engineering of discussion"*: the discussion has to be regularly led by managers (trained in activity analysis) with their teams, about work situations faced by these teams that need to be improved or developed with concrete actions collectively built.
- *An engineering of the "organizational space"* in which this discussion takes place: allowing teams to gather regularly means to recognize this exchange time as a working time, by planning it in the organization of the production; it also implies that all the

hierarchical levels are involved and have enough autonomy, leeway and power to support the implementation of the proposed action.

Figure 22: Synthesis of the criteria needed to design the discussion (Detchessahar, 2011 et 2013 ; Van Belleghem & Forcioli Conti, 2015 ; Rocha, 2014 ; Conjard & Journoud, 2013)

RESEARCH OBJECTIVE / QUESTION

We understand that the design and implementation of such a "Work Discussion" and "Space" requires a significant evolution of the system, toward a participatory management that supports "subsidiarity" (i.e. decision-making at the lowest relevant level of the hierarchy).

To operationalize these theoretical propositions, the research aims to:

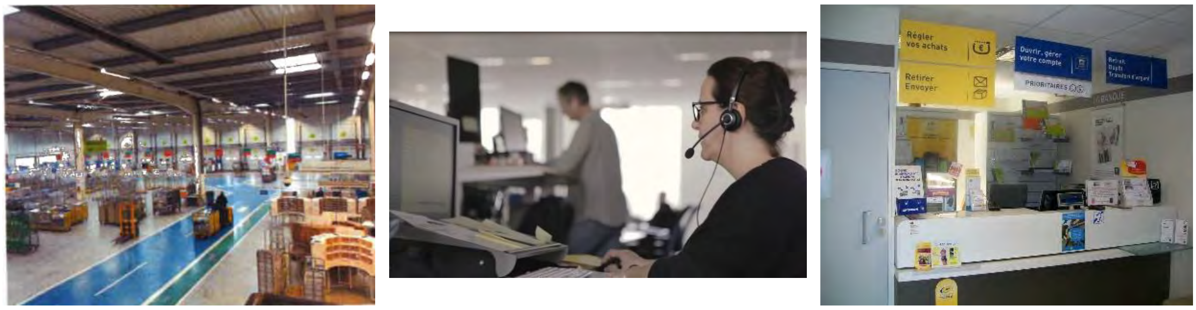
- *Specify the WDS's principles* (kind of subjects discussed, frequency, duration, leaders and participants, facilitation rules...), *objectives and outputs* (problem solving, practice share, collective work regulation, social dialog improvement…); and to *adapt these criteria* to the team's different socio-economic issues, current contexts and concerns.
- *Find levers to make the system evolve*, so that it provides *propitious conditions* to better take into account the reality of work: evolution of the managers' role toward a support for the activity of regulation, of the decision-making and organizational processes (encouraging an "organization of the organizational work" that relies on internal feedbacks and suggestions, finding modalities to include this discussion and its outputs within the organization…)

We thus assume that the implementation of the designed methodology, adapted to each specific context, should enable the teams to voice their concerns and act to improve their work situations in concrete terms, restoring the lost performances due to organizational silence.

METHODOLOGY

- **Phase 1 : Work Discussion Spaces experimentation**

Work Discussion Spaces were first experimented on 3 sites of the French Post Office (an industrial platform sorting mails, a financial center and a post offices network), in response to a request from the Quality of Work Life Direction which wanted to implement a social agreement; this agreement provided "time for the expression of postal workers (…) periodically organized by managers on the working time (…) to make collective improvements in the realization of daily work".



The field study was carried out in 5 steps (cf. Figure 2): a *diagnosis* (to understand work, its organizations, the management, the existing exchange opportunities…); a *design* step (to build the WDS's principles and consider how they could be implemented in regards with the existing situation); a *training* step (30 managers were instructed on work analysis methods, on how to facilitate their team's expression, and on how to collectively build proposals to improve work situations); *manager's support/tutoring* and *experimentation's assessment* steps.

Figure 23: the fieldwork methodology carried out (phase 1)

- **Phase 2 : pre-deployment experimentation**

A pre-deployment was then tested to identify the favorable conditions for extending the approach more widely and adapting it to different contexts (cf. Figure 3): 45 "WDS guides" divided into 4 groups are undergoing a training of 6 days, spread over 9 month, to carry out the same fieldwork on 35 establishments representing various trades (mail and package distribution, support services, other financial centers and post offices…).

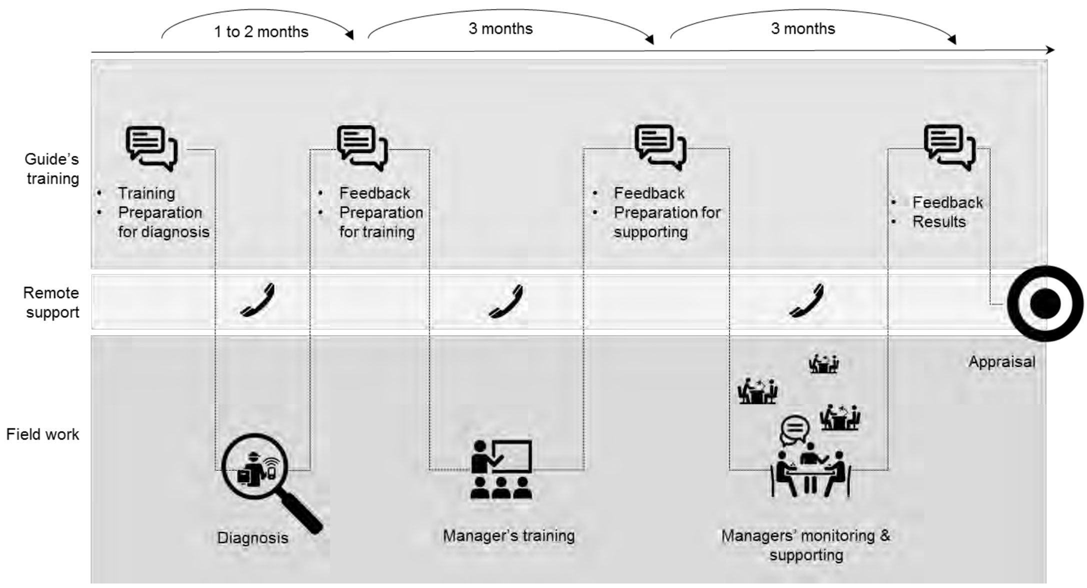


Figure 24: the pre-deployment methodology tested (phase 2)

- **The research methodology**

To study how the WDS were implemented and adapted to the different contexts, the research methodology relies on the instrumental approach of Rabardel (1995). In this theory, an instrument is defined as the combination of:

- An artifact: an object (i.e. a baseball bat)
- And use patterns: how this object is used and for what purpose (i.e. to play baseball)

The author also describes how instruments can evolve while they are used, through an "instrumental genesis" process: the artifact can be modified itself or used differently than expected (i.e. using the baseball bat to break a glass).

In that perspective, defining Work Discussion Spaces as instruments means to characterize (Cf. Figure 4)

- The artifact: the WDSs' principles (kind of subject discussed, duration, frequency, leaders and participants, terms of participation…)
- The use patterns: how WDSs are used (conditions of implementation such as decision-making, organizational and participatory terms) and for what purpose, regarding the socio-economic issues, current needs and concerns.

It also requires to follow the instrument's evolution over time.

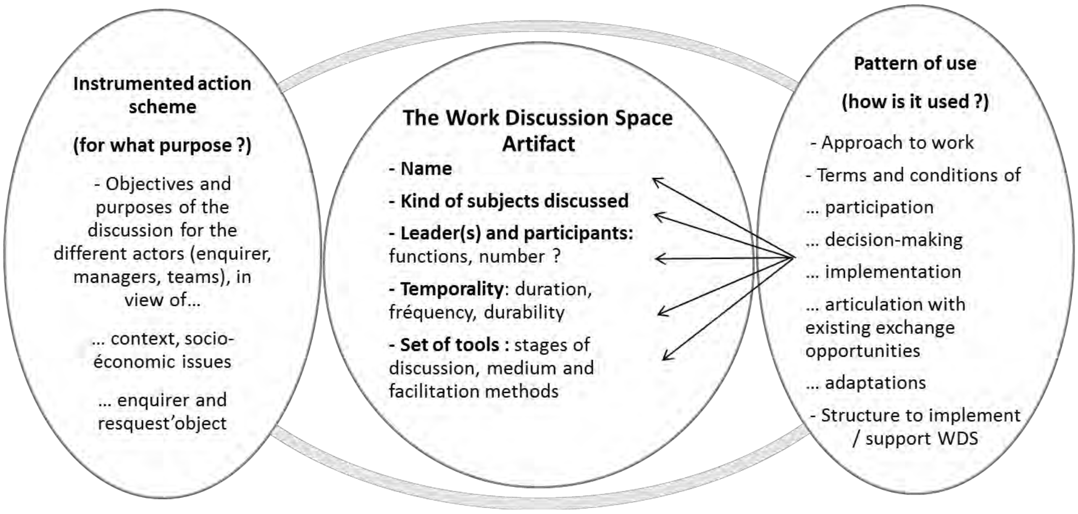


Figure 25: Work Discussion Spaces as an instrument

To be able to characterize such an instrument and appreciate its actual implementation, 3 WDSs were observed and 25 semi-directive interviews were conducted (during the monitoring and supporting step) with the managers trained in the phase 1, before and / or after their first WDS. The same data collection is planned after one year of implementation and for some managers of the phase 2.

RESULTS

➢ Adapting Work Discussion Spaces for making constructive activity compatible with productive activity

As a result of the diagnosis and design step, the following WDSs' principles were suggested to managers in the training step (Cf. Figure 5): a one-hour Work Discussion Space per month, co-facilitated by them with their team (8 to 10 participants), complementing the existing exchange opportunities (work situations could be reported by employees before the WDS in a meeting called " space-time communication" – i.e. 1/2h of top down-information followed by 1/4h of reported concerns – and feedbacks on the decisions taken or actions implemented could be provided in the usual service meetings).

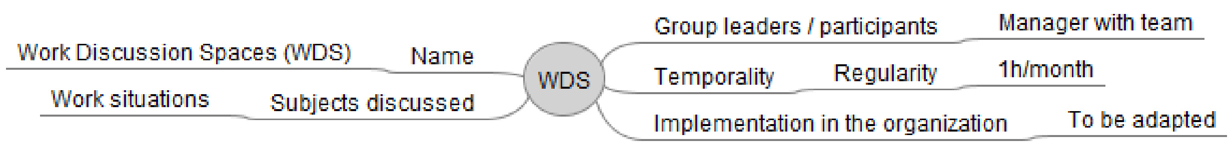


Figure 26: WDSs' principles adopted in the training step

Furthermore, to focus the discussion on “actual work” and lead it to concrete actions, managers were equipped with a five-steps methodology (Cf. Figure 6): introduction with “game rules” (expressing freely, listening without judgment, accepting divergence of opinion as an opportunity to open up possibilities and errors as an opportunity to learn…); elicitation interview and collective analysis of the situation before developing proposals and committing to implement them.

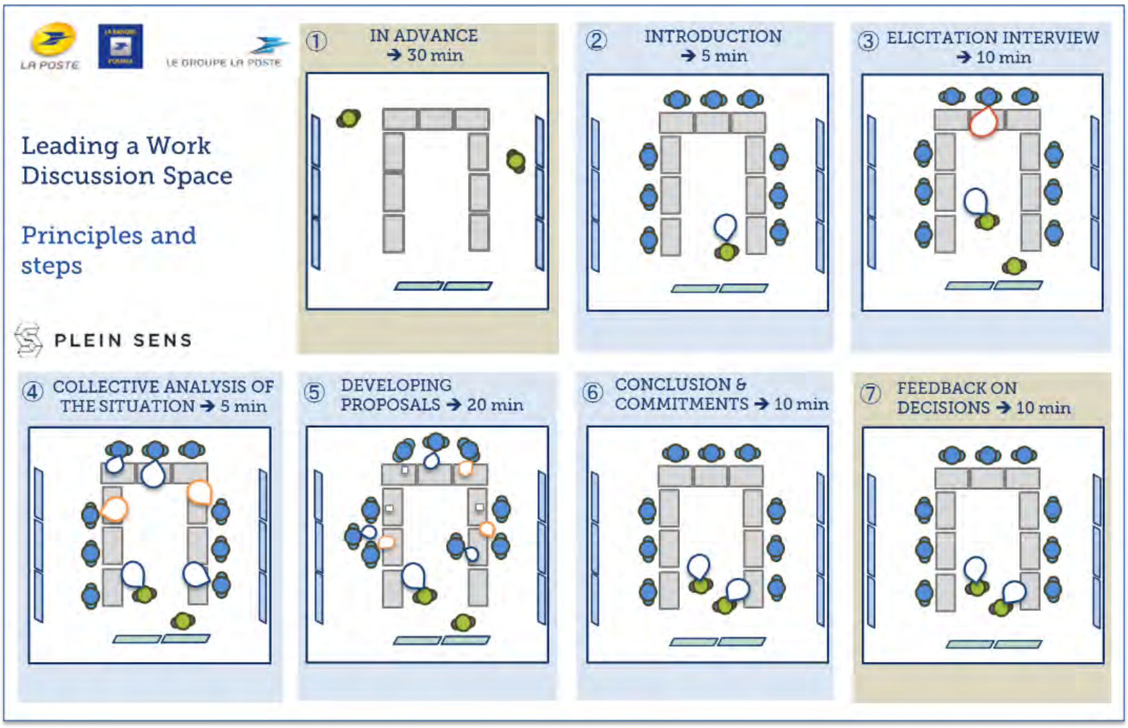


Figure 27: sequence of the discussion's steps

Finally, when implemented, the WDS’s principles were adapted to the teams’ specific contexts. For instance:

- WDSs were held ¾ h once per month in the post offices that used to be closed once a week to the public for team meetings so that the service was provided as usual;
- In the financial center, two direct managers leading two different teams of the same service decided to lead together the WDSs, one month with the first team, and the following month with the other team, to regulate their workload;
- The management of the industrial sorting mail platform included the hour of discussion in the planning tool as a work session, so that this constructive activity didn’t affect the productive one.

Figure 7 shows the instrumental genesis, i.e. how the initial principles were adapted to better fit the specific situations that were met.

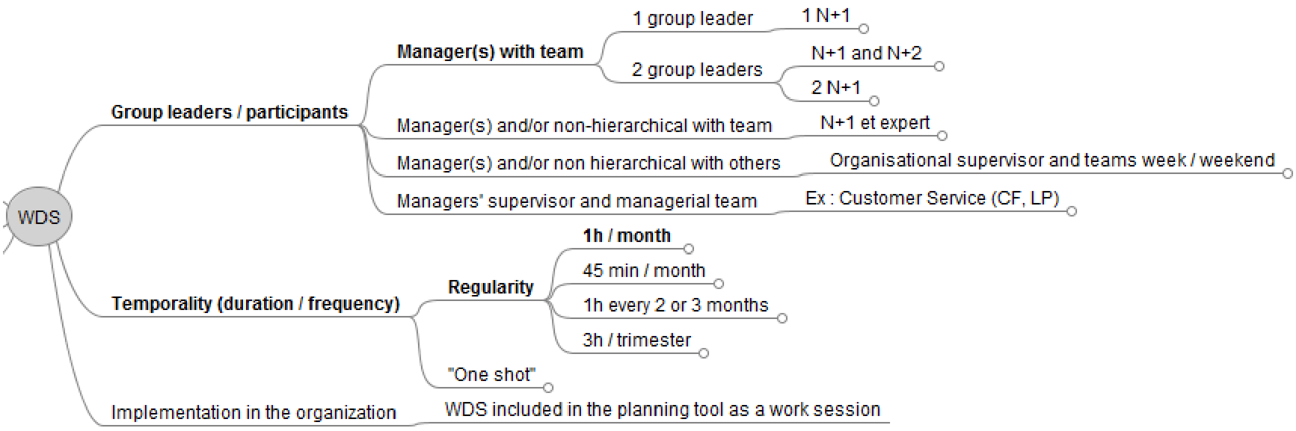


Figure 28: WDSs' principles adapted in the implementation

- **Contribution of Work Discussion Spaces to different aspects of performance**

Altogether, in 6 months, 17 WDSs were conducted. All the topics dealt with covered aspects of performance: *quality of service* (e.g. avoid jams in mail sorting machines or misdirected packages), *resources development* (e.g. change a script unsuitable for the situations encountered), *organizational and collective performance* (e.g. better define the role and tasks' distribution between two teams; attend decision committees to better process a file; collectively catch up with a delay). It can be noticed that these topics mostly address technical or practical problems, that can be dealt with at the team level, rather than situations concerning subjective engagement in work or conflicts of quality criteria, that were also expected.
The facilitation of these WDS was performed in various ways, according to the managers (their path, their "charism", their ease), the teams (their work, constraints and resources, interpersonal relations, "ratio of power"), and the situations (e.g. uncertain future or climate of tension VS. good economic health and relationships of trust).

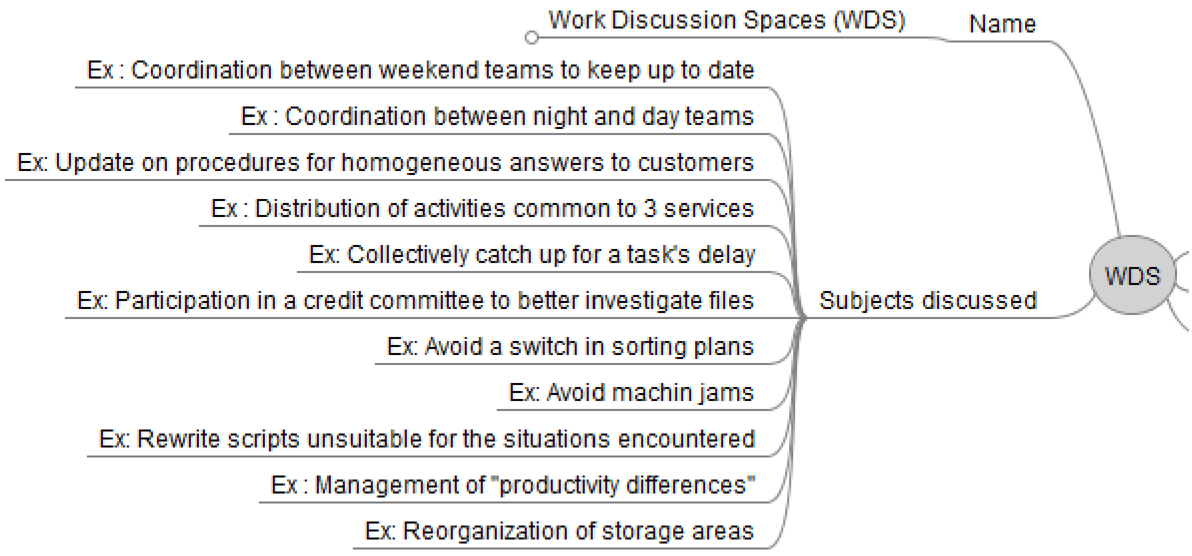


Figure 29: Subjects discussed

DISCUSSION-CONCLUSION

Some managers found in WDS tooling a structuring support in their role of manager; the feedback of the agents was mostly positive (the WSD allowed them to express their views), with however a cautious expectation regarding the actual implementation of the proposed

actions. A follow-up study of these actions' implementation and of the WDSs' longevity is planned (as far as possible through interviews with managers and teams, observations of WDS and of work changes – if observable – or monitoring of indicators specific to the topics discussed).
Such a methodology requires to determine whether it is relevant or not to implement WDSs depending on the context and the participants, and what modalities need to be adapted (frequency and duration, meeting leader…). It also requires a coherence between the participatory approach of WDSs and the whole organization functioning. For instance, some teams adapt prescribed procedures at their level without any organizational support; others experience difficulties in holding WDSs, in terms of means or time allocated to allow both discussion and production. That is why a pre-deployment phase is being tested with a view to extend this system wider. It raises many questions and paradoxes such as how to "deploy"… a bottom-up methodology, or how to change a management culture.

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SUPPORTING AGRO-ECOLOGICAL TRANSITION ON FARMS: CO-DESIGNING A CHANGE MANAGEMENT SUPPORT APPROACH

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KEYWORDS
Design, agro-ecological transition, activity-centered ergonomics, reflective activity, projective activity.

SUMMATIVE STATEMENT
The agro-ecological transition requires farmers to redesign their work system. To support farmers' change towards agroecology, we develop an ergonomics "enabling intervention" in a change management context to help them in the development of them design activity. By allowing farmers to reflect on their trajectories and their project regarding agroecology transition, our research-intervention aims at enhancing the farmers' capacity to design their work systems. Also, this research-intervention aims at equipping agricultural change management facilitators - who are not ergonomists - (e.g. farmers' advisors) with tool designed to embed the farmers' work in their counselling approach. These pursued goals require to design approaches, particularly tools, positioning farmers as work system designers. This is what we are trying to do in this research-intervention.

Soutenir la transition agroécologique dans les fermes : un travail collectif de conception pour appuyer une démarche de gestion du changement

MOTS-CLÉS
Conception, transition agroécologique, ergonomie centrée sur l'activité, activité de réflexion, activité projective

SOMMAIRE
La transition agroécologique exige que les agriculteurs transforment leurs systèmes de travail. Afin d'accompagner les agriculteurs dans cette transition, nous avons élaboré une « intervention capacitante » dans un contexte de gestion du changement pour les aider à concevoir de nouvelles activités. En permettant aux agriculteurs de faire le bilan de leurs parcours et de leurs projets quant à la transition agroécologique, notre recherche-action vise à améliorer la capacité des agriculteurs à concevoir leurs propres systèmes de travail. En outre, cette recherche-action a pour but d'outiller les promoteurs de la gestion du changement agricole, qui ne sont pas ergonomes (p. ex., les conseillers agricoles), pour qu'ils tiennent compte du travail des agriculteurs dans leur démarche de conseils. Les objectifs poursuivis consistent à développer des méthodologies, notamment des outils, pour placer les agriculteurs au centre de la conception des systèmes de travail. C'est ce que nous tentons de faire dans cette recherche-action.

PROBLEM STATEMENT

In France, several agricultural and political actors promote agroecology to cope with the major economic, environmental and societal challenges that agriculture must face. A transition towards agroecology involves profound changes in the work of farmers and usual forms of agricultural advice are challenged. Thus, support approaches need to be designed, both for and by farmers, but also with the actors who accompany farmers to fit their own work constraints in the context of the agro-ecological transition.

RESEARCH OBJECTIVE

This research-intervention is situated in the activity-centered ergonomics community, especially constructive ergonomics (Falzon, 2014) which aims at the worker's development in and by his/her work. Our intervention intends to be enabling. "Enabling" is used with the meaning proposed by Constructive Ergonomics (Falzon, 2014), in reference to Sen's work (2003). That is to say building an organization that promotes the emergence and development of organizational rules, allows individuals and collectives to act effectively, to safeguard their health, to be in a learning process and to develop themselves (Arnoud, 2013; Coutarel & Petit, 2009 ; Daniellou & Coutarel, 2007; Falzon, 2005 ; Barcellini, 2015). In this sense, the epistemic dimension of our work deals with a better conceptualisation of what an "enabling intervention" deployed on a case study and in a sustainable manner could be. We focus on the developmental aspect of this intervention. It may therefore be assumed that enabling interventions have to support *reflective activity* regarding the way farmers manage changes ; and *projective activity*, dealing with the development of new strategies for farmers to cope with change. We regard the reflective activity as an activity allowing the worker to construct a reflection on their past action (i.e. Barcellini & al., 2014; Mollo & Nascimento, 2014), and the projective activity as an activity to construct a reflection on the possible areas of future actions, taking into account past actions. Thus we aim at designing tools that will support the transformative change of farmers' work and that will eventually equip the work of the facilitators of agricultural change management. These tools are the methodological ground of our change management approach. In this communication, we focus on how we design these tools with farmers.

METHODOLOGY

a. Case study

We work with 4 farms and 6 facilitators. In this communication, we concentrate on one of the cases that we follow more particularly. We are intervening with two grain farmers, who have been partners for 4 years and who have been converting to organic for one and a half years. Their partnership is a limited company located in the Centre of France. Their motivations for initiating this process are ethical and economic. These farmers have to comply with the specifications of organic farming which advocate the protection of rural areas and the strengthening of the social fabric. It is characterized mainly by the non-use of synthetic products of crop protection and fertilization in crops and the implementation of methods allowing the renewal of biodiversity and its preservation. Previously practicing no-tillage crop production, they have maintained this practice. This practice, coupled with the conversion to organic, seems to be very difficult in terms of work. The combination of organic farming and no-tillage crop corresponds to an agriculture recognized as extremely difficult to implement and to sustain in the agricultural world (Lefèvre, 2013).

b. Design and implementation of two tools supporting the transformative change of farmer's work

Our change management support approach is composed of two tools, one supporting the reflective activity, and the second supporting the projective one.

1) The "Chronicle of change": this tool aims at providing several items to farmers : (i) to generate a discussion about change ; (ii) to outline the change process according to the determinants of the farmer's work and (iii) to support the farmers' reflexive development.

To do that, the Chronicle of change requires an interest in the difficulties, the goals and the resources of farmers. Figure 1 illustrates this tool.

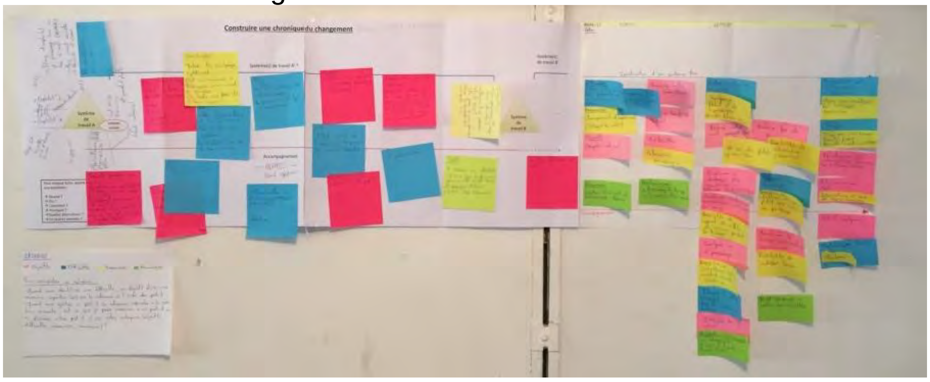

Figure 30 : The Chronicle of change

Figure 1 shows the support representing a historical timeline. Several post-its representing objectives, difficulties and resources have been written and positioned by farmers with the help of the ergonomist. The ergonomist works regularly with farmers to complete the Chronicle of change. The basis of this tool was built by the ergonomist ; its building has been continued by the farmers when experimented in the actual context of their farm.

2) The “Dis-jumble”: this tool aims at providing several items for farmers : (i) to plan their various tasks, (ii) to anticipate their different tasks and what each requires the farmer to do, (iii) to have a reflection on what they have done, (iv) to have a reflection on what they wish to do, (v) to have a reflection on what they think of the various difficulties encountered and objectives set, (vi) to revise this "scheduling" in real time through actual work and (vii) to have a traceability of their actual work to see the future work (adjustment, regulation, reflexivity). Figure 2 illustrates this tool.

Figure 31 : The Dis-jumble

Figure 2 shows a type of task planning moving. Different colors and different lines allow the use of this support. This tool has been designed only by farmers, with the presence of the ergonomist.

These two tools stay in the farm to be used by the farmers when they need to.

c. Methods of data collection and analysis

Several meetings with the farmers in their farm allowed them to manipulate and to push forward the two tools. Our main interest will be the experimentation of these tools and the continued designing of these tools in farm by farmers. For that we analyse interviews (audio data) and workshops (video data) and identify the direct impacts of the farmers on the design of the tools :

- The Chronicle of change: a first support and functioning was proposed to farmers. The support is positioned in the farm. The ergonomist comes once a month to complete it with farmers using post-its. Our question is to understand how farmers participate in the modification of the tool by using it. To answer that, we analyze five interviews and the evolution of the support.

- The Dis-jumble : farmers designed the support in two steps. First they drew it on a scrap paper. Secondly the ergonomist asked them to design it on a solid and malleable support. Our question is dual. First, what criteria from the point of view of their work appear in this conception ? Secondly, what types of exchanges does the design of this tool create between farmers ? To answer these questions, we analyze two movies : two sessions of design. First a draft design with paper and pencil. Secondly, a "solid" design during which the ergonomist proposed different materials to use : plated metal, magnets, post its, colored papers, etc..

RESULTS

The *reflective tool* "Chronicle of change" was designed by the ergonomist to underline different dimensions in change management (goals, difficulties and resources). It helps the farmers to step back from their trajectories of change and work management. During its use, the farmers and the ergonomist agreed on the definition of different components of the support like post-its, lines, etc.; the farmers also appropriated the specific words of the ergonomist like "agricultural work system", "resource". Farmers expressed their doubts: "I have trouble, I need an example"; and their difficulties to use the support "They are not easy to use, your post-it, because there are many of them". Thus, the ergonomist proposed adjustments over the use of the support such as : "I simplified it a bit because (…) there was too much information". Farmers also expressed their needs concerning the use of the Chronicle of change : "We must read again a little what we have already put" speaking of post-its written earlier. The ergonomist kept an open attitude towards the proposals of the farmers, to which he answered : "We can take again (the post-it written at the latest interview) and we see (today) where you are and we see if we add new things ?".
Farmers and ergonomist made the rules of the use of the "Chronicle of change" evolve through its experimentation. For example, at the first use, a farmer proposed : "We are gonna talk more and you (ergonomist) are gonna put the post-its". At the fourth utilization, the ergonomist proposed : "Maybe it would be good for you to take control of it", speaking about post-its.

The *projective tool* "Dis-jumble" was designed by the farmers themselves with the help of the ergonomist, in order to facilitate its sustainability for farmers. The two farmers decided to organize their tool along two main elements: a time scale (two years) and the crops (spring/ autumn). The functioning of this tool is based on the dispersion of magnets indicating mainly an action, in time and concerning a crop, for example : to sow the wheat. These magnets are used to allow the farmers to adjust the planed action in real-time.
Thanks to this process, farmers engaged in a projective activity. They exchanged and adjusted their vision of work and what they were planning to do. We realize farmers did that thanks to a reflexive activity : they reflected on what they had done the previous year to plan forthcoming work. For example, a farmer explained to the other : "Remember last year, we struggled to harvest the faba bean as it was too ripe. We should anticipate and harvest the faba when we harvest the wheat, or even before the wheat". The reflexive activity seems to be necessary to develop a projective activity. Also, it helps farmers to take decisions and to develop new strategies for more efficiency. For example : Farmer 1 "We may improve our system if (…) I do not know if it is possible, but we might find a variety of faba bean that could be harvested in early July" ; Farmer 2 "We would not have to bother to store it for a year". An over example : Farmer 1 "There is order and delivery, these are 2 different things" Farmer 2 : "It happens a week or 2 between those 2 (...) because if we don't anticipate, we are lousy" Farmer 1 : "Yes". Thus, this tool seems to support the farmers to reflect on new operating rules in order to cope with difficulties and goals identified thanks to the chronicle of change.

DISCUSSION

The work described in this communication is a “one-shot” experiment, but a key challenge of our research in order to promote the “sustainability” of our approach is the development of the use of our tools by agricultural change management facilitators actually advising farmers. This may imply: (1) construction of a large scale deployment approach with facilitators and (2) refinements of our tools. The problematic point, seems to be the difficulty of the two different approaches : technical approach / work approach. Facilitators are, in part, animators or advisors working with an approach rather targeted at the technical side whereas the ergonomist’s approach is rather targeted at the working side. Thus, it seems very important to reflect on the transfer, appropriation and re-designing of tools by facilitators based on their taking into account the farmer’s real work.

CONCLUSIONS AND PERSPECTIVES

This research-intervention allows us to support farmers in the design of new work situations by designing - with them - *ad hoc* reflective and projective tools. But a key issue of our work is to deploy the approach on a broader scale and thus to transfer it to change management facilitators. The tools have been presented to agricultural facilitators and seem to meet some of their needs to accompany farmers in the agro-ecological transition. Thus, we will follow a second step : to continuing their design with agricultural facilitators by making them use the tools by themselves and by collecting their feedbacks through observations of their work. A design workshop will help the appropriation and adaptation of these tools to the work of these facilitators.

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TRACING THE CONTRADICTIONS AS A FUNDAMENTAL STEP FOR FORMATIVE INTERVENTION AND DEVELOPMENT

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KEY WORDS: Formative intervention; Change Laboratory; constructive ergonomic
Symposium: HFE interventions in organisational design

SUMMATIVE STATEMENT: Theoretical and conceptual aspects of the Change Laboratory methodology are presented and discussed to bring out possible connections and sources of inspiration for the development of ergonomics in organisational design interventions with a view to contributing to the construction of bridges between ergonomics and the Expansive Learning Theory proposed by Engeström and colleagues.

Déceler les contradictions comme étape essentielle à l’intervention et à l’évolution formatives

MOTS-CLÉS : Intervention formative, laboratoire sur le changement, ergonmie constructive

SOMMAIRE : Les aspects théoriques et conceptuels de la méthodologie du laboratoire sur les changements sont présentés et discutés afin de mettre en évidence des liens ou des sources d'inspiration possibles pour que l’ergonomie soit davantage prise en compte dans les interventions de conception organisationnelle afin de créer des ponts entre l'ergonomie et la théorie sur l’expansion de l’action d’apprendre proposée par Engeström et collaborateurs.

PROBLEM STATEMENT: The analysis of organisations using the Human Factors Ergonomics (HFE) approach makes significant contributions to the comprehension of the present work situation and serves as a foundation for ergonomists’ recommendations for transformations of and innovations in the organisational project. However, the HFE, specifically the constructive approach (FALZON) seems to lack a pedagogy or a theory of learning such as would enable the participating actors to master the process as a whole, seeing that the agency remains, almost throughout the whole process, in the hands of the ergonomists.

RESEARCH QUESTIONS: What contributions can the Expansive Learning theory developed by Engeström and colleagues, make to constructive ergonomics in view of the organisational project? How can the agency and the participation of the actors in all the stages of the intervention (analysis of the current situation, historical analysis, identification of contradictions, preparation and testing of the solutions) be ensured and developed? How were the present and historical contradictions in the system identified by the actors? What is the connection between revealing contradictions and promoting participants' agency? What solutions were found and what was the process of testing and development like?

OBJECTIVES: to explore and illustrate, based on a case of formative intervention applied in CEREST, the principal dimensions and phases of intervention using the CL; to present the conceptual elements and the practical procedures used in the formative intervention undertaken at a Reference Workers' Health Centre with emphasis on the participants' protagonism and the construction of solutions for the service's problems.

METHODOLOGY: The 11 sections of CL were planned to follow the expansive learning cycle using the strategy of double stimulation (Engeström). The data were recorded and analysed using a qualitative approach. The products constructed by the participants such as historical line, figures and models were analysed to answer the research questions and goals given above.

RESULTS AND CONCLUSIONS: It was possible to manifest the strength and consistency of the methodology regarding the specific variables of interest in the present assessment of the case. The earlier climate of despondency and weak commitment were seen to change for the better during the course of the CL sessions, with the involvement of the actors whose participation intensified consistently. The debates were intense and provided the opportunity for the expression of the different perceptions of the actors, in accordance with one of the principles of the method: multivocality and confrontation of different views. It was observed that in the initial sessions the actors sought individual explanations and that the systemic explanations gradually emerged more clearly. The ethnographic data such as interviews, the collection of service production data and cases of success and failure served as the first stimuli for the discussion of the present practice. Conceptual devices such as the Surveillance Concept and the Activity System (AS) triangle worked as triggers for the understanding of the contradictions existing in the system that were blocking the achievement of more durable results in the surveillance activities. The discussion and reinterpretation of the timeline together with the expansive learning cycle made it possible to identify the history of the changes made in the object of the activity. The offer of these second stimuli was appropriated by the participants and provided the deepening of the learning, the subjects' collective mastery of the reality experienced and the visualisation of the necessary innovations that are being tested and are now underway.

WORKPLACE PRACTICES AND POLICIES TO PREVENT MSD: DEVELOPING AN IMPLEMENTATION GUIDE

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KEYWORDS
Research to Practice; MSD prevention; Implementation; Knowledge Transfer and Exchange

SUMMATIVE STATEMENT
Musculoskeletal disorders (MSD) continue to be a major burden on Canadian workplaces and workers as well as insurance and health systems. Evidence-based practice includes guidance from scientific evidence as well as practice expertise and experience; however these sources of evidence are rarely synthesized. The synthesis of scientific and practice evidence addresses important research-to-practice gaps and the development of an implementation guide.

Pratiques et politiques de travail en vue de prévenir les TMS : élaboration d’un guide de mise en œuvre

MOTS-CLÉS
Recherche à la pratique, prévention des TMS, mise en oeuvre, transfert et échange des connaissances

SOMMAIRE
Les troubles musculosquelettiques (TMS) demeurent un fardeau important pour les entreprises et les travailleurs au Canada ainsi que pour les systèmes d'assurance-maladie. La pratique fondée sur les preuves comprend des lignes directrices tirées de preuves scientifiques ainsi que de l’expérience et de l’expertise issues des pratiques. Toutefois, ces sources de preuves sont rarement synthétisées. La synthèse des preuves scientifiques et des pratiques aborde des lacunes importantes dans la recherche à la pratique et l'élaboration d'un guide de mise en oeuvre.

PROBLEM STATEMENT
Work-related musculoskeletal disorders (MSD) are problematic worldwide. Previous estimates indicate that 40% of the world’s occupational and work-related health care costs are attributable to MSDs (Takala, 1999). Work-related MSDs and injuries are also a consistent and sizeable problem for many Canadian provinces accounting for 40 to 60% of all lost-time injuries (WCB Manitoba, 2013; Workers’ Compensation Board of Nova Scotia, 2013; WorkSafeBC, 2013; WSIB, 2013).Thus, the magnitude of the impact of MSDs on workers, employers, health care systems, and society is staggering. Difficulties in the classification and assignment of work-relatedness of MSDs suggest that the reported rates of MSDs are likely underestimated (Van Eerd et al., 2003). Additionally, workers with MSD symptoms and suffering pain at work may not report their condition (Sullivan and Cole, 2002). Thus the burden of disabling musculoskeletal pain and injuries arising from work-related causes in many Canadian workplaces remains substantial.

There are many known occupational risk factors for MSDs including: physical (e.g., heavy physical load, awkward postures, working with arms above shoulder level, repetitive movements, same activity for prolonged periods, vibration, etc.); psychosocial (e.g., psychological demands at work, control at work, social support at work, job satisfaction, etc.); and personal (e.g., years of employment) factors (Bongers, 2006; Van Der Windt, 2000). A multi-causal problem, such as MSDs, likely requires multi-faceted solutions (Amick, 2009). In addition, current practices in the management of MSDs are diverse. These include various interventions in the workplace (e.g., ergonomics training, workstation adjustments, work redesign, etc.), in the clinical setting (e.g., physiotherapy clinic at the worksite), and in disability management programs (i.e., those implemented by employers, insurers and jurisdictions).

One way to address MSDs in workplaces is with an evidence-based practice (EBP) approach. EBP evolved from the evidence-based medicine model which first emerged in the mid-1980s and was clarified by David Sackett in 1996, with the following definition: “the conscientious, explicit and judicious use of current best evidence in making decisions about the care of individual patients. ... [It] means integrating individual clinical expertise with the best available external clinical evidence from systematic research." (Sackett, 1996). Evidence-based approaches should help identify and implement more effective solutions. Optimal EBP employs the knowledge and experience of practitioners along with the most up-to-date evidence from the scientific literature in the context of the client (patient, worker, etc.) to determine prevention solutions.

EBP is the desired approach but there remain research-to-practice gaps. One reason for the gaps is because the necessary research of sufficient quality is not available. This is frustrating for practitioners such as ergonomists.

RESEARCH OBJECTIVE/QUESTION

The research objective is to synthesize evidence from the scientific literature, practice evidence (i.e., workplace policies and practices), and workplace experiences from OHS stakeholders in Ontario and British Columbia (i.e., Occupational Health and Safety (OHS) professionals, disability managers, supervisors/managers, human resource personnel, joint health and safety committee members, labour representatives, and workers).

A second objective is to create a practical guide to support the implementation of effective and innovative MSD prevention programs in workplaces.

METHODOLOGY

This project will build on IWH’s series of published systematic reviews, one in particular by Van Eerd et al., “Effectiveness of workplace interventions in the prevention of upper extremity musculoskeletal disorders and symptoms: an update of the evidence and messages for practitioners” (Van Eerd, 2016), which synthesized the evidence on effective interventions for MSD prevention.

Stage 1: Synthesis of Peer Reviewed Literature

Building on the suite of IWH prevention reviews (Irvin, 2010), we are synthesizing the studies that described details about the implementation of MSD interventions in workplaces. We are paying particular attention to those implemented in small businesses. To do this we are adapting the methods of a previous review by Van Eerd (2010) that answered the following question: “What is the evidence regarding context, barriers and facilitators to the implementation of participatory ergonomic interventions in workplaces that have the intent of improving worker health by attempting to make changes in: i) work processes, ii) work tools & equipment, and/or iii) work & workplace organization?".

However, the evidence from the published literature is only one of the sources of evidence noted in Sackett's (1996) original definition of evidence-based 'practice' (EBP). Sackett clearly noted that practitioner experience/knowledge and client (worker) values were also part of EBP. Therefore, we are supplementing the scientific evidence with current practices and workplace experiences to create a practical and digestible tool for Ontario workplaces.

Stage 2: Gathering current practices and workplace experiences.

Study sample:
Our study sample targets OHS stakeholders working and consulting in Canadian workplaces. The IWH engages regularly with a broad variety of OHS stakeholders in Ontario, Manitoba and British Columbia. For the proposed project, we will gather current practices and workplace experiences from OHS practitioners (i.e., Health and Safety Association consultants, ergonomists, OHS professionals) and workplace personnel (JHSC members, workers and supervisors with OHS roles, including several key small business representatives). To approach these target stakeholders, we are consulting with a stakeholder advisory committee, our current active stakeholder network, and our contact database (which contains approximately 700 contacts who have identified as having OHS roles and are willing to be contacted for research studies).

Data collection:
In order to gather best practices related to implementing MSD interventions we are using the Public Health Agency of Canada's (PHAC) best practices portal to assist us in structuring our dialogue with stakeholders (http://cbpp-pcpe.phac-aspc.gc.ca/resources/planning-public-health-programs/.) The PHAC lists six stages for evidence-based decision making:

1. **Clarify context, assumptions and overall framework for planning**
2. **Collect evidence to support *guide* development**
3. **Design the *guide* based on evidence**
4. Establish indicators of success
5. Develop an evaluation plan
6. Manage the project

Specifically we will adapt the first three stages to gather contextual information, best practices and experiences and develop an implementation guide for MSD prevention.

Procedure for gathering best practices and experiences:
We are using the following methods to engage with our stakeholders and solicit evidence for Stage 2 of this project.

Web based survey.
An online survey has been created and will be available on the IWH website (http://www.iwh.on.ca). We are recruiting survey participants through the help of our various stakeholder contacts as well as a variety of OHS organizations. Potential participants are sent an email inviting them to participate in the web-based survey. The email contains a link to the survey along with opportunities to provide open-ended comments on each item. Email reminders are sent to increase the response rate (Dillman, 2000). Potential participants are asked to read a consent statement and indicate their agreement before participating. Guided by the PHAC approach, the survey includes a brief section on context and demographics (including: sector, company size, respondent job title, job tenure), a section on MSD concerns and previous (or ongoing) interventions (including: who is responsible for implementation, implementation steps, best practices and policy), and finally a section on implementation experiences (including: facilitators and barriers to implementation, program sustainability).

Focus group.
We are also inviting a group of stakeholders to participate in a focus group to discuss best practices within the context of the Ontario prevention system. The focus group will be 90-120 minutes long, facilitated by a knowledge exchange associate (KEA) from IWH. The focus group will be convened with a goal to ask stakeholders about their innovative strategies to effectively prevent MSDs in their workplaces and conducted at a time and place that is convenient to the participants. The structure of the focus group will cover key aspects from the survey (see above) in more depth. The focus group will allow for a discussion about individual as well as organizational best practices. In addition, the participants will be asked to suggest how to improve the prevention of MSDs within their work/job context.

Interviews.
We are also inviting a small sample of stakeholders to participate in an individual interview conducted by a KEA at IWH to better understand their prevention strategies/processes. Those who agree will undergo a 45-60 minute semi-structured interview to discuss their organizations use and development of best practices. The semi-structured interview will explore and focus on participants' implementation experiences, gaps, and what aspects need to be improved. Where it is not possible to arrange for an in-person interview, a telephone interview will be conducted.

<u>Analysis</u>:
The data from the stakeholders will be analyzed in a descriptive way. The focus group and interviews will be transcribed and imported into a qualitative computer software package (NVivo). The transcripts will be analysed by looking for themes that emerge related to implementation of interventions in workplaces. The web-based survey data will also be analyzed descriptively and organized according to the main themes that emerge from the interviews/focus groups.

The data from interviews and focus groups will be transcribed and then reviewed, and analyzed for content, and organized into intermediary matrices (Guest, 2012). Open-ended responses from the survey will also be organized into the matrices. This will allow us to descriptively analyze the content that emerges from the qualitative data collection. Descriptive analysis will be useful in understanding stakeholder views of intervention implementation, workplace experiences, and perceived barriers to implementation. Interview and focus group data will be categorized into salient themes with participants' quotes used to express their experiences about implementation. The analyzed content will be anonymized and presented to the stakeholder advisory panel for review. Results from this analysis, along with the expertise and experience of the stakeholder advisory panel, will form the basis for designing an implementation guide (see below).

<u>Synthesis</u>:
Detailed information about implementation steps from the published review (Stage 1) will be synthesized along with implementation details we gather from OHS stakeholders via survey, interview and focus groups. The synthesis will be guided by the key themes that emerge from the Stage 2 analysis. This ensures that we are guided by concepts and terminology familiar to stakeholders leading to meaningful implementation messages and increased uptake into practice. We will complete the integrated approach by working with stakeholders to develop the guide employing only information meaningful and useful to the implementation of MSD prevention in workplaces.

<u>Products and Guide/Tool development</u>:
After analyzing the results of the focus group, interviews and survey, we will work with our stakeholder committee to develop a guide for the implementation of MSD prevention programs.

RESULTS

Results from a recently updated systematic review revealed 61 high and medium studies addressing MSD. The studies described 30 different intervention categories. There was strong evidence that resistance training has a positive effect and moderate evidence that stretching, using a feedback mouse, and workstation forearm supports have positive effects. However the level of evidence was too low to make recommendations for many other interventions.

Stakeholder feedback to date has provided useful information about terminology, data collection and messaging. We heard that terms such as ‘best practices’ or ‘promising practices’ may be interpreted differently by different audiences. Therefore we are focusing on current practices but collecting data to help us determine which practices are perceived to be useful and effective in prevention MSDs. We were encouraged by our stakeholders to hold joint labour and employer workshops to discuss survey, interview and focus group findings to ensure that the messages from the data are meaningful to all parties. The workshop idea was strongly encouraged and is consistent with a fully integrated knowledge transfer and exchange approach which increases the likelihood of uptake (Keown, 2008).

DISCUSSION

Evidence-based practice entails making decisions about how to promote injury prevention and occupational health and safety by integrating practitioner expertise, worker values, expectations and preferences, and the best research evidence. This is done in a manner that is compatible with the environmental and organizational context (EBBP, 2007). These principles are readily transferable from the clinical setting to a workplace based occupational health and safety setting. The research evidence, by itself, does not make the decision, but it can help inform implementation process. The full integration of these three components into the creation of the guide enhances the opportunity for optimal workplace outcomes (Sackett, 1996).

CONCLUSIONS

With this evidence, we plan to co-create (with OHS stakeholders) a practical guide to help workplaces develop and implement effective practices and policies to prevent MSD and help workers with MSD return to work safely.

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Technical Session 11: Office Ergonomics

Séance technique 11: Ergonomie du bureau

OFFICE ERGONOMICS TRIAGE PROCESS

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KEYWORDS
Office ergonomics, Musculoskeletal Diseases, Employee Empowerment, Remote Consultation, Self-Evaluation

MAIN MESSAGE
An office ergonomics triage process was developed 8 years ago by the Fraser Health Ergonomics Program to maximize resources, efficiently service the geographical area that the Ergonomists have to support and to engage the participants as active members of their office ergonomics education. This triage process also allows us to reduce our time from request to initial contact with the employee.

Le processus de triage en matière d’ergonomie du bureau

MOTS-CLÉS
Ergonomie du bureau, troubles musculosquelettiques, responsabilisation des employés, consultation à distance, autoévaluation

MESSAGE PRINCIPAL
Il y a huit ans, un processus de triage en matière d'ergonomie du bureau a été mis au point par le programme d'ergonomie de Fraser Health afin de maximiser les ressources, de servir efficacement les employés dans les zones géographiques soutenues par les ergonomes, et d'amener les participants à jouer un rôle actif dans leur formation liée à l'ergonomie du bureau. Ce procesuss de triage permet également de réduire notre temps entre la requête et le premier contact avec l'employé.

PROBLEM

Risk factors related to musculoskeletal injuries (MSIs) in office work include sustained non-neutral postures of the upper limbs, prolonged sitting while using the computer, and awkward postures of the head and neck. Work characteristics associated with MSIs appear to be multi-factorial in nature and include design features of the workspace, hours worked at the computer, and a variety of psychosocial factors (Robertson, Huang & Larson, 2016). These risk factors can have a large impact on the number of MSIs reported with computer use as the number of workers using computers in the workforce has increased in the last 20 years (Marshall, 2001; as cited in Sonne & Andrews, 2012). Computer use is also increasing in healthcare as more technology is moving to online formats. In Fraser Health, there are over 160 employee requests for individual workstation assessments annually.

In healthcare, the most commonly reported injury type is MSI. In 2016 in Fraser Health, 50% of reported incidents and 65% of claims were MSIs. When looking at the injury mechanisms associated with MSIs, the top three were patient handling (40% of claims), slips/trips (20% of claims) and material handling (15% of claims). Incidents reported due to office ergonomics were low (less than 0.1% of reported incidents and claims).

As part of the office ergonomics program, the following initiatives are in place:

- Computer workstation standards have been developed for new builds and renovation projects; the standards include options for furniture configurations based on ergonomics guidelines
- Information on the intranet “Office Ergonomics” page is available including recommendations for commonly ordered items including chairs, and contacts for furniture and computer equipment moves
- Education resources are available on a variety of topics including how to adjust office equipment, using a laptop, tips for using a mouse, and eye tips for computer users
- An interactive, online workstation self-assessment tool is available for employees to access

The workstation self-assessment tool was originally designed as a proactive tool for employees to assess and make changes to their workstation when they are new to the organization or have moved workstations. The Ergonomics team decided to incorporate the use of the self-assessment tool as a first step when an employee was requesting assistance due to issues or concerns with their workstation (as a reactive tool). It should be noted that this tool is used to educate employees on basic ergonomics principles of workstation set up and is not intended to be used for specific employee accommodations.

Prior to implementing this as a first step, an ergonomist would perform a site visit for any employee experiencing MSI signs or symptoms, however this proved to be problematic:

- Our incident and claim data supports the need to focus on patient handling as an organizational priority
- As the number of employees within our organization grew and as the number of requests for workstation assessments grew (35-50% per year from 2010-2012), the team was challenged to keep up with the volume of work and respond in a timely fashion
- On-site computer workstation assessments are time consuming due to time for assessments (conservatively estimated at 30 min.), time for documentation (estimated at 30 min.) and time associated with traveling to various locations (average 1 hour to and from site)
- We were receiving repeat requests for office workstation assessments when employees moved offices or when their workstation was adjusted when someone temporarily used their workstation

The Ergonomics team decided to implement a multi-step process for office ergonomics assessments to empower employees to learn and make changes to their workstations. Engaging the participants has been described as empowerment learning and is considered the optimal method for adults to learn and facilitate changes in work behaviour (Bohr, 2002).

CONTEXT

Fraser Health services 1.8 million people living in communities in southwestern BC (Lower Mainland), stretching from Burnaby to White Rock to Hope. Within Fraser Health, there are over 25,000 employees providing services at more than 200 locations including acute care hospitals, residential care facilities, and mental health care, public health and community care sites.

The Ergonomics Program team at Fraser Health is within the Workplace Health department. The goal of the program is to optimize the health and well-being of our employees, including reducing musculoskeletal injuries. Patient handling injuries are the number one source of injury to our employees, therefore the primary focus of the ergonomics team is on our safe client handling program. In spite of negligible claims and costs associated with office ergonomics, our team receives over 160 requests per year for office workstation assessments. As we want to support all employees yet add value to the organization, we have looked to streamline our processes for office ergonomics requests.

ACTIONS

A triage process was created to efficiently manage and document the office ergonomic assessment requests and allow us to focus our efforts on our program mandate of supporting safe patient handling practices for Fraser Health. Figure 1 outlines the process - this information is posted on our intranet site for employees to access.

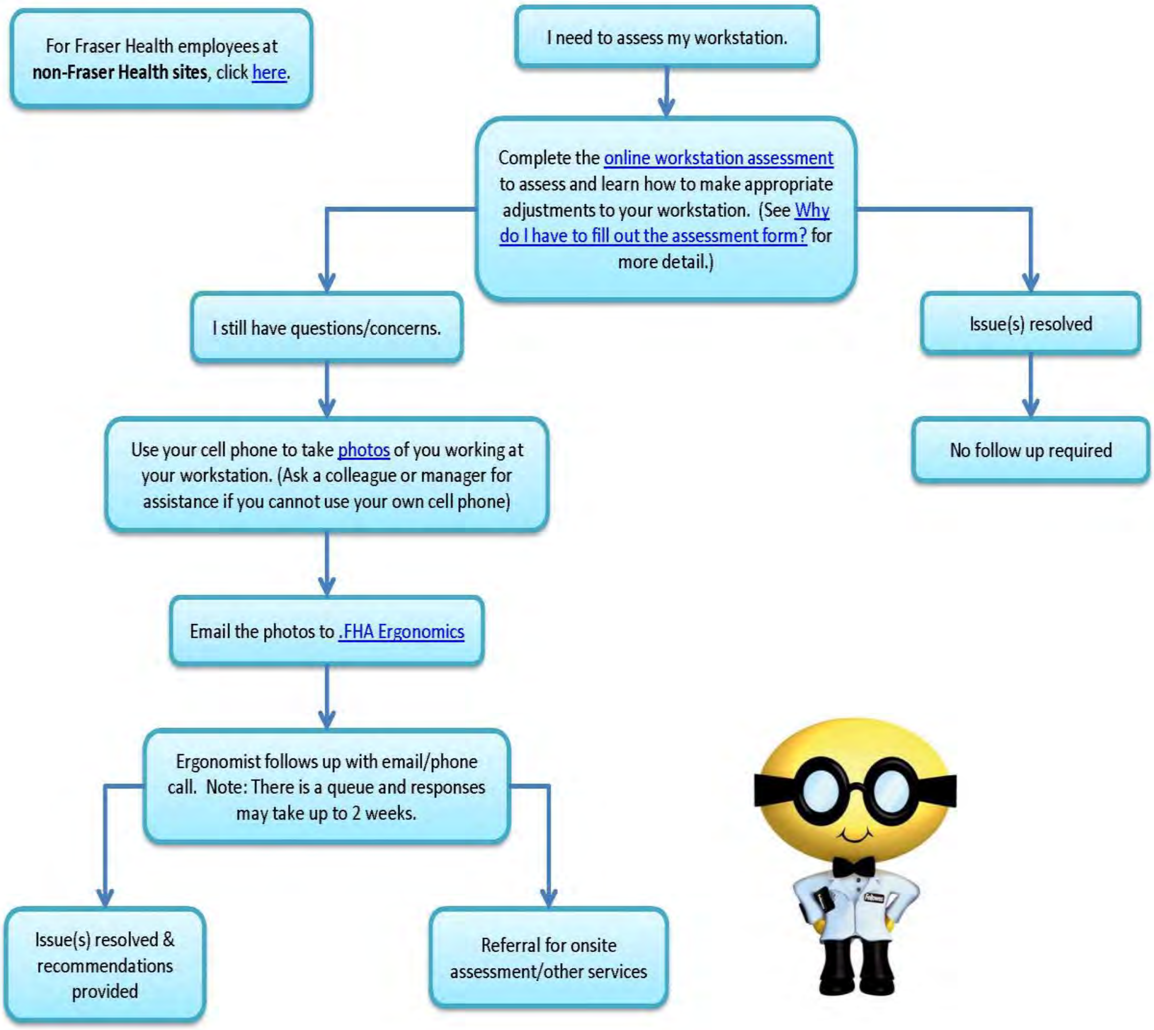

Figure 1: Office Ergonomics Triage Process

When employees initially request a workstation assessment for any reason, they are directed to complete the online workstation assessment tool, which is an online survey (or paper survey when requested) that walks them through the basics of setting up their workstation based on ergonomic principles.

The tool begins by asking for employee contact information, what have they done to manage their concerns (e.g. have they informed their manager, seeking medical treatment, etc.), what they feel would improve their workstation, and location and severity of pain. This is followed by a series of questions about how their computer workstation equipment is set up and can be adjusted.

The tool is interactive and directs staff to our developed office ergonomic resources based on their responses. For example, if the employee indicates that their back is not supported by their chair's backrest, a pop-up provides information on how to adjust the backrest.

If the employee still has questions or concerns after completing the workstation assessment tool, they are instructed to email a photo of themselves sitting at their workstation (See Figure 2). The photo provides the Ergonomist with visual information about the equipment used at the workstation and how that equipment is fitting the employee. When the online workstation assessment tool has been completed and a photo is received, the employee is contacted by an Ergonomist to schedule a phone assessment.

Figure 2: Workstation Photo Example

The phone assessment is conducted to provide the employee with straightforward recommendations on adjustments and/or equipment purchases for their workstation and/or provide the Ergonomist with more details about the employee's concerns. If a phone call cannot be scheduled, initial recommendations are emailed to the employee. If the concerns cannot be resolved remotely (by phone or email) then the Ergonomist refers the request to the Ergonomist responsible for that location for an on-site assessment or to other services (e.g. Disability Management program, etc.).

The Ergonomist completing the onsite assessment is provided with the information that has been already collected so they are able to focus their time on the employee's primary concerns during the site visit. All recommendations from the phone and on-site assessments are documented and copies are emailed to the employee and manager for discussion. This helps facilitate communication between the manager and employee and supports the employee with making requests for changes to their workstation. All communication is charted in our internal system for reference.

It is important to highlight that in conjunction with this process, the Ergonomics team has established furniture equipment standards to ensure quality and consistency across the organization. Resources on how to use and adjust the equipment were developed and processes for ordering were established. Having furniture equipment standards makes resource development easier, as detailed directions can be included on how to make adjustments to the equipment that the majority of staff will be using.

OUTCOMES

The number of requests for assistance received by the Ergonomics Program team, phone assessments and on-site assessments completed are tracked in a spreadsheet for the purposes of reporting out. Since 2010 when tracking began, over 2000 employees have completed the online workstation assessment tool and numbers continue to increase annually. There has also been a corresponding increase in the number of employees requesting assistance after completing the survey, moving from an average of about 130 per year in 2012 and 2013, to 160 in 2015 and 2016 (more than 3 per week).

See Figure 3. The trending shows that:

- consistently about 55-60% of the requests are resolved from completing the online workstation assessment tool alone
- over time, there has been an increase in percentage of concerns resolved by phone or email
- over time, there has been a corresponding decrease in percentage of site visits being conducted

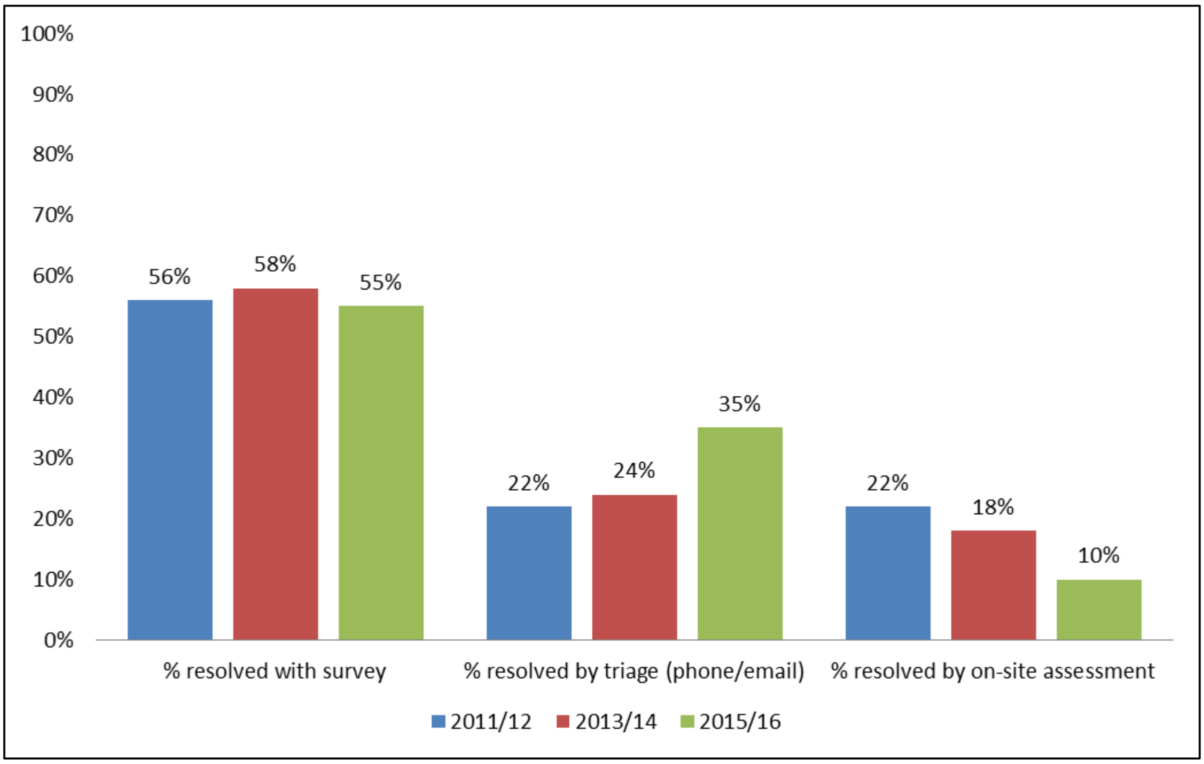

Figure 3: Office Ergonomic Assessment: Resolution Outcomes

There are time savings with this process as we are only completing an average of 30-35 on-site computer workstation assessments per year. 67% of remote assessment outcomes are for straightforward equipment recommendations (e.g. footrests, chairs, document holders, etc.) We are able to support employees in a more timely fashion as remote assistance can be scheduled faster than on-site assistance.

In November 2016, the latest version of the workstation assessment tool was re-created when we moved to a new online survey platform. At this time, we added a question for employees to rate the effectiveness of the tool. Since this time, the overall average effectiveness rating is 2.8 out of 5 (for all respondents). For those employees requesting additional assistance, the rating of effectiveness is 2.7, and for those that did not require additional assistance, the rating is 3.7. Comment details are reviewed periodically and suggestions are implemented within the tool to improve the content.

DISCUSSION

As our organization moves towards more mobile workers, the number of shared and drop-down workstations is increasing making it important to engage employees as active members of their office ergonomics education. The workstation assessment tool accomplishes this and empowers employees to apply the learnings to any workstation they use (e.g. at work, home, etc.). This process allows the Ergonomics Program team to efficiently manage the office ergonomic requests and focus on our program mandate of supporting Safe Client Handling practices in the organization. This is also reflected in our claims costs as injuries related to patient handling is number one in our organization and claims costs related to office ergonomics is very low.

Additional benefits of this process include being able to provide assistance to staff in a timely manner, being available to refer staff to appropriate resources and supporting managers to make financially responsible decisions on equipment purchases.

In the beginning, implementation of the process was a challenge. It was difficult to overcome staff perception that an onsite assessment was required to address their concerns. Employees often put up barriers for completing the online workstation assessment and sending photographs. It was time consuming to enforce the process and reiterate the reasons for following it, but over time this has become less of an issue, perhaps as employees become more accustomed to the process.

We continue to be challenged managing the increasing numbers of requests we receive. Our team has had to increase the Ergonomic support provided for remote assistance to accommodate for this but we are also able to decrease our time managing onsite assessments. Another challenge is that it can sometimes be difficult to support staff with implementation of the recommendations as it is a department's responsibility to do so. This can be especially difficult if a renovation is needed to improve an area and is likely to be implemented only as a longer term solution.

As a support service for employees we also receive requests for office ergonomic assessments when the underlying issue may not be related to workstation set up. These types of requests can be difficult to manage as the employee may require support beyond our program's capability. We can assist by referring them to other support services and to discuss their concerns with their manager.

We are continuing to measure, assess and improve our process. As technology changes and becomes more accessible, we hope to increase the interactivity of our resources (e.g. online videos, learning modules, etc.)

CONCLUSION

For our organization based on our program mandate and injury data we feel our office ergonomic triage process is effective and efficient. The triage process provides a timely service for staff, provides efficiencies for the Ergonomists in providing support and empowers staff to learn and facilitate changes with their own workstation set ups.

It is important for us to be consistent and diligent with adhering to this process. Ongoing measurement and improvement of the triage process continues including incorporating feedback from staff.

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AN ACTIVITY BASED FLEX OFFICE – PLANNING PROCESSES AND OUTCOMES

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KEYWORDS
Activity-based office, design, employee involvement, satisfaction, perceived performance.

SUMMATIVE STATEMENT
This longitudinal case study addresses activities used in the planning process of a new activity based flex office (A-FO), and addresses results after the relocation. The results show that several activities were used to involve employees in the planning process. Employee satisfaction and perceived performance were rated in more positive terms after the relocation than before. The company's process can be considered as a good example of planning and design processes.

Un bureau flexible : le processu de planification et les résultats

MOTS-CLÉS
Bureau flexible, conception, participation des employés, satisfaction, rendement perçu

SOMMAIRE
Cette étude de cas longitudinale porte sur les activités utilisées dans le processus de planification d'un nouveau bureau flexible basé sur les 'activités et aborde les résultats après le déménagement. Les résultats montrent que plusieurs activités ont été utilisées pour faire participer les employés au processus de planification. La satisfaction des employés et le rendement perçu ont été évalués comme étant plus positifs après le déménagement qu'avant ce dernier. On peut dire que le processus de l'entreprise reflète un bon exemple de planification et de processus de conception.

PROBLEM STATEMENT
There is a trend to implement activity based flex offices (Appel-Meulenbroek et al., 2011; Seddigh et al., 2014; Vos & van der Voordt, 2002). The idea of the activity-based flex office (A-FO) is not only to change the physical office design but also to change workstyle. Thus the concept challenges daily norms and routines on how to perform work (van Koetsveld & Kamperman, 2011). However, few studies declare the benefits and drawbacks following relocation and the results are inconsistent (de Been & Beijer, 2014; van der Voordt, 2004). A reasonable assumption is that the planning process and implementation strategy affects employee satisfaction with the A-FO, as well as of individual and group performance (Meijer et al., 2009). To our knowledge there is a lack of longitudinal studies that address the planning process, especially the early stages, of A-FOs.

RESEARCH OBJECTIVE
The aim of this study is twofold: (i) to describe activities and procedures used in the planning of an activity based flex office (A-FO), and (ii) to explore how satisfaction and performance are perceived before and after relocation from a mixed office to an A-FO.

METHODOLOGY

Setting

The study was conducted at an IT service company, located in the outskirts of Nässjö, a small-sized Swedish town, whose goal was to become the best workplace in Sweden. In 2013 the company discussed new office premises and choice of office type. At that time the workforce consisted of employees, managers and owners, with a total of 4 females and 31 males. Units consisted of consultant support, in-house IT support, IT-development, hardware sales, stock, and support functions such as administration and management. A majority of the workforce served as consultants in other organizations and was present in the office one or two days/week. The company anticipated growth and consequently an insufficiency in office space. The premises consisted of mixed offices; cell offices (7 employees), shared offices (12 employees), and small office landscapes (13 employees). Four consultants did not have their own workstation. Reconstruction of the existing premises was examined but excluded as an alternative due to a high cost-benefit ratio.

Research approach

A mixed method strategy with data triangulation was applied for this longitudinal interactive case study. The researchers took an initiative to a first meeting and thereafter the company initiated collaboration in this interactive study. An overview of research methods and company activities is shown in table 2. The research was conducted through work analysis, questionnaires, interviews and documentation. The interactive work analysis inspired by De Keyser (1991) was facilitated by the researchers and conducted by the workforce. The work analysis was performed in the initial stage of the company's planning process (thus described in section "planning processes and activities") and included beehive workshops, focus groups interviews, diaries, and questionnaires. The rest of the process was monitored by questionnaires every 6 months (Figure 1). Questionnaire results were fed back, interpreted and discussed with the company. The planning process was further monitored through documentation, observations and individual interviews with the project leader, owner and CEO. Digital communication such as the company's web page and blog was documented as well as their internal project site for the new office. Blueprints and other written documents concerning the planning process and design were studied. Project manager and owner were interviewed at the company's office and telephone meetings and e-mail correspondence kept the researchers updated. Moreover observations of the premises and workshops, and photographs were taken at the premises.
The researchers were also involved in a post-relocation evaluation with observations and 45 individual interviews with the workforce (90% participated) nine months after relocation. Questionnaire 4 and 5 were distributed three and nine months after relocation. An oral presentation for the workforce of the evaluation, initiated a post-relocation follow-up group. This paper presents questionnaire results for the evaluation of perceived change in satisfaction and performance.

Table 2. Overview of the planning process, with methods facilitated by researchers (R) and activities conducted by the company (C).

Autumn 2013		**Spring 2014**		**Autumn 2014**		**Spring 2015**		**Jun**	**Sep**	**Autumn 2015**		**Spring 2016**	
● Work analysis ● Feedback on flowchart ● Repr. visit ref. site ● Wall of inspiration	R C C C	● Deciding office concept ● Workshops ● Questionnaire 1	C C R	● Groundbreaking ceremony ● Kickoff and workshop ● Questionnaire 2	C C R	● Interior design group work ● Questionnaire 3	C R	**Relocation planned**	**Relocation executed**	● Questionnaire 4	R	●Questionnaire 5 ● Individual interviews ● Observations	R R R

Questionnaire study

The purpose of the questionnaire study was twofold: (i) to follow-up on perceptions of the current and future office during the change journey (ii) to compare satisfaction, health and perceived productivity pre- and post-relocation. All questionnaires regarded satisfaction with office characteristics, office type preference, distractions, overall performance, and health and well-being. Questionnaire 5 also included perceived change of different parameters from their previous office to the present office. In this paper 14 questions have been selected from the full questionnaire. The longitudinal questionnaire study consisted of 5 web-based questionnaires; 3 pre-relocation and 2 post-relocation (Figure 1). Every May in 3 consecutive years, starting in 2014, large questionnaires (96-138 questions) were distributed. Between these 2 smaller (38-41 questions) questionnaires were distributed in early December.

Figure 1. Time of distribution of the longitudinal questionnaire study

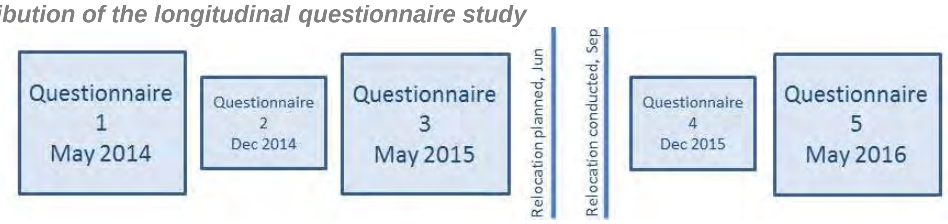

Table 32. Response rate of the longitudinal questionnaire study.

	Questionnaire 1	Questionnaire 2	Questionnaire 3	Questionnaire 4	Questionnaire 5
Employees	37	40	44	49	50
Complete responses	34	28	38	41	45
Response rate	92 %	70 %	86 %	84 %	90 %

All employees, managers and owners at the company were included in the questionnaire sample. The number of employees in the workforce at the company increased from 37 in May 2014 to 50 in May 2016 (Table 1). The response rate was on average 84 % (Figure 1 for details). During the three year study period 23 people were employed and 11 seized their employment. Of the 28 people that were employed during the entire period, 16 (57 %) responded to all five questionnaires. A descriptive statistics analysis was conducted in SPSS for each measurement on the whole population as well as on the 16 respondents that responded to all questionnaires. Moreover a one-sample t-test and multivariate regression analysis was conducted on the final questionnaire (n=45).

RESULTS

Planning processes and activities

The planning activities (Table 3) can be divided into three general aims; 1) deciding office concept, including work analysis 2) designing the physical environment, and 3) designing the organizational and social environment. Vision of the future office, analyses, problem solving and reviewing were iterated while the concept evolved from idea to detailed physical, organizational and social work environment. Interviewees reported that all employees were encouraged to participate in all activities and be involved in the planning process in at least one way. Groups were formed with different responsibilities to make the planning process manageable; a reference group with an internal employee as project leader, an IT group, and an interior design group, consisting of employees from the company, local interior designers and ergonomists.

Table 3. Planning activities divided by aims of analyzing the existing work processes, and designing the physical, organizational and social environment.

Work analysis (base for deciding office concept)	Designing the physical environment	Designing the organizational and social environment
Beehive workshops, Focus groups interviews, diaries, Questionnaires	Reviewing documents (employees and external experts) Reference site visits Wall of inspiration Model Workshops	Workshops - codes of conduct - concerns and problem solving Focus group interviews Ground-breaking ceremony Lecture on giving feedback

Deciding office concept and work analysis activities

According to online documents the owners were inspired by a visit to reference A-FO site in May 2013 and initiated a change process with discussions on relocation objectives. Interviewees report that the decision to implement an A-FO depended on the match between work activities undertaken at the company and the design of such A-FO, as well as employee support to the concept.

In September 2013 the work analysis was conducted in order to understand the needs of the employees regarding the layout and desirable design of the new office. Four groups were formed by the company, each responsible for separate functions in the organization with their unique wishes and needs for a satisfactory work environment. The four groups were administrative personnel, IT-support personnel, management and IT-technician personnel. Methods in the work analysis included beehive workshops, focus groups interviews, diaries, and questionnaires. The beehive workshop gathered all activities performed at the company. The focus group interviews regarded needs, stressful situations and quality defects. The diaries mapped the occurrence of the activities. Based on focus group results with the respective group and individual diaries regarding work activities, needs were compiled by the researchers. In order to validate the needs a questionnaire was used to follow up by assessing extent of the needs. To further validate the work analysis the results were presented and discussed with the personnel at a work meeting. Thereafter the work analysis was presented and handed over to the architects in a collaborative meeting with project managers, researchers and architects. In November 2013, the architects delivered a flowchart (Figure 2) based on the work analysis. Interviewees report that the design seemed to match the work activities and employees seemed to support the concept. Thus, in the spring of 2014, the decision was taken to implement the A-FO concept.

Activities for designing the physical environment

The physical design process involved reviewing documents, reference site visits and a wall of inspiration, according to observations and digital communication. In a workshop the employees reviewed the match between flowchart and work processes and questioned “is this design what we want?”. Workforce thoughts and desired adjustments of the flowchart were fed back to the architects. Next, a blueprint (Figure 2) was received and reviewed by the workforce, the researchers and other experts within different fields (e.g. acoustician, lightning expert, safety engineer, and ergonomists). A physical model (Figure 2) was placed at the entrance of the premises in order to remind the workforce and create a desire for their future work environment.

Figure 33. Flowchart, blueprint and model of the A-FO.

To further inspire and spur innovative problem solving employees from each unit visited an A-FO reference site. Thoughts were shared with the rest of the company. A wall of inspiration was used to initiate discussions on different concepts and ideas. All employees were encouraged to add items.

Activities for designing the organizational and social environment

Workshops were held to deal with concerns of the employees, anticipated problems, problem solving and new ways of working. Concerns included filing, office use, privacy, control and IT problems. Innovative solutions and feedback were encouraged by management throughout the project. Employee concerns were also discussed in focus groups conducted by the researchers in the spring 2014. Possibility to anonymously express concerns was given in questionnaire 1, 2 and 3.

In early autumn 2014 all employees dug in a ground-breaking ceremony, to collectively feel anticipation of the new office, and participated in a kickoff workshop where discussions on codes of conduct were introduced. Several workshops (facilitated by employees) continued discussions on codes of conduct in smaller groups. For example it was discussed where interaction was allowed and encouraged, where interruptions and telephone conversations were forbidden, whether or not it was allowed to occupy the same desks in consecutive days. Decided codes of conduct were presented orally at a weekly meeting and up-loaded to the intranet. In addition a lecture and workshop on giving feedback was given.

Employee performance and satisfaction after the relocation

Perceived performance

The descriptive analysis of questionnaire results showed a higher mean perceived productivity rating after the relocation to the A-FO than in the mixed office, for both the whole (n=28-46) and matched populations (n=16). Also, the mean distraction was rated lower after the relocation (Figure 3).

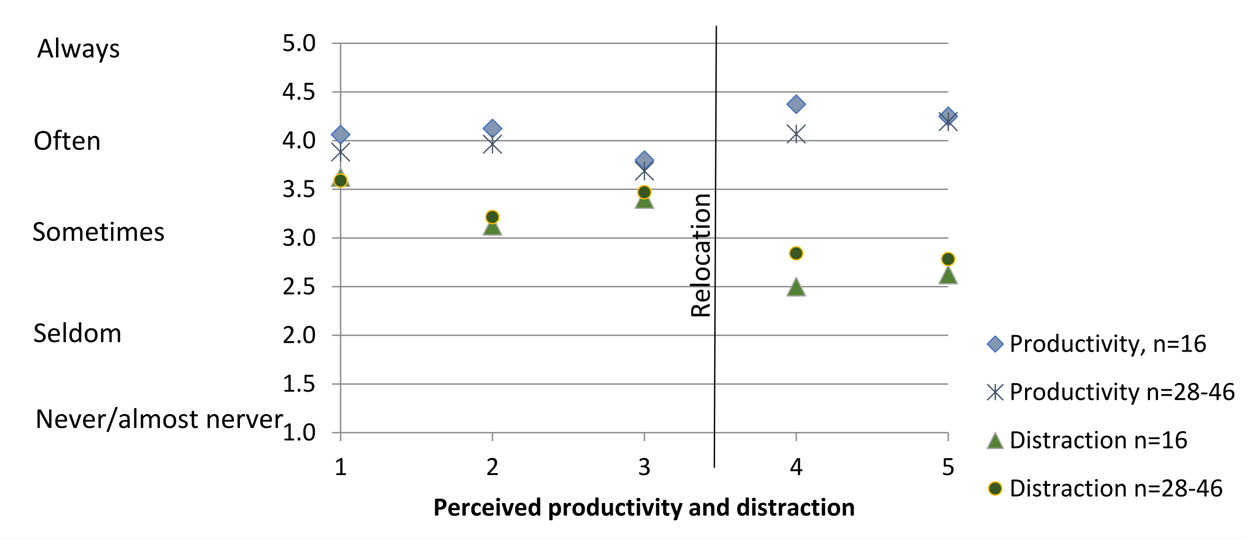

Figure 34. Mean perceived productivity ratings before and after relocation (blue), measured in commonness of being able to be productive at the workplace. Mean distraction before and after relocation (orange), measured in commonness of not being able to fully concentrate on the task at hand. The scale ranges from 1=Never/almost never to 5=Always.

At the last measurement (questionnaire 5), one sample t-test showed that employees perceived their ability to work in the A-FO as good, rather than neutral or bad ($p<0.001$). T-test also showed a significant perceived increase in efficiency of cooperation ($p<0.001$) but no significant perceived change in individual efficiency of work ($p=0.17$). Moreover, t-test showed that the majority of the employees agreed that the post-relocation office design matched their work tasks ($p<0.001$).

Satisfaction

The descriptive statistics analysis of the questionnaire results showed higher mean overall satisfaction ratings with the physical environment after the relocation from the mixed office to the A-FO, for both the whole and matched populations (Figure 4). T-test of the final questionnaire confirms that the majority of the employees were satisfied with the physical work environment, rather than neutral or dissatisfied ($p<0.001$). Three employees were dissatisfied with the physical work environment.

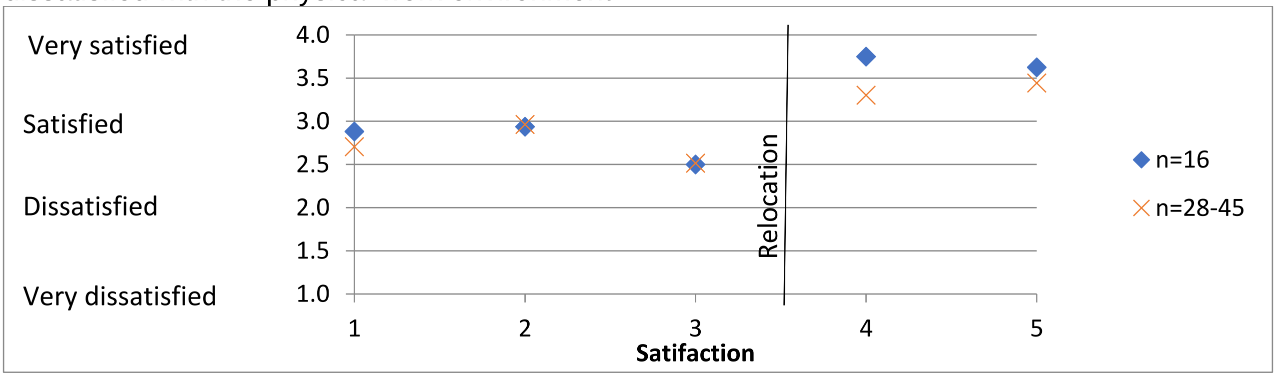

Figure 35. Employee satisfaction with the physical work environment before and after relocation on a scale from 1= very dissatisfied to 4=very satisfied.

Predictors of perceived performance and satisfaction

In the final follow-up questionnaire (questionnaire 5) t-test showed that the A-FO layout and design was perceived as inspiring ($p<0.001$), pleasant ($p<0.001$) and well-ordered ($p<0.001$) rather than boring, repulsive and messy by an absolute majority of the 45 respondents (Figure 5). Moreover, employees perceived the A-FO as calm rather than stressful ($p=0.02$), pulsating rather than calm ($p<0.001$) and exposed rather than private ($p=0.01$). Responses regarding the office's sound level (noisy/quiet) were equally distributed ($p=0.59$).

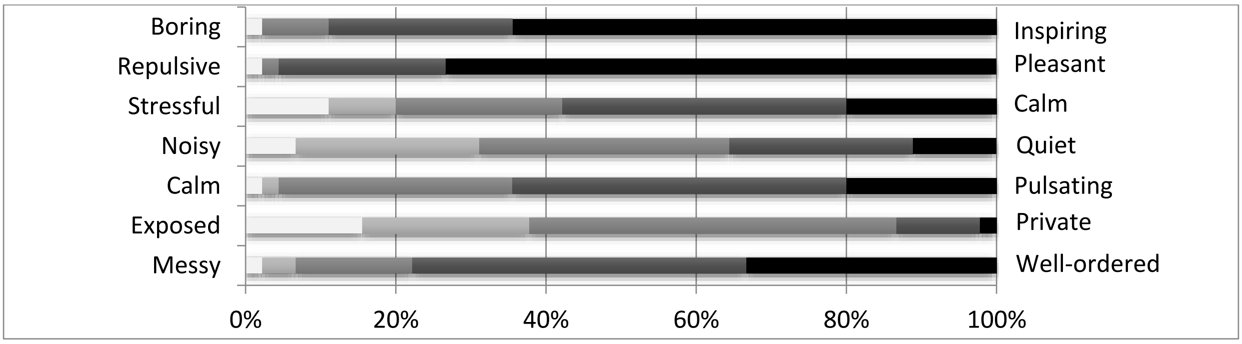

Figure 5. Perception of the office environment on 5-point scales.

The multivariate regression analysis showed that satisfaction with the physical work environment could be predicted by how inspiring/boring (b= 0.43, $p<0.001$) and well-ordered/messy (b= 0.30, $p<0.001$) the office was perceived ($R^2=0.72$).

DISCUSSION

This case study describes a planning process of activity-based flex offices with positive outcomes regarding employee satisfaction and perceived performance ratings. Perceived performance and satisfaction with the physical work environment increased while distraction decreased. Decreased distraction is consistent with the findings of Seddigh et al. (2014). Research has shown no or limited effects of A-FO on perceived productivity (Meijer et al., 2009; Wolfeld, 2010), thus further studies are needed. Increased satisfaction with the office is consistent with previous research findings (C. B. Danielsson & Bodin, 2008; Vos & van der Voordt, 2002).

The new A-FO was perceived as inspiring, pleasant, calm, pulsating, exposed and well-ordered. Ratings on perceived noise/quiet were equally distributed. The regression analysis showed that employee perception of inspiration/boredom and well-ordered/messy in the office environment substantially predicted the variation of satisfaction with the physical work environment in the A-FO. In this case study the aesthetics (inspirational, pleasant, well-ordered) of the office were better predictors of satisfaction with the physical work environment than noise level found in other studies (C. Danielsson, 2005; Rolfö & Eklund, 2015).

The planning process and activities performed during the process may contribute to the successful ratings. Rather than copying and mimicking other organizations, the work analysis activities (beehive workshop, focus groups interviews, diaries and questionnaire) created a thorough and validated list of needs and activities, originating from the company's own foundations, which was used as a requirement specification for the new office concept. The work analysis seemed to be adequate and well communicated, as the office design matched the work tasks, according to the questionnaire responses. Moreover the work analysis made the employees think about their way of working and improvement opportunities. The importance of having a thorough analysis of the existing office is emphasized by van Meel et al. (2010).

The activities also involved and engaged the employees throughout the planning process. The work analysis enabled early employee involvement, even before the decision of office type was decided. That the employees could, during the activities, express their office type preference and objections, rather than the decision being forced on them may be a strong satisfaction contributor. User particpation in the design process, enabling psychosocial control, has been shown to contribute to satisfaction of the workplace (Veitch & Newsham, 2000; Vink et al., 2006), and feelings of belonging and ownership (Vischer, 2008).

Activities, such as workshops, beehives, focus groups, forming of work groups stimulated interaction within the company. Van Koetsveld & Kamperman (2011) stress the importance of interaction for changing workstyle in A-FOs. Moreover, according to Broberg et al. (2011) visualization methods and mediating objects (such as blueprints, models and a wall of inspiration used in this case) facilitate and encourage employees to get involved, ideate, consider different solutions, share thoughts and spur spontaneous initiatives. The facilitated interaction, through the activities and mediating objects may be contributors to the positive outcomes.

Other contributing factors to the high satisfaction and perceived performance ratings in the planning process could be the high ambition with clear goals and the planning duration. The company aimed at becoming the best workplace in Sweden, an ambition indicating that the company valued its workforce. Van Meel et al (2010) and van Koetsveld & Kamperman (2011) stress the importance of having clear goals for successful outcomes. The planning duration, a 2.5 years long planning process, was likely enough time for the workforce to accept the idea and recognize advantages that contributed to the high satisfaction ratings. Further investigation is needed to examine the various factors' contribution to the successful outcomes.

The mixed methods approach attempted at reaching a detailed comprehension of the planning process. The interactive study was useful as the researchers could learn about the organization and the planning process during the facilitation of workshops and by reactions to feedback that the researchers provided. The longitudinal study enabled comparison over time, and the possibility to study the whole process, from knowledge base for decision making, to a post-relocation evaluation, with sufficient time for the workstyle to settle in the new office environments. For the evaluation t-tests were performed only on symmetrical Likert scales as these have been shown to generate similar results as interval scales (Traylor, 1983). The evaluation also included a regression analysis. The results points in the same direction giving the results robustness. However three employees were dissatisfied with the physical work environment. All results are significant on a 0.01 level (or smaller) implying low risk for incorrect conclusions.

CONCLUSIONS

In conclusion this longitudinal case study describes a thorough planning process of an activity-based flex office with high employee participation, and explores outcomes after the implementation. Activities performed in the planning process supported analysis of the existing work processes, involved employees at the initiation of the planning process and throughout the process, and facilitated interaction within the company.

Employees' perceived performance and satisfaction with the physical work environment were higher while distraction was lower after the relocation compared to before. The new activity-based flex office was perceived as inspiring, pleasant, calm, pulsating, exposed and well-ordered. Employee perception of inspiration in the office environment and how well-ordered it is, substantially predicted the variation of satisfaction with the physical work environment in the activity-based flex office.

The vast majority of the employees rated the activity-based flex office in positive or very positive terms. The company's process can be considered as a good example of planning and design processes.

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POLICIES FOR SHARING WORKSPACES IN ACTIVITY-BASED FLEX OFFICES

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KEYWORDS
Rules, codes of conduct, activity-based office, desk-sharing, speech level

SUMMATIVE STATEMENT
Policies for maintaining non-territoriality (desk-sharing and clean desk policies) and for maintaining zones with different sound levels vary between activity-based flex offices. Five policies were identified as crucial for making the activity-based office concept work. In cases without explicitly expressed policies employees reported uncertainties and interpretations of how to act in the office.

Des politiques pour le partage des espaces de travail dans les bureaux flexibles

MOTS CLÉS
Règlements, codes de conduite, bureau basé sur les activités, bureau partagé, niveau vocal

PROBLEM STATEMENT

Today many companies implement non-territorial activity-based flex offices (A-FOs) with different satisfaction outcomes (Appel-Meulenbroek et al., 2011; de Been & Beijer, 2014; van Koetsveld & Kamperman, 2011). The A-FO concept is intended to provide a variety of workplaces for various activities (Brunia et al., 2016) and is usually dimensioned for 70 % of the workforce (Danielsson & Bodin, 2008). The A-FO also aims at stimulating interaction (de Been & Beijer, 2014) and new ways of working (van der Voordt, 2004) where the employee determine where, when and how to carry out work activities (Appel-Meulenbroek et al., 2011). Individual interaction is, according to Porras and Robertsson (1992), the most difficult aspect to change in an organisation. Moreover, changing the ways of working and behaviour is difficult to maintain (van Koetsveld & Kamperman, 2011).To achieve this change and to ensure the rotation of employees in A-FOs, a desk-sharing or hot-desking policy is applied (Knight & Haslam, 2010). In offices that follow a desk-sharing policy, workstations are taken on a 'first-come-first-served basis' and users are required to follow a clean-desk policy i.e. leave the workstations clean after use (ibid.). However policies can range from written to unwritten ones (van Koetveld & Kamperman, 2011) and the duration of using a workstation and the frequency of changing workstations, are not elaborated on in previous studies. In addition, case studies present A-FOs with spaces designated for different types of work such as concentrated work and interactive work. Speech policies vary between these types of spaces. There is a lack of studies comparing speech policies in different A-FOs.

RESEARCH OBJECTIVE/QUESTION

The focus of this paper is the use of different desk-sharing and speech policies in activity-based flex offices. The aim is to identify and compare explicit and implicit policies.

METHODOLOGY

105 semi-structured interviews were conducted at four case organisations (table 1) that had relocated to A-FOs: two cases with explicitly written and two cases with implicit and unwritten policies. In addition, written policies were collected from the process managers at each case organisation. All employees at respective organisation were invited to interviews and could sign up for participation. The interviews were held at least two months after relocation at the respective organisations' premises and lasted on average 30 minutes. All interviews addressed background information, work tasks, office use, and strengths and weaknesses regarding work conditions. The interviews were audio recorded and transcribed verbatim. A thematic content analysis of the transcripts was conducted jointly by the authors and facilitated by a qualitative data management tool (NVIVO).

Table 1: Type of organisations, number of employees, employee mean age, gender distribution and number of interviewees at respective case.

	Company 1 (C1)	Company 2 (C2)	Company 3 (C3)	Company 4 (C4)
Type of organisation	Knowledge and training provider	ICT service and support providers	Insurance company	Science park
Total employees in the A-FO	40	49	79 (+20 consultants)	13 (+30 external stakeholders)
Number of interviewees	24	43	26	12
Age, mean (min-max)	50 (37-65)	38 (23-61)	43 (31-60)	47 (27-65)
Gender Female/Male	20/4	5/38	10/16	7/5

RESULTS

The identified policies that addressed desk-sharing were: (i) to remove belongings, (ii) to use the same desk in consecutive days and (iii) to use scarce zones. Furthermore, speech and interruption policies were identified: (iv) to be quiet in designated zones, (v) not to talk on the phone in designated zones, and (vi) not to interrupt coworkers in designated zones. The policies had varying clarity and varying levels of restrictions/constraints in the different cases e.g. desk use duration.

Desk-sharing policies

Desk-sharing policies, or clean desk/hot desking policies, were used at the cases for maintaining non-territoriality. The policies regarded duration of attending the same workstation in an open area or in a scarce zone in consecutive days, or duration of unattended use of a workstation.

To remove belongings

To remove belongings addressed clearing the workstations when finished and the duration in which the desks were allowed to be claimed but unattended. This was the only common rule across the four cases. At the knowledge providing company (C1), the employees were explicitly required to remove their belongings by the end of the day. However, at the ICT support company (C2) the duration of unattended use was limited to two hours. Their written rule statements explained that 'We want our workstations to be as available as possible. Therefore it is suitable to remove your belongings from the workstation when you plan to be absent more than 2 hours so that your colleague can use it'. The interviewees at the insurance company (C3) reported various restrictions on the duration of unattended use (between 30 minutes and 3 hours), thus implicit and ambiguous policies were present: 'There is no rule regarding the duration of absence from a desk before I should clean it up so that someone else can use it' (I8-C3). At the science park (C4), the employees were allowed to book the workstations for duration of two days.

To use the same workstation in consecutive days

To use the same workstation in consecutive days addressed the duration of using the same work desk. This policy was not explicitly documented in any of the cases. The interviewees in cases 1,3, and 4 reported uncertainties about policies regarding repeatedly using the same desk. For example, one of the interviewees at the insurance company (C3) mentioned: 'There are people sitting at the same desk all the time. Everyone has a different opinion on this matter' (I4-C3). However, the interviewees at the ICT support company (C2) reported that it was allowed to use the same work desk in consecutive days: 'Nobody is forcing you to move. In fact, you are allowed to use the same desk everyday if you want, as long as it is not occupied' (I16-C2).

To use the scarce zones

To use the scarce zones addressed duration of using the back-up rooms or quiet rooms dimensioned for 1-2 persons. To use back-up rooms was allowed and enabled through a booking system in all cases except the insurance company (C3) where the purpose and use duration of back-up rooms were not clearly defined and communicated. The duration of using the scarce zones was limited to one day at the ICT support providers (C2), and two days at the science park (C4), imposed by their booking system. However, it was allowed to book the scarce zones in consecutive days. At the knowledge providers (C1) and insurance company (C3) no duration was specified and as a result ambiguities were reported: 'There are no outspoken rules, but it is perhaps needed' (I22-C3).

Speech policies

Speech policies indicate presence of specific spaces with various speech levels and address whether or not interacting with colleagues and speaking on the phone were allowed. In quiet zones with a strictly quiet speech policy (only provided in C1), interactions with colleagues or answering phone calls were forbidden. The semi-quiet zones (provided in C1 and C2) varied depending on policies regarding to speak on the phone and interruption policies. There were zones in all cases where interacting with colleagues was encouraged. In C3 and C4, the interviewees reported on zones that lacked clear speech policies.

To interact with colleagues in different zones

This policy indicates presence of specific spaces with or without restrictions on interacting with colleagues. The knowledge providers (C1) and ICT support providers (C2) had designated zones with different speech policies, such as quiet and semi-quiet zones, and specific zones where interacting with colleagues was explicitly encouraged. Moreover, the interviewees in C1 and C2 reported on designated non-interruptive zones where specifically initiating conversations was forbidden: 'Here, it is not ok to interrupt each other. You can sit here and be sure that you get to work undisturbed' (I35-C2).

The insurance company (C3) and the science park (C4) had similar speech levels across all zones and lacked designated quiet zones. The interviewees in C3 discussed ambiguities regarding the different speech levels, and whether speaking was allowed in different zones: 'in the beginning, we received different information about these rooms [...] that these were supposed to be some kind of quiet room' (I2-C3). In C4, interviewees reported ambiguities for all zones and expressed a need for speech policies and quiet zones: 'I don't know if this is the quiet zone, or if this is the interactive zone and if you have to leave if you want a quiet work environment. On what level is it okay to talk and such' (I7 C4)'.

To speak on the phone in different zones

This policy indicates presence of specific spaces with or without restrictions on having phone calls. According to the interviewees at the knowledge providers (C1), phone conversations were not allowed in the strictly quiet zone. At the ICT support providers (explicitly) and the insurance company (implicitly) phone conversations were allowed in all zones, according to the interviewees. At the science park (C4) the interviewees mentioned ambiguities regarding whether it was allowed or not: ‘I don’t know if one is supposed to leave when receiving phone calls’ (i7-C4). In summary, no zones in C2-4 were strictly quiet. As a result, the interviewees expressed a need for speech policies and quiet zones: ‘we have to [...] create policies so that this workplace can function properly’ (I3-C4).

DISCUSSION

The aim of this paper was to identify and compare explicit and implicit policies in activity-based flex offices. In total 5 central policies were identified in the four case organisations:

1. To remove belongings
2. To use the same workstations in consecutive days
3. To use scarce zones in consecutive days
4. Allocation of zones where interaction with and/or interruption of colleagues was allowed/forbidden.
5. Allocation of zones where speaking on the phone was allowed/forbidden.

Implicit and explicit policies in A-FOs

The explicit and written policies were (1) to remove belongings after a specified duration e.g. by the end of the day or after a maximum of two hours of unattended use, (2) using the scarce zones with a specified duration, and (3) allocation of zones where speaking on the phone, and interacting with and interruption of colleagues were forbidden or allowed. The implicit policies were (1) to remove belongings where no duration was specified for duration of unattended use, (2) using the same workstations and/or scarce zones in consecutive days with unclear limitations on duration, (3) unclear or undefined speech policies for the different zones.

What are the implications of desk-sharing policies?

To remove belongings at the end of the day was an explicit policy in all cases. As the A-FO concept builds on sharing workstations (Appel-Meulenbroek et al., 2011; 2015), the policy of removing belongings at the end of the day seems fundamental for making the A-FO work. Nevertheless, the policies regarding the duration of unattended use of workstations varied among the cases. In cases with implicit time restrictions, employees’ interpretation and application of the policy varied. Interpretations of a policy may run the risk of having employees disregarding the policy and having varying expectations of colleagues’ actions. In two of the cases, duration of unattended use was not limited. Thus, to clean the desk every time employees leave the workstation for longer than a few hours, was not expected in all cases, which is inconsistent with de Been and Beijer’s (2014) description of A-FO policies. However, applying time restriction policies may be more critical and necessary in A-FOs with high workstation occupancy ratio. Thus, office capacity may be an influencing factor on choice of policies.

Most cases expressed uncertainties about policies concerning using the same desk in consecutive days, and employees expressed uncertainties about how to act in a correct way. Repeated use of the same workstation may lead to nesting and an implicit assignment of workstation. Not having assigned workstations is a key ingredient of the A-FO (de Been et al., 2015) and distinguishes the A-FO from the open-plan office. Expected values of desk-sharing are e.g. improved communication (de Croon et al., 2005), and increased teamwork quality (Hoegl & Proserpio, 2004). These benefits may be inhibited by nesting. Not having assigned workstations also means that the employees have autonomy to choose between a variety of workplaces, depending on personal preferences and task at hand (de Been & Beijer, 2014). This autonomy is put forward as an advantage of the A-FO concept. If nesting occurs in the office, the variety of workplaces and autonomy may decrease. However, according to Vos and van der Voordt (2002) if people get the chance, they choose the same workstation repeatedly and nesting tendencies in A-FOs have been found by de Been et al., (2015), and by Brunia & Hertjes-Gosselink (2009). Reasons for nesting could be e.g. the lack of territorial privacy (van der Voordt, 2004), time loss (Wolfeld, 2010), difficulties with finding a suitable workplace (Brunnberg, 2000), problems with adjusting the workplace, and finding colleagues (van der Voordt, 2004). The policy of using the same desk in consecutive days is therefore important to address. It should also be noted that imposing limitations on using the same desk in consecutive days may conflict with employees' work needs as they may perform the same task in consecutive days. Therefore when specifying desk-sharing policies all employees' tasks need to be considered. With clearly stated policies employees may feel more secure in their choice of actions.

What are the implications of speech policies?
The results showed a large variation in terms of allocation of spaces with different speech policies. Two of the cases provided a variety of workspaces with explicit limitations on interacting with/interrupting colleagues or speaking on the phone. The other two cases, however, did not provide explicit speech policies for the different workspaces leading to no variations in terms of speech levels in the A-FO. Lacking a variety spaces with different speech policies may have negative implications for individuals' work conditions in an A-FO setting. In A-FOs where the majority of workspaces have no quiet speech policy, the users are not provided with the possibility to control their exposure to disturbances and interruptions. This compromises one of the main benefits of A-FOs described by Wohlers and Hertel, (2016) i.e. the ability to choose between different activity-related workspaces. In studies comparing different office types, employees report higher levels of job satisfaction in cellular offices and A-FOs in comparison with open-plan offices (e.g. Danielsson & Bodin, 2008). Lacking allocated spaces for concentration in an A-FO can lead to lower job satisfaction as the work setting will resemble an open-plan office with desk-sharing policies. It is however important to highlight that provision of quiet spaces per se may not lead to having quiet workspaces, especially if the layout and configuration of the workspaces does not allow sufficient soundproofing. According to a study by Appel-Meulenbroek et al. (2011), users are likely to make misfitting choices of workstations, e.g. having meetings in workspaces allocated for concentration. Having spaces with clear and sufficiently varied speech policies should therefore be complemented with efforts to encourage employees to comply with the policies and maintain the different speech levels. Therefore, further research should address whether speech policies are complied with in A-FOs, and if the intended zoning is achieved and maintained.

Methodological considerations
Having four cases enabled comparison between policies of organisations with different size, location and organisation type. Thus, shared results may imply a certain degree of generalizability. The extensive number of interviews (105) gave an in-depth understanding of how the offices were used, and of strengths and weaknesses regarding the policies and work conditions. Moreover the joint analysis by the authors gave further reliability to the results.

Focus of this paper was on identifying and comparing policies in the four cases. Thus deliberations on the planning process, work tasks, office layout and office use were excluded. However, the relation between these factors and policies, and compliance with policies may be of interest for further studies.

Besides the five policies, other policies were also identified such as visitor policies and eating in office. However these policies were excluded as they were applicable to other work environments and not central to A-FO concept.

CONCLUSIONS
Five policies were identified in the four organisations. Three of the policies addressed desk-sharing; (1) to remove belongings, (2) to use the same workstations in consecutive days and

(3) to use scarce zones in consecutive days, and two addressed allocation of zones with different speech policies; (4) where to interact with and/or interrupt colleagues, and (5) where to speak on the phone. The five identified policies were central to all four organisations. In the cases where no explicit policies were stated, ambiguities, uncertainties and interpretations of policies emerged, and a need for clearly defined policies was expressed. The results imply that the five identified policies may be few in number, but they are crucial in A-FOs for (i) making the non-territorial office concept work, and (ii) providing a variety of environments with different speech levels.

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STUDY OF WORKSTATION AND WORKING CONDITIONS IN A TECHNICAL, COMPUTER-INTENSIVE WORK ENVIRONMENT

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KEYWORDS
Technical worker, workstation, discomfort, perception

SUMMATIVE STATEMENT
The posture, workstation dimensions, work habits, and discomfort were studied for 30 technical consulting employees who are typically engaged in computer intensive work at two sites of one company. Discomfort was common in the lower back, shoulders, neck, and eyes. Keyboard relative to seated elbow height and eye-screen distance were typically poor relative to ergonomics recommendations. Where workstation adjustments were available, employees did not know how to take advantage of these.

Une étude de postes de travail et de conditions de travail dans un milieu de travail intensif et technique sur un ordinateur

MOTS-CLÉS
Travailleur technique, poste de travail, inconfort, perception

SOMMAIRE
La posture, les dimensions du poste de travail, les habitudes de travail et l'inconfort ont été examinés auprès de 30 employés d'une entreprise de services techniques travaillant généralement de façon intensive à l'ordinateur dans deux bureaux de l'entreprise. Le sentiment d'inconfort était fréquent au niveau du bas du dos, des épaules, du cou et des yeux. En général, le clavier n'était pas à la hauteur des coudes et la distance entre l'écran et les yeux n'était pas adéquate selon les recommandations ergonomiques. Lorsque les postes de travail étaient dotés de réglages, les employés ne savaient pas comment en tirer parti.

PROBLEM STATEMENT
This study was requested by the management at a consulting engineering and environmental science company who wanted to understand of their employees' current working discomfort, and the sufficiency of the company's practices relating to ergonomics. Objective feedback on current conditions was key.

RESEARCH OBJECTIVE/QUESTION
The objective of this study was to quantify employee perception and the dimensional sufficiency of worker and workstation matching in a technical computer-intensive work environment. It was expected that physical discomfort would correlate to workstation layouts inconsistent with ergonomic recommendations, and that organizational constraints contribute to physical discomfort complaints. Two office locations of the same technical consulting

company were studied, and while the nature of the work at both locations was the same, several aspects of the physical and organisational work environment varied.

METHODOLOGY

This research was approved by Université de Moncton's research ethics board. All gave informed consent prior to starting their participation. Two research teams comprised of one senior researcher and one student of ergonomics worked collecting data using similar methodologies at two different work sites: (A) Dartmouth NS and (B) Moncton NB. The Dartmouth data collection occurred first and was reviewed during data collection in Moncton. In each case, the data collection occurred over 2 working days, and only those present in the office on those days were considered for participation.

In both cases, relevant anthropometry and workstations dimensions were recorded. Individuals' current discomfort and perception of their working situations were recorded. Each participant responded to demographic, physical discomfort, and work organization questionnaires during a 40- minute intervention. In site B, consistency between workstation dimensions and participant anthropometry was measured for distance from ergonomics recommendations as cited in Worksafe NB's Office Ergonomics guidelines (2010), the University of Waterloo's online Office Ergonomics Guide (N.D.) and the CSA Z412-00 (R2011). If that distance was at least 7 cm, it was deemed a "poor" match and between 4 cm and 7 cm was designated "fair".

RESULTS

Demographics and work organisation

At site A, 16 workers participated, representing 23% of the workforce, and including 10 men. At site B, 14 workers participated, representing 35% of the workforce, and including 8 men. All of the key work types were represented in the populations studied (Table 8). Except for the reception workstation which occasionally was used by alternative employees, in all cases, the workstation measured was used only by the person measured. Site A had more employees than site B (approximately 70 and 40 employees, respectively). Their ages and experience in the current type of job were similar across population sites (

Table 9). As would be expected, most were right-handed. Over half used vision correction (wore glasses of contact lenses). Nearly all spent nearly all their time seated, and while in the office, more of those in site A were in front of a computer screen than in site B (88% and 76% on average, respectively).

Table 8. Job categories of participants by site

Job categories	Site A	Site B
Engineer /Scientist	7	2
Technologist	6	4
Architect / Designer	1	2
Reception	0	1
Manager	2	5
Total	*16*	*14*

Table 9. Demographic data collected from each of the two sites

	Site A (N = 16)			Site B (N=14)		
Category	**Nbr.**	**Average**	**Std. Dev.**	**Nbr.**	**Average**	**Std. Dev.**
Age		37.6	9.9		36. 6	10.8
Experience in similar job (years)		8.7	9.2		11.9	8.6
Years in current job		*	*		5.2	3.3

	Site A (N = 16)			Site B (N=14)		
Category	**Nbr.**	**Average**	**Std. Dev.**	**Nbr.**	**Average**	**Std. Dev.**
Hours worked weekly		40,9	2,0		42.7	3.7
Vision correction	9	56%		7	50%	
Right-handed	13	81%		13	93%	
% day in seated posture (estimate)		94.8%	6.1%		97.5%	5.1%
% workday spent in front of computer screen		88%	7.2%		76.4%	20%

* Data for this item was not collected at this site.

There were some variations in worksite organization. While, at both sites, workers were able to take breaks when they desired, and took a lunch break, the duration of lunch varied from 10 to 60 minutes, depending on the individual. In site A, all workers were expected to start at the same time (and finish no earlier than 8 hours later), whereas in site B, workers were allowed flexibility to arrange their required hours over the work week. The total weekly working hours was slightly more than the anticipated 40 hours a week in both sites (Table 2).

Anthropometry

Relevant participant anthropometry was measured in both sites (Table 3), and was similar between worksites. Amongst participants in site B, seated elbow height and bottom of monitor height (even when accounting for the different points of reference) were lower than in site A, but keyboard height was higher. For site B, these key dimensions were subsequently related to the recommended dimensions of the workstation components (Table 4). The correspondence or divergence of observed worker-workstation dimensions indicate the degree to which working conditions correspond to ergonomics recommendations. In Site B, most participants' keyboard height, and eye-screen distance were problematic (Table 4). Note that in this location, up to three screens were used simultaneously.

Table 3. Anthropometric and key workstation measurements

	Site A		Site B	
Measurement (cm)	**Average**	**Std. Dev.**	**Average**	**Std. Dev.**
Standing height	177.6	9.1	174.64	8.8
Standing elbow height	116.1	6.0	110.0	9.0
Standing eye height	164.8	10.4	165.0	9.0
Monitor height (bottom visual area)[1]	94.3	6.0	86.5	11.9
Seated eye height	121.5	4.2	119.2	4.2
Seated elbow height from floor	77.0	3.8	66.7	4.6
Keyboard height	73.8	1.1	76.8	3.0
Horizontal monitor distance (Left / Middle / Right)	66.2	14.4	77.4 / 75.3 / 70.9	16.9 / 12.2 / 13.2
Monitor size (inches)[2]	13.2	0.9	22.2	1.08

1. *Measured from bottom of visual area at site A, of external frame at site B*
2. *Measured vertically at site A; on the diagonal at site B*

Table 4. Difference (cm) between observed and ergonomically recommended values in site B	**Avg.**	**Max.**	**Absolute average difference**	**% poor**	**% fair**
Monitor height (top) Vs Seated eyes	4.5	19.5	9.5	15%	54%
Keyboard Height Vs Seated elbows	10.1	20.5	20.5	79%	86%
Armrest Height Vs Seated elbows	3.6	24	12.5	31%	54%
Seat Height Vs Leg knee center	-4.2	3	5.0	29%	43%
Distance Eyes – left Screen Vs Arm length	10.7	41	19.2	64%	71%
Distance Eyes – middle screen Vs Arm length	12.3	21	0.0	67%	67%

Distance Eyes – Right screen Vs Arm length	5.7	26.2	26.2	45%	73%

Discomfort

Physical discomfort was experienced by a majority of participants in one or more body regions: 87.5% at site A and 100% at site B, respectively. Most of this discomfort was consistent with computer-intensive sedentary work, occurring in the neck, shoulders, and lower back (Table 5). Furthermore, in these regions, when participants were asked if they believed that the discomfort was due to their current work, these same areas were prominent. Interestingly, in site B, half the participants complained of eye discomfort, whereas in site A, no such problems were mentioned.

In the course of data collection, it was observed that in most cases, the keyboard was placed on the desk surface. Chairs were height adjustable, typically with vertically adjustable armrests and a varying degree of lumbar support. Participants were bothered by physical discomfort, but typically were unaware of how to improve their workstation layout to reduce it.

Table 5. Percentage frequency of discomfort by body region and worksite, and percent of these perceived as being work-related

Body Region	Site A		Site B	
	Frequency	Work-related	Frequency	Work-related
Eyes	0	-	50	100
Neck	6	50	57	63
Shoulder	38	83	50	71
Arm	31	100	0	-
Back	44	73	79	45
Elbow	0	-	7	0
Leg	13	100	14	0
Knee	0	-	21	0
Ankle	0	-	21	0

DISCUSSION

Two offices of a consulting company which specialises in engineering and environmental science were studied. Nearly one third of the workers across those two sites participated in the data collection. These workers were typically experienced and worked mostly in a seated posture with a computer and multiple computer screens. This work is highly computer-intensive and using computer-aided design tools and technical drawings leads to workers typically requiring multiple computer screens.

The anthropometry of the participant populations were consistent with North American adults of working age (Pheasant and Haslegrave, 2005). In site B, observed worker-workstation dimensions diverged significantly for keyboard – elbow height and horizontal distance from the eyes to the computer screens. These data are consistent with the high frequency of physical discomfort found in the neck and shoulders and eyes in that same worksite. Indeed, shoulder and back were consistently high locations of discomfort across worksites with a majority of these being perceived as related to the observed work environments. The computer keyboard was typically placed on the desk surface which may contribute to the higher-than-desirable keyboarding height.

CONCLUSIONS

Physical discomfort symptoms in this technical work environment were typical of computer-intensive work environments using fixed height work surfaces. While highly trained in their technical field. Participants had limited knowledge of recommended workstation adjustments for comfort.

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OFFICE ERGONOMICS INTERVENTIONS: WHAT HAVE WE LEARNED AND WHAT IS NEXT?

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KEYWORDS
Office ergonomics, interventions, training, sit/stand workstations

SUMMATIVE STATEMENT
A high prevalence of musculoskeletal symptoms in the neck, upper extremities and lower back has been linked to increased computer usage among knowledge and office workers (Sillanpaa et al., 2003). Office ergonomics programs need to focus on injury prevention in a more proactive, systematic manner so that all workplaces are ergonomically designed from the outset and all employees receive some ergonomics training.

Des interventions en ergonomie du bureau : les leçons tirées et les prochaines étapes

MOTS-CLÉS
Ergonomie du bureau, interventions, formation, postes de travail assis-debout

SOMMAIRE
La prévalence élevée de symptômes musculosquelettiques au niveau du cou, des membres supérieurs et du bas du dos est liée à l'utilisation plus intensive des ordinateurs par les travailleurs du savoir et les employés de bureau (Sillanpaa et coll., 2003). Les programmes d'ergonomie du bureau doivent s'attarder à la prévention des blessures de manière plus systématique et proactive afin que tous les lieux de travail soient conçus de façon ergonomique dès le départ et que tous les employés reçoivent une formation portant sur l'ergonomie.

PROBLEM STATEMENT

With increases in computer-based technology, more intense work and unhealthy working conditions are emerging, leading to an increase in work-related musculoskeletal symptoms and discomfort. Moreover, these computer-intensive users, who are often knowledge workers, may encounter psychosocial problems, such as time pressures, low decision latitude, lack of control over one's job and stressful work (Wahlstrom, 2005). To mitigate these adverse musculoskeletal health trends, organizations are shifting to a more proactive injury prevention perspective of health, wellness, and well-being promotion rather than a reactive program focus. Part of this shift involves redesigning physical workspaces and providing ergonomics training.

RESEARCH OBJECTIVE/QUESTION

The goal of several longitudinal organizational interventions was to specifically investigate the benefits of implementing a comprehensive proactive ergonomics program that combined ergonomic workstations and chair design with office ergonomics training (Hedge, 2014; Amick et al., 2009; Robertson et al., 2008). Furthermore, additional studies have investigated the effects of training modalities and engagement on work-related musculoskeletal symptoms (King et al., 2012). Informed by the findings from those longitudinal interventions and laboratory studies, the current research questions are: 1) What are the key components of a strategic office ergonomics program? and 2) What is the role that office ergonomics can have on improving knowledge, attitudes and behaviors?

METHODOLOGY

A literature search was conducted with specific key terms related to office ergonomics; office ergonomics training; musculoskeletal discomfort associated with computer, office and knowledge workers. This paper synthesizes the current research in office ergonomics interventions with a specific focus on the effects of ergonomics training on workers' musculoskeletal and visual symptoms, behaviors and performance.

RESULTS

Integrating several field office ergonomics interventions findings along with extended laboratory studies, a conceptual overview emerged which noted key indicators for successful implementation and positive outcomes. A comprehensive, macroergonomics systems viewpoint was found to be critical to demonstrate significant, positive findings. It was also noted that training programs alone positively influence safety practices and behaviors, but not musculoskeletal symptoms (Robson, 2009). Upon review, none of the ergonomic training programs were designed within an instructional system design (ISD) paradigm. Training development experts recommend using ISD to develop and test the effectiveness of training programs (e.g., Cook et al., 2005; Gordon, 1994; Robertson, 2002).

DISCUSSION

Training is an important component of effective multi-component/multi-level occupational health and safety prevention strategies (Robson et al., 2012; Robertson, 2008; 2009; Kennedy et al, 2008). However, training alone may not reduce MSD outcomes if the workplace hazards are not changed and there are limited affordances provided in the work environment (e.g., Brewer et al., 2006; Robertson et al., 2009; Dainoff et al., 1999). It was found that incorporating a macroergonomics or work system design approach provided the necessary framework to address musculoskeletal and visual symptoms, while enhancing healthy computing behaviors and performance.

CONCLUSIONS

There is a need for more intervention research to effectively design training programs that link knowledge about workstation adjustments to the actual practice changes reducing MSD risks along with providing ergonomically designed, adjustable workspaces. Applying a work systems design approach, along with training, can lead to improved work environments, behavioral translation, and improved worker health and performance.

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Technical Session 12: Ergonomics In Practice

Séance technique 12: Ergonomie dans la pratique

EFFECTS OF MURAL NATURE PHOTOGRAPH ON WORKPLACE ENVIRONMENT

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KEYWORDS
medical staff, forest photo, SD method

SUMMATIVE STATEMENT
Sixteen nurses evaluated large size nature photos of a forest, a lakeside and a seaside on the wall of their ward. The impression of the workplace with nature photos was better than that without photos, although out-of-season scenes (e.g., a seaside in fall) were not preferable.

Les effets de photos murales illustrant la nature sur le milieu de travail

MOTS-CLÉS
Personnel médical, photo d'une forêt, méthode SD

SOMMAIRE
Seize infirmières et infirmiers ont évalué de grandes photos illustrant une forêt, un lac ou un bord de mer qui avaient été affichées aux murs de leur unité. Les photos illustrant la nature ont eu un effet positif sur le lieu de travail comparativement aux murs sans photo. Toutefois, les photos de scène non pertinente à la saison (p. ex., un bord de mer en automne) ne représentaient pas une option optimale.

PROBLEM STATEMENT
Medical staff, e.g., nurses may work in highly stressful conditions. Even though walking in a forest may reduce stress, doing so is difficult in everyday life. Large size photographs of a forest and/or other nature scenes posted on a wall in their workplace (hospital) may have some positive effects of healing. Only a few photographs can be selected from innumerable nature scenes, and some may be more effective for healing, but some may have negative effects.

RESEARCH OBJECTIVE/QUESTION
What kinds of nature scenes, e.g., forest vs. the sea, are preferable? How do the staff feel by mural photos in their workplace? What kind of negative impressions do they have?

METHODOLOGY
Large size (950W x 2000H mm in an elevator (EV) hall, 2490W x 1100H mm in a hallway) photos of a forest, lake side and seaside were posted on the wall of an EV hall and a hallway in a ward (Fig.1). One photo was posted in each place (forest photo on the EV hall wall and seaside photo on the hallway wall) for one week, then it was replaced by aother photo (a lake side photo at the EV hall and forest photo at the hallway). Six (two places X three conditions including no photo condition) questionnaire forms were distributed to 27 nurses. The questionnaire forms contained several questions about their preferences (5level rating scale), image evaluation by semantic differential (SD) method (20 pairs of adjectives), and openended questions for respondents’ comments.

The rating scale data were categorized into two categories, positive and negative, by excluding the neutral category 'neither', and were analyzed by chisquare tests. Factor analysis was used to derive three factors from the SD data. Factor scores were analyzed by ANOVA to find the significant differences between the photos and the no photo condition in each place.

RESULTS

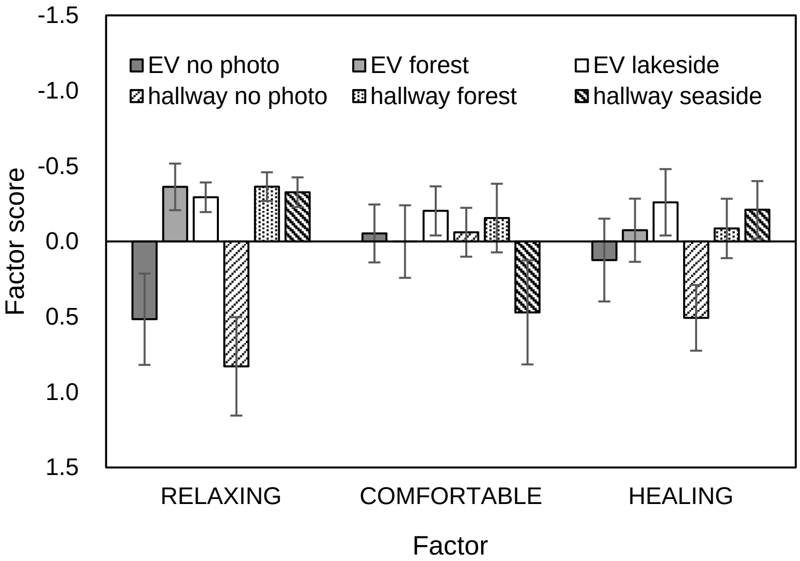
The questionnaire forms were returned from 19 nurses (70.4%). Three respondents whose forms were incomplete were excluded. Therefore, sixteen (two male and fourteen female) of them were analyzed.

Significantly more respondents answered that they were healed by the photos for every photo (Table 1). In the image analysis (SD method), factor1 (relaxing) scores of all conditions with photos were significantly larger than that of the condition without photos. However, no significant difference was found between the two photos. No significant main effects were found in factor2 (comfortable) or factor3 (healing) (Fig.2). The Hawaiian seaside photo was criticized by three respondents in that it lacked the sense of season because they evaluated it in late November.

Table 1 Evaluation of healing effect (n=16).

place	photo	very healed	healed	neither	not healed	not healed at all	χ^2	p	□□□
	forest	1	9	5	1	0	7.364	0.007	0.988

Fig.1 Photos of forest (top left and bottom left. Interstate State Park, MN), seaside (top right. Hapuna Beach State Park, HI) and lakeside (bottom right. Lake Quinault, Oympic National Park, WA). All photos were taken by one of the authors (Miyake).



elevetor hall	lakeside	0	10	5	1	0	7.364	0.007	0.988
hallway	forest	0	9	6	1	0	6.400	0.011	0.979
	seaside	0	10	4	1	1	5.333	0.021	0.961

DISCUSSION
Although the number of respondents in this study was not large, a significantly larger number of medical staff felt that they were healed by the nature photos and the statistical power was sufficiently large (1-□ >0.95). It is also suggested that they prefer a forest landscape to a seaside. Farley and Veitch (2001) reported that trees and lawns are one of the most desirable views from therapy rooms. Furthermore, seasonally illmatched photos, e.g., a beach scene in fall-winter, are not preferable. Individual differences in preference to such large size mural photos were remarkable, but those who gave negative comments were only a few of the respondents in this study.

We have to select only one photo for one place for one period. If an 'optimal' photo is selected, most workers may feel good, although a few of them dislike it, as our results indicated. Appleton (1975) argued that people prefer landscapes that give us the oppotunuity to see (prospect) without being seen (refuge). This prospect-refuge theory can be helpful to select the most preferable landscape photo.

Posting large size photos, which are virtual windows in a sense, on a wall in a windowless environment like a hallway in this study can be very effective to reduce the stress level of

Fig.2 Three factors from SD method. Minus scores indicate positive effects. Bars represent standard errors of the mean.

workers working there. A stress assessment should be done at the same time. Unfortunately, we did not obtain evaluations from patients in this study. How they feel is also very important. When we introduce these kinds of nature photos into a hospital, we must also consider the patients' views.

We combined two cells into one cell (e.g., 'very healed' + 'healed' = positive) ignoring the neutral responses to simplify the statistical analysis. In this kind of data obtained by a 'YES or NO' choice, for example, if 75% (3/4) of respondents answered 'YES', more than 25 respondents (sample size) provide sufficient statistical power (>0.80) (Cohen, 1988).

CONCLUSIONS

Large size nature photos, especially seasonal forest scenes, on the wall of the workplace have a healing effect.

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ERGONOMIC ASSESSMENT OF A CRAFT BREWERY

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KEYWORDS
Ergonomic assessment, ergonomic risk factors, manual materials handling and repetitive motions

SUMMATIVE STATEMENT
Workers at craft breweries work long hours and are subjected to repetitive movements, awkward postures and high strength demands. This research examined measures of musculoskeletal risk in this environment to better understand the job demands of this industry and suggest work improvements to the employer and workers.

Une évaluation ergonomique dans une brasserie artisanale

MOTS-CLÉS
Évaluation ergonomique, facteurs de risque ergnomique, manutention manuelle, mouvements répétitifs

SOMMAIRE
Les travailleurs de l'industrie des microbrasseries travaillent de longues heures et sont exposés à des mouvements répétitifs, des postures contraignantes et des exigences élevées sur le plan de la force. La présente recherche a examiné les facteurs de risque musculosquelettique dans cet environnement afin de mieux comprendre les exigences professionnelles de cette industrie et de proposer des améliorations de travail à l'employeur et aux travailleurs.

PROBLEM STATEMENT
According to data analysis of Occupational Health and Safety Administration of the United States (OSHA) records, between the years 2009 to 2012 craft breweries had almost four times the amount of safety violations compared to large breweries (Pell, 2013). Four deaths occurred during this same time period, and statistics suggest that multiple injuries are not reported at smaller craft breweries. This study focused on working with a local craft brewery to examine the workplace risks during typical operations and the data was provided to the manufacturer to improve their current work protocols.

RESEARCH OBJECTIVE/QUESTION
The purpose of this research was to examine musculoskeletal discomfort, muscle fatigue, energy expenditure and postural analysis from workers at a craft brewery pre and post shift.

METHODOLOGY
Participants. Nine males (mean age = 31 ± 8.37 years old) participated in this study. Participants' height and weight was collected for demographic information; the mean height was 178.88 cm ± 8.37 and mean weight was 83.41 kg ± 14.02. Participants were recruited

from the craft brewery's production staff and included individuals currently working in the following positions: cellar (n=2), driver (n=2), brewer (n=2), bottler (n=2) and box maker (n=1). Participants voluntarily consented and participated in the study and no compensation was provided. Two participants from 5 work stations were examined; cellar, driver, brewer, bottler and box maker. Of the 9 participants, 1 had incomplete data after leaving the brewery before their normal shift ended.

Instrumentation. Fitbit Surge (San Francisco, CA) activity tracker records steps, distance, floors climbed and activity minutes, hourly activity and stationary time. The tracker wirelessly and automatically syncs stats to smartphones (iPod touch 6th generation) and computers with a 6-meter range. It has a sampling rate for GPS of 1Hz. Sizing varies across trackers (small-x-large).

GoPro Hero 3+ LCD is a waterproof action camera that records 1080p60 and 720p60 videos and eight megapixel photos up to five frames per second with built in Wifi and Bluetooth.

The Grip Dynamometer is an analog device used to measure the power of the forearm and the flexion of wrist and gives an accurate measurement of grip strength in kilograms (kg) or pounds of force (lbf), and hence a general estimate for upper body strength. It has a range of 0-100kg.

Procedures. Data collection took place during the participant's regular shift times at the brewery from January to the end of February, 2016. This study was approved by the University Research Ethics Board.

On the day of data collection, participants were first provided with an information letter, consent form, and the Nordic Questionnaire (Kuorinka et al., 1987, Curwin et al., 2013). The Nordic Questionnaire is a standardized questionnaire that allows comparison of low back, neck, shoulder and general complaints for use in epidemiological studies. This provided a subjective evaluation of discomfort-fatigue for each participant.

Participants were then asked to perform a grip strength test using a handgrip dynamometer, both pre- and post-shift. Participants were asked to stand with their arms in line with their sides, while not touching the body, and to keep their elbow in extension. Both hands were tested twice using a handgrip dynamometer, and the higher values of each hand for the pre-shift test were used for data analysis. Participants altered hands after each trial to ensure a small break period between each strength tests.

An activity tracker (Fitbit Surge, San Francisco, CA) was used to monitor heart rate and step count. Each participant was asked to wear the activity tracker for their entire shift. Participants were asked to keep the activity tracker on their non-dominant hand and above the wrist at all times. Participants were advised to ensure a fingers width could fit between their arm and the strap of the tracker in order to prevent any unnecessary rubbing and interference with the tracker.

The researchers followed and filmed participants' regular work tasks using a video camera (GoPro Hero 3+, San Mateo, CA). The camera was stabilized using an extension mount in order to ensure video data was focused and balanced. For consistency, the same researcher filmed all participants so the height and method of collecting video data stayed relatively the same.

Data Analysis. The data collected was analyzed offline (Excel). The Nordic Questionnaire results were tallied by responses, and then percentages were applied to the total numbers of each category. Due to the small number of participants, the results were not divided between workstations. Instead, the Nordic Questionnaire gave an overall consensus of what areas of the body appeared to cause the most trouble to all workers in the brewery.

The handgrip dynamometer values collected for each participant were recorded analyzed pre and post shift. Participants were asked to produce 2 trials of maximum force with each hand per collection, for a total of 8 grip strength values by the end of their shift. Grip strength values (pre and post) were compared to determine if there was any muscle fatigue occurring between pre- and post-shift.

The researchers then determined the Health Benefit Rating score of each participant using guidelines developed by Canadian Society of Exercise Physiology (CSEP). Using the pre-shift data, each hand's highest grip strength score was taken into account. These two values were added together to form a total grip strength score. Using CSEP's guidelines (CSEP, 2013) every participant's total score was compared with their age to determine their Health Benefit Rating zone.

The activity trackers were used to measure participants' heart rate and step count throughout their total shift. Data recorded by each activity tracker were then extracted to obtain heart rate values in 5-minute increments and step count values in 15 minute increments. These values were plotted on an axis of time from 06:00 till 16:30, as all participants' shifts fell within this period. The total step count of each participant was calculated, and then the number was divided by their total shift time to give a mean value of steps per hour.
Energy expenditure was estimated in KJ/min using the following (Keytel et al., 2005)

$$EE = gender \times (-55.09069 + (0.6309 \times HR) + (0.1988 \times weight\ kg) + (0.2017 \times age)) + (1 - gender) \times (-20.4022 + (0.4472 \times HR) - (0.1263 \times weight\ kg) + (0.074 \times age)).$$

Where gender =1 for males and 0 for females.

The video data were analyzed using 3D Match Postural Analysis (Sutherland, C., Albert, W., Wrigley, A., & Callaghan, J. 2008). Video clips were created for each participant and or work station using Pinnacle Studios 18. Each video clip was then processed using Virtual Dub (v1.10.4) to remove audio and reduce the framerate to 3Hz for easier digitization on a frame by frame basis. Previous research has identified that the reduction of the video frame rate to 3Hz for the purpose of posture and joint loading can be done with minimal error (Sutherland, C., Albert, W., Wrigley, A., & Callaghan, J. 2008). The videos were separated based on the different workstations at the brewery. The researchers examined each frame of the video data and assessed the participants' postures (full-body, trunk and arms) following the set angle guidelines used in the program (neutral, mild, and severe).

RESULTS

The results of the Nordic Questionnaire showed musculoskeletal discomfort and pain in the shoulder and low back of workers. The estimated energy expenditure values of the participants showed varied results between the five workstations. The cellar and brewer stations had overall higher values of energy expenditure during their shifts compared to the driver stations.

The results of the grip strength data are shown in Table 1. The grip strength results showed a range of health scores and grip strength did not decrease after the work shift. Grip strength data was collected pre- and post-shift, but for measuring the health benefit rating score only the pre-shift data was used. Based on the results of the grip strength test, those completing repetitive movements during their daily tasks had a higher score than those who were doing more heavy lifting. There was a significant range between the two cellar workers, suggesting that other activities or physiological factors may have an effect on the results. With a mean age of 31 the workplace had a health benefit rating of fair.

	Health Benefit Rating	
Position	**Grip Strength (kg)**	**Zone**
Cellar	65.5	Poor
Driver	74.0	Poor
Driver	94.5	Good
Brewer	95.9	Good
Bottler	97.0	Good
Bottler	100.5	Good
Box Maker	107.0	Very Good
Cellar	111.5	Very Good
Mean	93.2	Fair

Table 1: The health benefit rating scores of participants' pre-shift grip strength.

The postural analysis results showed that all workers reach severe angles during the different tasks required. The video data of a brewer lifting bags into an auger system to prepare batches of beer showed a lot of time spent in severe flexed posture of the right shoulder. The cellar workers complete awkward positions working around the silos, and 3D Match showed severe angles while twisting, laterally bending, and flexing the spine. Figure 1 shows the severe angles of the cellar workers' posture analysis. While the box maker station did not spend a significant amount of time in severe angles, the workers' shoulders were out of neutral the entire task. The bottler station required flexed posture of the shoulders for both the loader and unloader. There was some severe spinal twisting for the loader, and the unloader flexes their spine whenever they place a box on the pallet. The drivers suffer from spinal flexion when loading boxes onto pallets, but appear to have okay posture when loading kegs into the trucks.

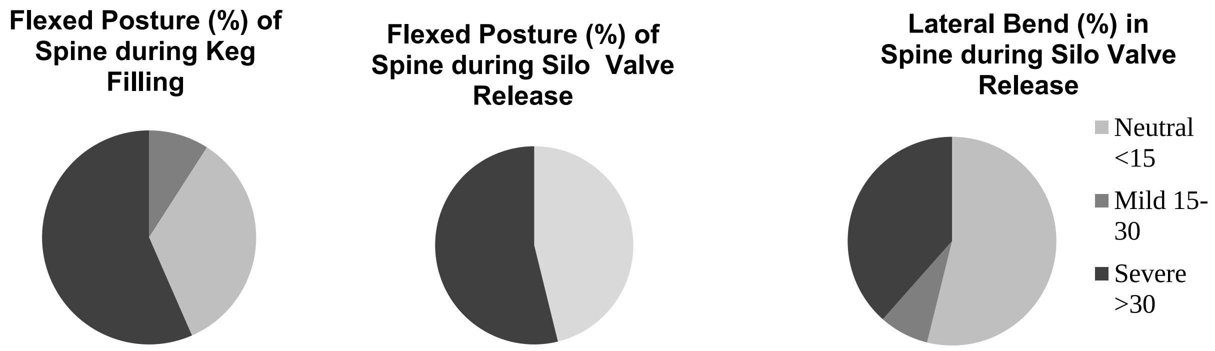

Figure 1: Twisting, lateral bending, and flexion of the cellar workers' spines (lower-back) during different tasks of the workstation.

DISCUSSION

The craft brewery in this research study was a fairly small production facility, therefore the sample size was limited to 9 participants. It would be worthwhile to include other craft brewery companies in future studies to increase the sample size and to explore if the trends observed in this work are consistent across the industry. One of the challenges of this industry is that the workers at the brewery complete many tasks throughout their shift, which includes constantly assisting workers at different workstations. The brewery needs its workers to be versatile as they are a small facility with only a few employees, so there is a high rate of job variability for each position. Workers may not always be at their specific workstation, so the results of the study may not represent their usual tasks and daily workload. During data collection, the researchers filmed the workers while they were completing their primary tasks at their workstation. After the video data was collected, the researchers left the workplace until post-shift data collection took place; during this time it is difficult to determine what exact tasks the participants were completing.

The posture analysis results of this research study showed that workers are currently completing some awkward postures while completing heavy lifting, but the actual load on the body is unknown. Future studies could explore the use of the NIOSH Lifting Equation to assess the lifting requirements and the associated manual material handling risks (Middlesworth, 2016). The workers at the brewer station are required to lift items between 25 - 35 kilograms, and the workers at the driver station are lifting 60 litre kegs which each way approximately 82 kilograms. The use of the NIOSH Lifting Equation would also help the employer to set guidelines regarding the amount of load put onto the workers' bodies.

This research study could have had limitations or conflicting factors that may have affected the results. One possible limitation of this research study was that it was conducted during the brewery's offseason which is after the winter holidays. The product demand significantly reduces after the holidays, causing the number of workers at the brewery to also decrease. The researchers only collected data from each participant once, however this may have narrowed the findings of the study. Had the researchers reduced the number of participants and increased the number of shifts to collect data, the results may have been different. This would depend on the workers' tasks and if they complete any changes day-to-day.

CONCLUSIONS

In the future, more studies could be conducted to specifically focus on individual workstations at the brewery. A more thorough analysis of each station would assess the risk of acute or chronic injury in more detail, and consider all tasks of each job. For example, the cellar workers spend considerable time completing tasks while in awkward postures, and they may be at higher risk of developing a work-related injury caused by awkward postures compared to other stations. This research study was not able to assess the drivers in their trucks; however, this is an area for future research and could help highlight whether there is any risk of injury due to the truck's space and equipment, or because of the actual driving. The jobs examined tended to be monotonous. studies could also explore job stimulation, job satisfaction, and job rotation at the brewery to ensure all employees are alert and stimulated while at the workplace. The bottlers and box makers may benefit from more frequent job rotation to provide an aspect of job stimulation. Future studies exploring the implementation of ergonomic solutions will help to develop better work protocols related to specific job tasks and methods to reduce risk of injury due to hazards.

While craft breweries are becoming more popular, there is little published data with respect to workers in this industry. This preliminary investigation found that depending on the workstations at the brewery there is a potential risk of either acute or chronic injuries. The brewers and drivers appear to do the majority of heavy lifting and manual materials handling, and therefore are at risk for either an acute or chronic injury. The box maker and bottler stations have workers completing many repetitive motions, which may lead to a chronic injury. Finally, the cellar workers complete the most awkward postures throughout their shift, putting them at risk for chronic injury. The data obtained will help the brewery develop improved work protocols to reduce the risk of injuries in the workplace.

ACKNOWLEDGEMENTS

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VICTORIOUS VALIDATION – A PROCESS FOR IMPROVING THE ACCURACY OF ERGONOMISTS' REPORTS

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KEYWORDS
PDA, Validation, Process Improvement

MAIN MESSAGE
A document that is intended to provide an objective, quantitative description or evaluation of job demands should be validated, or verified, by someone who knows the job.

Une validation victorieuse : un processus pour améliorer l'exactitude des rapports des ergonomes

MOTS-CLÉS
AEP, validation, amélioration des processus

MESSAGE PRINCIPAL
Cette communication vise à expliquer pour quelle raison la description quantitative ou l'évaluation des exigences physiques devrait faire l'objet d'une validation ou d'une vérification par une personne qui connaît le travail.

PROBLEM

Amongst ergonomists, it is fairly common practice to validate a report; a worker and/or management representative typically review the report to confirm that the ergonomist fully understood the job (i.e. did not miss tasks, or over- or under-report frequencies), and used accurate input data (i.e. production rates, product mix, etc). This validation process ensures that the assessment outcome appropriately reflects the risk or job match. However, a physical demands description or ergonomics assessment is often completed with a deadline, having been requested in order to meet an order, Workplace Safety and Insurance Board or insurance company requirement, or to facilitate timely return to work. Therefore, the validation process is sometimes compromised. This paper reviews a best practice for validation.

CONTEXT

Validation can be completed informally at various stages of a project, and formally, when a draft report has been completed. The easiest method of validation for the ergonomist involves leaving (or sending) a "draft" copy, with instructions regarding what to pay particular attention to. This process may not be "easiest" for the validators, because it requires them to work through a fairly technical document, on their own. When using this method, sections of a PDA for which the client cannot be expected to validate (e.g. postural demands, push forces that were measured) can be shaded out on the report to allow the validators to skip these sections and focus on the information on which they can provide feedback. One challenge that ergonomists face is getting this process completed in a timely manner.

ACTIONS

Early task validation helps to get the supervisors and employees involved in the process; the ergonomist reviews the task list (or develops it in consultation with the supervisor and employees) to ensure that s/he understands the basic flow of work. For new projects, validating the draft report in-person ensures timely finalization and gives the client an opportunity for face-to-face feedback. For on-going clients, the report is sent or left with them, including instructions, with a request to complete the validation within 5 days. The ergonomist must follow up to ensure that the validation is completed.

OUTCOMES

In-person validations have the most success, but require more time. Further, when clients are engaged throughout the project, they tend to respond with more prompt validation turn-around. Where a corporate validator (i.e. a manager who may not work on-site, and has had little contact with the ergonomist) is required to validate the reports, the turnaround time is longer. This delay can compromise a project, especially if decisions regarding return-to-work or implementation must be made by a certain deadline.

DISCUSSION

Our practice is to schedule a validation meeting at the end of the first project for new clients, and for projects with new validators. They then understand the process and value of providing their input, and are more likely to see timely validation of future projects as a priority. The presentation will review some case studies where good and poor validation had consequences in the workplace.

Occasionally, projects cannot be validated, because the validators do not make themselves available to do so. A report must still be issued without “sign-off”, in order to have value in the decision making process. It can either be issued as a draft for distribution, or a final draft can be issued with a note that it was not validated (and why).

CONCLUSION

Report validation is a very important and sometimes overlooked step in the ergonomics process. In-person validation, for at least the first project, presents opportunities to develop relationships and improve buy-in to the process. However, with appropriate written instructions and accountability, other methods can also be used effectively.

BOOT CAMP: CONSIDERATIONS WHEN SELECTING SAFETY FOOTWEAR FOR WORK

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KEYWORDS: Work boot design, comfort, safety footwear

MAIN MESSAGE: With the media pushing people to stand in order to minismize the hazards of prolonged sitting, workers are inadvertently being placed at risk from the hazards associated with prolonged standing. Further, as workers age and transition into less active jobs, they may also find that standing, in comparison with walking, leads to discomfort. Workers may experience foot, leg, knee, hip and back discomfort, fatigue and even heart disease, especially if working on hard surfaces. This paper first discusses how to evaluate an employee's risk of injury due to prolonged standing, and then provides recommendations to offset that risk, including identifying features workers should consider in the selection and purchase of footwear, with a focus on warehouse employees.

Les éléments à prendre en considération dans le choix de chaussures de sécurité pour le travail

MOTS-CLÉS : Conception de bottes de travail, confort, chaussures de sécurité

MESSAGE PRINCIPAL : Comme les médias incitent les gens à demeurer debout afin de minimiser les risques associés à rester assis trop longtemps, les travailleurs sont exposés par inadvertance aux risques associés à rester debout trop longtemps. De plus, à mesure que les travailleurs vieillissent et évoluent vers un emploi moins actif, ils peuvent aussi se rendre compte que rester debout entraîne un sentiment d'inconfort contrairement à la marche. Les travailleurs peuvent ressentir des douleurs au niveau des pieds, des jambes, des genoux, des hanches ou du dos, de la fatigue ou souffrir de maladie cardiaque, notamment s'ils travaillent sur des surfaces dures. Cette communication examine d'abord comment évaluer le risque de blessure chez un employé qui travaille debout pendant une longue période, et fournit ensuite des recommandations pour réduire ce risque (p. ex., les caractéristiques à prendre en compte par les travailleurs dans le choix et l'achat de chaussures) en mettant l'accent sur les employés d'entrepôt.

PROBLEM: Standing in a static posture on a hard surface for more than 4 hours per day is associated with increased foot, knee, hip and back discomfort, and overall fatigue due to a decreased blood flow to the lower legs (CSA Z412-2011, OHSCO, 2008). An increased risk of cardiovascular disease is also associated with prolonged standing at work (Krause, 2000). Research (CSA Z1004-12 based on Carson's work, 1994) suggests that an ideal job would involve some combination of walking, sitting and standing over the course of the shift. Safety footwear is typically designed to first and foremost to protect the worker from some chemical or physical hazard with comfort and functionality often as an afterthought of the designer. Guidelines on work boot design that would mitigate the effects of prolonged standing, however, is often limited to research conducted on a specific population (e.g. firefighters), or to a simple activity such as walking, and not with general work population or in an industrial

environment. For example, Turner, et al., (2010) found that heavier work boots increase metabolic and respiratory outputs in firefighters, but found no significant effects related to boot design (i.e. material). Tian et al., (2017) reported that "inflexible and heavy work boots restrict foot movement and require greater torque at the ankle to propel the body forward, which may increase physical strain and the risk of musculoskeletal injuries", but the study was limited to 15 male civilians, using protective footwear designed for oil rig workers. As Dobson's et al., (2017) research ultimately concluded was that one boot design does not fit all; a wide assortment of safety footwear is needed to ensure that each worker's individual occupational safety, comfort and physical needs can be met.
This project addressed employees' concerns with working in a warehouse environment. Staff were convinced that the concrete floors of the warehouse, and the footwear that they were required to wear according to company policy, were contributing to their foot, leg and back pain.

CONTEXT: Warehouse employees reported discomfort as a result of working and walking on concrete floors to put away or pick stock. Many of these employees had worked for more than 25 years in a field service role without complaint. After only a few years of working in a warehouse environment, they reported back, hip, knee, leg and foot disorders. The ergonomist was asked to evaluate the employees' concerns, and provide recommendations to minimize potential hazards, if any, including suggestions for appropriate footwear.

ACTIONS: The ergonomist obtained timed trials for the receiving and picking tasks, to quantify the frequency/duration of static standing, sitting and walking. Where anti-fatigue matting was present, the time spent standing on matting and on concrete was captured separately. Since attendants perform receiving tasks in the morning and picking tasks in the afternoon, the picking and receiving trials were averaged to determine an employee's average exposure to static standing over the course of a shift. The overall static standing exposure was then compared to ergonomics guidelines to determine risk (OHSCO, 2008-MSD Prevention Guideline for Ontario). In addition, the ergonomist reviewed the company policy on footwear, evaluated the employees' existing footwear against ergonomics guidelines and against the company policy, and conducted research at a local safety boot supplier on possible alternatives to improve comfort.

OUTCOMES: Although overall static standing demands were found to present a low risk of injury (total duration of static standing on a hard surface less than 4 hours), the ergonomist looked for opportunities where matting or sitting could be provided. In addition, nine different work boots were compared based on arch support, toe clearance, cushioning (inside and out), weight, and flexibility. The ergonomist identified safety boot models that would offer foot support a better fit, and comfort, which would still meet the company's safety requirements.

DISCUSSION: The investigation revealed that the employees misunderstood the company's footwear policy, and had selected footwear that was more appropriate for work in outdoor environments, which was heavy, had minimal padding and was inflexible. These features were not conducive to the type of tasks performed in a warehouse environment (e.g. crouching to stock lower shelves), resulting in contact stress and increased foot and lower leg demands. While the ergonomist was able to identify boot features and models that were more "ergonomically friendly" for this job, ultimately, the actual fit with the employee's foot (e.g. foot length and arch support) will ultimately determine the ideal boot style for each individual. The ergonomist also discussed the value of workers purchasing removable gel-filled insoles to provide additional comfort in existing footwear.

CONCLUSION: Ergonomists are often asked to provide advice regarding whether a job involves too much standing, or whether a certain type of footwear (or other personal protective equipment) is acceptable. Although there is limited research and even fewer guidelines available for this type of assessment, ergonomists can use prolonged standing guidelines to objectively quantify demands and evaluate risk. They can also offer suggestions that improve comfort, within constraints presented by company policies and budgets. This case study reviews the application of a simple “4 hours per shift” threshold, with a successful outcome.

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ERGONOMIC-DESIGNED ENVIRONMENTAL HEALTH AND SAFETY (EHS) CHANGE MANAGEMENT

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KEYWORDS
Change management, Ergonomics, Safety, Health, Environment

MAIN MESSAGE
Balancing micro-ergonomics and macro organisational design concepts to design an interactive, scalable change management tool.

Un outil de gestion du changement fondé sur l'ergonomie et la santé et sécurité au travail

MOTS-CLÉS
Gestion du changement, ergonomie, sécurité, santé, environnement

MESSAGE PRINCIPAL
Établir un équilibre entre les concepts de conception de micro-ergonomie et ceux de macro-organisation afin de concevoir un outil de gestion du changement qui est à la fois interactif et évolutif.

PROBLEM
What does a user-friendly, global process evaluation tool for change management look like? How do you design a tool to successfully meet a variety of user requirements across a multinational organization and align it to business processes?

CONTEXT
Many organizations have a mechanism to address EHS and ergonomics in change management processes through the use of checklists, criteria, standards or other specification requirements. However, the effectiveness and widespread use of such mechanisms are often limited by format (ex: Excel spreadsheets, electronic vs. paper), language barriers (ex: major operating business languages), defined process (ex: procedures and work instructions), scope (ex: new, modified or relocated equipment), user population (ex: Non-Safety experts) and/or appropriate content design (ex: sensitivity to legal jurisdictions, global demographics).

ACTIONS
Using principles of user-centered design, an interactive, scalable, change management tool containing EHS and ergonomics technical content was developed and mapped to core organisational business processes such as new product launch, innovation, new/modified equipment and transfer/relocation. To facilitate company-wide uptake, the tool was computer programmed in SharePoint, using Microsoft SQL Server and Visual Studio.

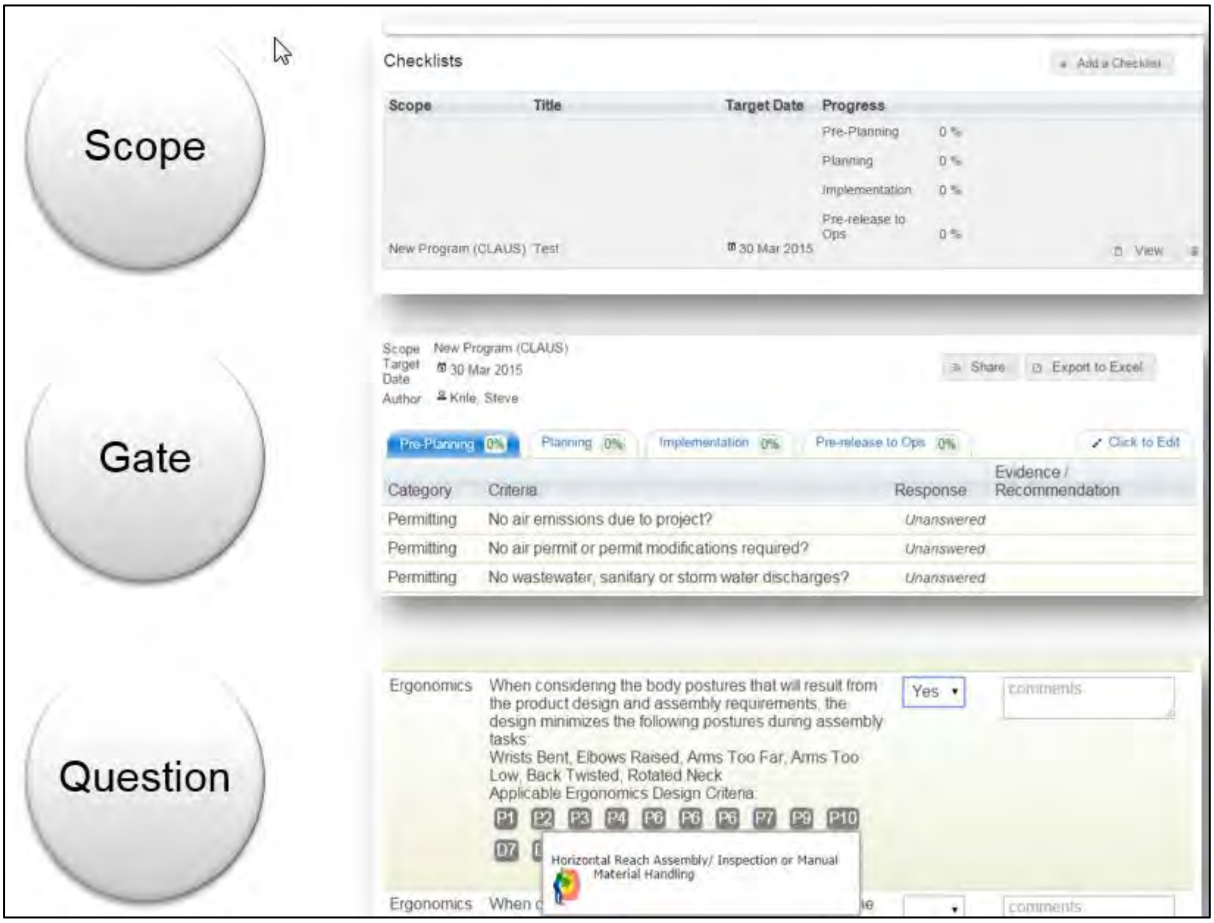

Figure 1: Micro ergonomics design application in checklist tool design framework

Further, the tool's application was directly embed into strategic and tactical process workflow elements like procedures, guidelines and work instructions. To achieve these integration points, the business case was developed, through project examples, that this tool was critical to meeting automotive industry standards such as IATF16949, improving design standardization, facilitating consistent capital equipment procurement processes and proactively designing for safety to support successful new product launch for customers. Stakeholders include safety, program management and engineering.

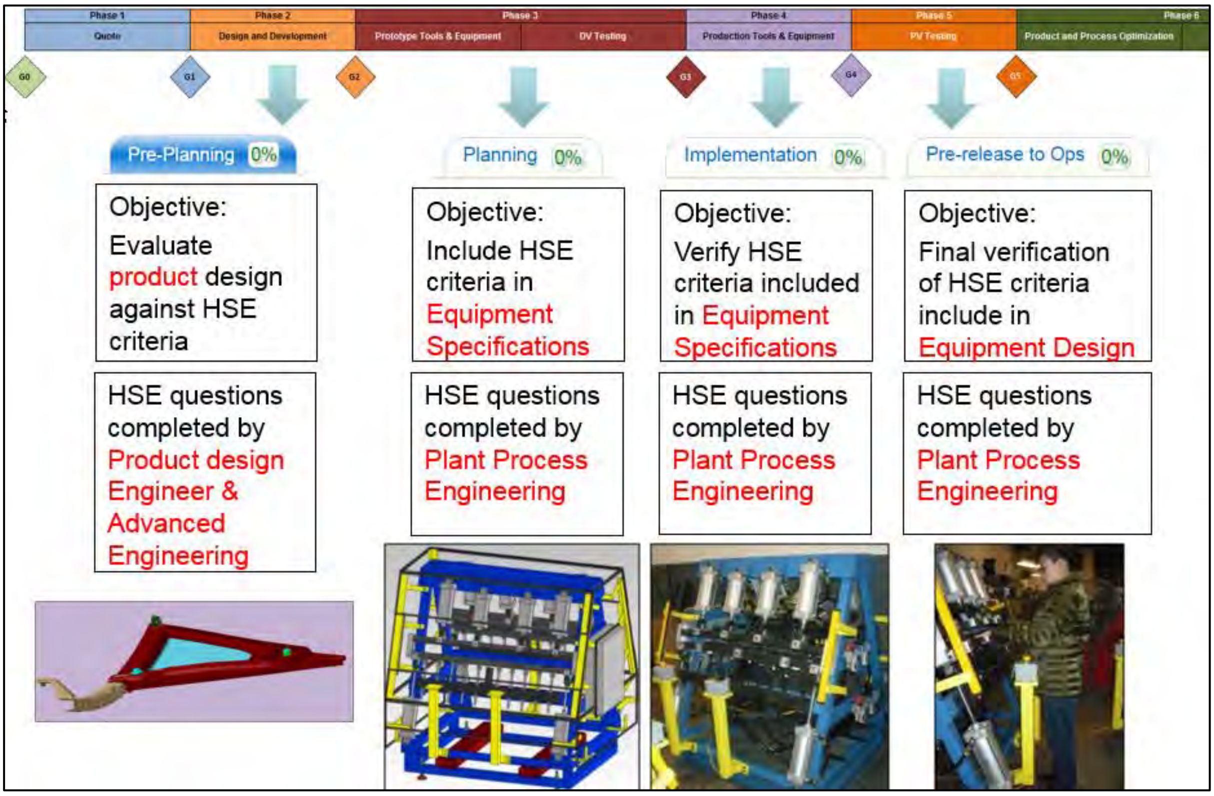

Figure 2: Macro ergonomics design application in integration to business process workflow

OUTCOMES

The EHS change management tool, primarily used in engineering work systems, is embed into the organization's key business, manufacturing and product design workflow processes in 20 countries. With more than 500 project applications in two years, the tool has documented more than 30,000 safety design checkpoints.

DISCUSSION

Over the course of two years, the company has demonstrated it is *doing* safety change management in using the tool as part of standardized key business process workflows. The focus now shifts to ensuring the organization is doing change management *well*. To measure the quality of safety change management across the organization, a gap analysis was applied.

CONCLUSION

Practitioners seeking to improve safety change management in their organization should: (a) apply a macro and micro Ergonomics approach to the design of a technical change management tool, (b) design for global user requirements and (c) ensure integration of the change management tool into the organization's business processes.

Technical Session 13: Human Factors, Quality, And Indicators

Séance technique 13: Ergonomie, qualité et indicateurs

GENERATING KEY PERFORMANCE INDICATORS FOR MODERNIZATION OF KNOWLEDGE MANAGEMENT IN AN ENGINEERING R&D FIRM

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KEYWORDS
Knowledge Management, Key Performance Indicators, KPIs, Metrics, Socio-technical Systems

MAIN MESSAGE
Knowledge capture of legacy systems presents an interesting challenge as long standing engineering research and development firms seek to modernize their processes. Through interviews and supporting survey items, we established a succinct set of metrics to measure the state of knowledge capture in such an engineering organization. This set of metrics will continue to be monitored in the future to show effectiveness of organizational interventions to support knowledge management.

Générer des indicateurs de performance clés en vue de moderniser la gestion du savoir dans une société d'ingénierie exerçant des activités de r&d

MOTS-CLÉS
Gestion des connaissances, indicateurs de performance clés (KPI), paramètres, systèmes sociotechniques

MESSAGE PRINCIPAL
Le transfert de connaissance lié aux anciens systèmes présente un défi intéressant pour les entreprises de recherche et développement en ingénierie de longue date cherchant à moderniser leurs processus. Grâce à des entrevues et des sondages de soutien, nous avons établi un ensemble succinct de paramètres pour mesurer l'état du transfert de connaissances dans une firme d'ingénierie. Ces paramètres continueront d'être surveillés afin de démontrer l'efficacité des interventions organisationnelles dans le but de soutenir la gestion des connaissances.

PROBLEM
Any business in operation for more than 10 years experiences pain with technological growth, particularly when it comes to data management. Generating new data, storing old data, and working between the two, challenges both legacy and current technological systems. Combine this incompatibility with the number of disparate data streams, sources, and formats inherent in many complex systems, and the problem is compacted. In this case study, we explored the topic with an engineering firm with a long-term product that has grown through data mediums since 1960.

Knowledge is getting lost, or maybe did not exist to start. This case study focuses on a product line with 60 years of operation and extensive history of disparate types of data. The growth of this organization instigated a number of structural, hierarchical, organizational, and technological changes. The growth of data recording opportunities and the emergence of detailed data analysis, the need for more comprehensive data analysis is growing. The organization needed to understand the state of knowledge management to anticipate requirements for a more complete data, information, and knowledge management system.

On this product line, the stakeholders' overarching objective was to employ machine learning to organize its immense amount of data.,The first goal in this process was to characterize the data. A six-month project created data maps and higher-level organizational charts, which followed the flow of data across the organization. This resulted in the identification of various process gaps and points of failure. The team organized these using the affinity diagramming methodology as described by Beyer and Holtzblatt in the Contextual Inquiry methodology (Beyer and Holtzblatt, 1997). (Please see our Actions section where we go into more details about the methodology for its use in developing the knowledge management indicators.) Three main themes rose to the top:

1. Knowledge is getting lost, or maybe did not exist to start.
2. The support structure is barely able to maintain current usage.
3. The process has built a culture of silos.

With the aim of completing a root cause analysis, the symptoms of these problems were identified and categorized. The management team, presented with a tradeoff of resources, time, and anticipated impact, selected "Knowledge Management" as the theme and focus of the study. From the initial instantiation of the Contextual Inquiry methodology, five sub-themes were generated:

1. I don't know where… to find data; to find people; to find information.
2. I don't know who… is the author of the data I need; has the information I seek; I should talk to.
3. I don't know when… the data was generated; is being delivered; needs to go out.
4. I don't know why… the data is necessary; the report is being created; this process is being used.
5. We knew why at some point.

From this first exploration, we found that confusion, frustration, delays, and continuing bad habits of data management were symptoms of general knowledge mis-management, but we had no metrics against which to determine the severity of the problem. Thus, our challenge was to build a repeatable tracking system, with key performance indicators to guide policies and decisions. These would help select which initiatives to undertake and indicate whether the organization was improving their knowledge management strategy. The issues themselves are likely organization-specific. Establishing a repeatable methodology will help the organization track and monitor the effects of any future initiatives, regardless of the shift in problems.

CONTEXT

The organization in this study focuses on many technical aspects of a few main product categories. The longevity of a cornerstone program creates the need for specified knowledge management practices. The organization experienced a number of re-organization and re-tooling initiatives, in addition to seeing many of its personnel retire, presenting the opportunity for knowledge loss and insufficient knowledge transfer.

Our team ultimately sought to propose strategies to remediate existing knowledge mis-management and build a continuing culture of usable knowledge capture and management for the engineers and management team. In knowledge management, there are four stages: Generation, Capture, Representation, and Dissemination (Girard & Girard, 2015). The hierarchy of data, information, and knowledge (in that order), also applies along this spectrum (Figure 1). The figure demonstrates that most data is generated, and then as the process moves forward into the capturing phase, data starts to become information and knowledge. In the case study, data was being generated. Information was also being generated from this data, and often captured. However, capture, representation, and dissemination of any of the information sources was not performing to the standards necessary for the longevity of the organization.

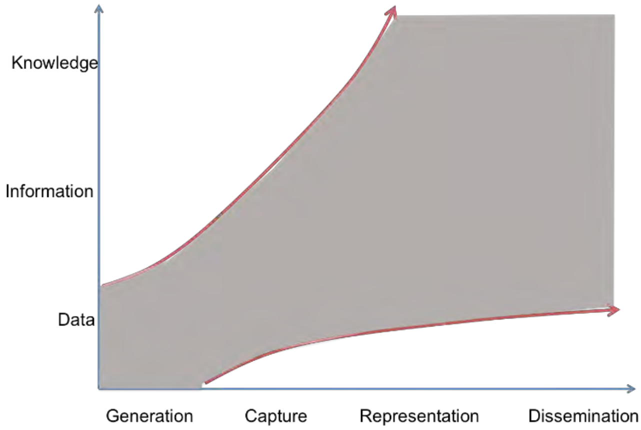

Figure 1: Knowledge creation and distribution process.

ACTIONS

We employed a methodology that aimed to quickly and adequately measure and analyze shortcomings or root causes, in current knowledge management, through customization of industry and academic benchmarks. We proposed mitigation strategies, techniques, and tools for improvement. We provided a methodology with a validation and control or tracking plan for diagnosing and tracking knowledge management success for engineering organizations.

Through the Contextual Inquiry methodology, we interviewed 21 subject matter experts, codifying and grouping the findings through Affinity Diagramming. We then surveyed the population of engineers to better understand the current state of knowledge capture. We established baseline metrics for the management to track organizational initiatives to improve knowledge management. Figure 2 demonstrates the process and the items informing the subsequent steps.

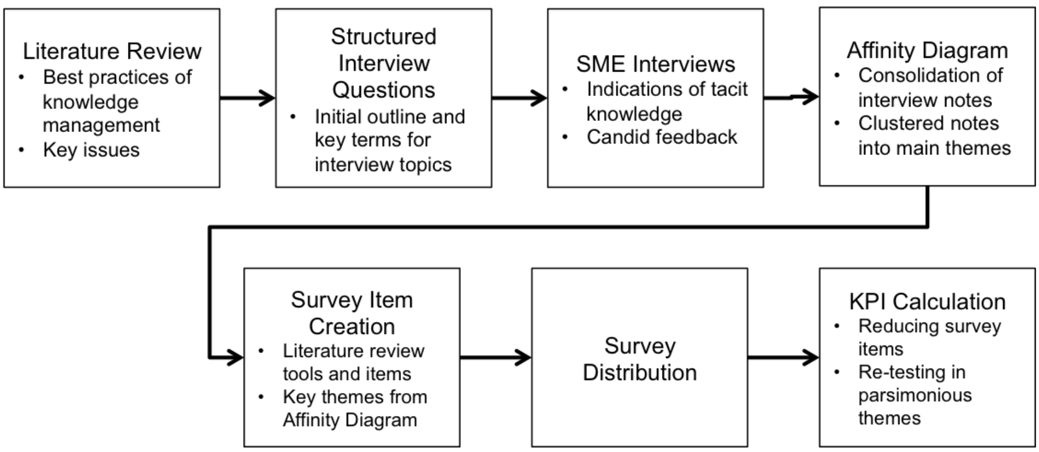

Figure 2: Methodology to build repeatable performance indicators for knowledge management.

Interviews can offer more candid insight into the daily tasks, emotions, and actions of an individual. The advantage of the interview is that the data in aggregation can indicate broader themes while allowing specific instances to be captured. The disadvantage is the cost of time to collect the data and the subjective nature of the content. For this reason, we collected 21 interviews of subject matter experts (SMEs) along the life cycle of both the product and the organization. SMEs were originally identified by the project stakeholders, some with referrals of other SMEs.

Directed interviews provided the platform to discuss a known set of topics with flexibility for the participant and interviewer to clarify points and obtain details or insights into specific subjects (Lehto, et al., 1992). Interviews lasted one hour with an interviewer, a note taker, and the subject matter expert. A list of topics and questions was used to prompt the interviewer. Although there were general information questions, such as job role, the main prompts are listed below:

1. What kinds of communication and documentation are necessary for you to have with other work units?
    a. How well does this inter-unit communication work?
    b. When you have to communication with a person on another task, how do you reach out?
    c. Who connects you?
    d. How do find them?
2. Describe the formal channels through which you typically receive information.
    a. What kinds of information do you tend to receive?
3. What tools do you use to document, receive, and send information?
4. Describe the informal channels through which you typically receive information
    a. What kind of information do you hear?
    b. How active are informal channels? (How many times do you get more done at the water cooler than through formal channels?)

Although these questions focused on communication, many of the conversations took a turn to traditional knowledge management topics, including collecting or retrieving data, aggregating and collaborating to form information, and representing and sharing knowledge. From each of the interviews, raw notes were turned into single-sentence insights. Major themes, needs, and gaps in current knowledge capture practices were determined through affinity diagramming process.

Notes from the interviews were transcribed to individual insights that were then clustered by their affinity. The Affinity Diagram is a powerful way to cluster individual notes into a hierarchy. Introduced by Kawakita (1982) and Brassard (1989), Beyer and Holtzblatt document the technique extensively in the Contextual Design methodology (1997). Notes are grouped based on similarity to each other. Beyer and Holtzblatt describe affinity as “two notes have affinity if they are saying similar things about the work as it relates to the design focus of the team,” (1997, pp. 156). The groupings of these notes reveal common themes, which are then labeled in design, or stakeholder terms.

Simultaneous to the interview methods, we researched institutionalized methods and metrics for knowledge capture. The International Communication Association Survey provided the most comprehensive measurement device (Downs and Adrian, 2012). This survey was originally developed in a suite of information elicitation techniques, but can also be used alone. The survey uses 122 questions in 8 sections:

1. Amount of information actively received about topics; Amount of information desired about these topics;
2. Amount of information actually sent about topics; Amount of information desired to be sent about these topics;
3. Amount of follow-up by people now; Amount of follow-up needed;

4. Amount of information received from sources; Amount of information desired from these sources;
5. Timeliness of information received from key sources;
6. Organizational communication relationships;
7. Satisfaction with organizational outcomes; and
8. Amount of information received from channels now; Amount of information desired from channels.

The project stakeholders sought to maximize the amount of data elicited from the survey, while minimizing the amount of time to take the survey. Indeed, this is the dilemma of any survey – achieving accurate results without inducing stress, boredom, or fatigue with the instrument.

Based on the interviews and goals of the project, we down-selected items and sub-items. Sections 6 and 7 only included a single sub-item each to assess the general communication structure of the organization. These sections did not pertain as strongly to knowledge management concepts, and would have provided a platform and bias for organizational issues not in focus for this study (e.g. pay, compensation, etc.). In addition to the metrics suggested by the method, we added organization-specific themes, akin to those found in the affinity diagram. These additions included access to training and learning resources, the amount of formal and informal learning and training available, and the participation in these programs. We adjusted sub-items to be specifically relevant to the terminology and hierarchy of the organization. This helped participants answer accurately, rather than interpreting more generic terms and concepts.

The resulting survey contained 30 distinct items with an average of 5 sub-items each. The sub-items referenced specific situations encountered, technologies, and organizational structures familiar to the participants. The survey was distributed to a sample of the population under study (65 people). From this sample, 39 people participated, approximately 60% of the targeted population.

OUTCOMES

The interview protocol provided candid context and major themes. The interviews, along with The International Communication Association Survey, added a method to widely collect repeatable metrics, or key performance indicators (KPIs) for the organization. This novel approach established a set of 15 key performance knowledge management indicators.

Interview outcomes provided repeated themes about communication, documentation, working across organizational structures, and receiving training formally or informally. Survey outcomes gave us metrics over all 30 items. Although average survey time was 20 minutes, the lower response rate— even with a more amenable audience— indicated that our methods may need to be shortened. In order to repeat this, we down-selected to the questions and metrics that our stakeholders were most engaged with. The final set of metrics is shown in Table 1. Of note, both participants and stakeholders were interested in the differences in amount of information both received and sent. Tangential to this topic is the amount of follow-up and source of that information.

Table 1: KPIs of Knowledge Management

Original Issue	**Item**
Multiple	Amount of information actively received about topics
Multiple	Amount of information desired about these topics
We knew why at some point	Amount of information actually sent about topics
We knew why at some point	Amount of information desired to be sent about these topics
We knew why at some point	Amount of follow-up by people now
We knew why at some point	Amount of follow-up needed
Multiple	Amount of information received from sources
Multiple	Amount of information desired from these sources
I don't know when	Timeliness of information received from key sources
I don't know who	Organizational communication relationships
Multiple	Satisfaction with organizational outcomes
I don't know where	Amount of information received from channels now
I don't know where	Amount of information desired from channels now
Accessibility of resources	Ease of use and access
Documented learning	Amount of information known now that wasn’t known before
Documented learning	Participation in the apprenticeship program

Each of the original sub-themes identified was addressed by at least one metric. This provides insight as management and stakeholders select the initiatives to employ among the workforce.

DISCUSSION

Knowledge management is the culmination of knowledge capture, translation, and distribution. The interviews conducted at the beginning of the research process uncovered problems across the knowledge management spectrum. In order to scope the indicators appropriately, we focused only on the knowledge capture aspects of the problem space. Thus, our methodology and performance indicators demonstrated current knowledge capture requirements, allowing for the generation of viable solution spaces. Key to identifying these solutions was engagement directly with the users and disseminators of the knowledge and information. Essentially, understanding the information requirements of the engineers within the organization allowed for specific, tailored, and meaningful solutions to be created. From our direct conversation and analysis with the engineers in the program, the thematic repetitions that dealt with the communication, documentation, and information flow across organizational structures, as well as the formal and informal training aspects, were able to emerge in a meaningful and impactful way, allowing management to get realistic and meaningful feedback about current knowledge management infrastructure.

Additionally, one of the main goals of this study was to establish repeatable metrics to serve as decision aids and indicators for future programs and initiatives. This process has not been repeated yet, but promises to be achievable.

CONCLUSION

The interview phase of this project was critical to generating a more precise and relevant focus for engineers. Developing survey items that elicited precise measurements related to the organization created a repeatable method that will provide the management with better insights to knowledge management initiatives.

The interviews provided potent insights beyond the initial hypotheses offered by the formal survey metrics although the survey results supported the content uncovered by the interviews. The next step will be to implement the metrics in other programs so that knowledge loss and insufficient knowledge capture do not hinder the workflow progress.

These methods demonstrated progress toward improving knowledge capture at the focus institution. As we face rapidly advancing data collection and storage methods and changing demographics in the workforce, the implementation of these presented methods offers insight for areas of improvement for an institution's knowledge capture processes.

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INTER-METHOD COMPARISON OF FOUR HUMAN RELIABILITY ASSESSMENT (HRA) MODELS

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KEYWORDS
Human Factors, Human Reliability Assessment, Reliability, HRA Models, HRA Models Comparison

SUMMATIVE STATEMENT
A qualitative comparison between reported most common HRA models, which includes Human error assessment and reduction technique (HEART), Technique for human error-rate prediction (THERP), Standardized Plant Analysis of Risk Human (SPAR-H) and Cognitive Reliability and Error Analysis Method (CREAM), shows that despite fundamental similarities, reviewed models have lack of uniformity among the pre-defined inputs. Also, none of them were reported validated models. Sensitivity analysis shows that HRA models responded differently to Performance Shaping Factors (PSFs) levels change, which could cause problems for the user to select an appropriate model.

Comparaison entre quatre modèles d’évaluation de la fiabilité humaine

MOTS-CLÉS
Facteurs humains, évaluation de la fiabilité humaine, fiabilité, modèles HRA, comparaison entre les modèles HRA

SOMMAIRE
Une comparaison qualitative entre les modèles HRA les plus courants – la technique d'évaluation et de réduction des erreurs humaines (HEART); la technique de prévision du taux d'erreur humaine (THERP); l'analyse d’implantation normalisée des risques humains (SPAR-H); la fiabilité cognitive et la méthode d'analyse des erreurs (CREAM) – montre que malgré les similitudes fondamentales, les modèles examinés manquent d'uniformité sur le plan des données d’entrée prédéfinies. En outre, aucun de ces modèles n’a été validé. L'analyse de sensibilité montre que les modèles HRA ont répondu différemment aux facteurs qui influent sur le rendement (PSF), ce qui pourrait entraîner des problèmes pour l'utilisateur lorsqu’il doit choisir un modèle pertinent.

PROBLEM STATEMENT
According to reviewed studies, HRA models are reported as useful methodologies to evaluate human error probabilities (HEP) and have been implemented in different industries, include manufacturing and medical sectors. Studies showed different models using different factors for HEP evaluation and they are providing different responses. Therefore, both qualitative and quantitative analysis has been implemented to compare these models to facilitate model selection and/or identify opportunities for improvement.

RESEARCH OBJECTIVE/QUESTION

Studies showed that unsafe work environment can cause human errors. Kirwan (1992) described Human Reliability assessment (HRA) approach was started since a century ago to evaluate workers contribution in having reliable operation procedures. Kirwan (1997) reported HRA models as the acceptable methods to determine human error analysis. HRA approach analyzes the probability of error occurrence based on occurred failures associated with workers' actions. Over the century several HRA models has been proposed. Calixto, Lima & Firmino (2013) mentioned that HRA method gradually developed in two generation. The first generation has a primarily focus on human error probabilities and operational human error that includes approximately 40 methods. The most commonly used methods for this generation are Technique for Human Error Rate Prediction (THERP) and Human Error Assessment and Reduction Technique (HEART). The second generation includes different number of methods which all has more focus on human performance factors, and cognitive processes. According to scientific literatures, the Cognitive Reliability and Error Analysis Method (CREAM), and Standardized Plant Analysis Risk-Human Reliability Analysis Method (SPAR-H) are the most used methods of this generation (Di Pasquale, Miranda, Iannone, & Riemma, 2016). HRA models are reported as a useful methodology to assess human interaction with both work and system design, in a certain time interval, explicit context, and different industries. However, there is no evidence available to guide the users among models. Despite the number of studies on fundamental HRA models, there are few studies of model comparisons. To our knowledge, there is no finding on reported common HRA models comparison. In order to address these gaps, following research questions are going to address:

1- What, qualitatively, are the similarities and differences between four common HRA models?
2- How do the different models respond, quantitatively, to similar changes in model inputs?
    - One Factor At a Time (OFAT) analysis to assess the impact of PSFs level changes in HEP evaluation for nominal base cases
    - Combined PSFs to analyze outputs at the highest and lowest error risk level to assess extreme cases

METHODOLOGY

In order to determine the outcome of these research questions, qualitative and quantitative analysis has been conducted.

- **Qualitative Analysis:**

This method fulfills RQ#1: A content analysis review was conducted with the aim of probing inquired HRA models. For this purpose the scientific research strategy was demonstrated in human error assessment, human factors, and reliability disciplines by considering relevant keywords, which leaded to create two research keyword categories. Identified keywords were combined based on (OR) and (AND) logics were implemented inside and between defined categories respectively. This searching approach helped to develop sets, to identify relevant papers. All these keywords were used to search through human factors and, reliability scholarly databases such as Engineering Village, Web of Science, Scopus, EBSCO, JSTOR, and IEEE. The chosen papers were used to distinguish other relevant papers by implying snowball strategy. This analysis compared the selected HRA models based on Input factors, sector of origins and applied industries, steps to evaluate HEP, reported advantages and disadvantages and validation evidence criteria. The outcome of this step supports the aim of this project to identify similarities and differences between selected HRA models.

- **Quantitative**

This method fulfills RQ#2: Quantitative analysis has been assessed based on a defined case study, which considered both manual and automatic tasks in 8-hour shift. For this assessment 8 common PSFs has been selected among all the reported PSFs in selected HRA models. Selected PSFs include complexity, time, skill, procedure, ergonomics, design, tool accessibility, and supervisory. All the PSFs levels according to studied literature reviews have been categorized into low, nominal, and high levels. Quantitative analysis was demonstrated in two sensitivity analyses.

1) One factor at a time (OFAT), for "Nominal", which is the acceptable tolerance value for error occurrence, as a base cases to compute PSFs impacts, calculated as a median HEP for the HRA models.

2) Combined PSFs having all “High" and all "Low" levels to evaluate extremes. In order to conduct consistence quantitative analysis, same procedure was applied on selected HRA models.

RESULTS

- **Qualitative Analysis:**

  - **Human Error Assessment and Reduction Technique (HEART):**

Input Factors: The HEART includes 38 Error Producing Conditions and 9 Generic Tasks input factors to evaluate HEP.
Sector of Origin and Applied Industries: This method was initialized in nuclear power plant. It was later implemented in both manufacturing, such as chemical, aviation, and rail, and medical sectors (Williams, 1988, 2016).
Steps to evaluate HEP: In this method, HEP evaluated based on number of premises by categorizing all the tasks based on generic human unreliability. This step helps to determine nominal human unreliability probability. Then, by recognizing applicable Error Producing Conditions for each task maximum nominal failure can be predicted (Williams, 2016).
Reported Advantages and Disadvantages: This method reported as quick and simple approach. But reported as increases the chance of “double counting” due to lack of a clear guideline (Kirwan, 1997).
Reported validation evidence: Studies showed, HEART was validated by Kirwan et al (1997) at UK’s nuclear power plant, which was the same plant that model first proposed. Although, there is no other evidence available to support the validity of this method (Kirwan, 1997).

  - **Technique for Human Error Rate Prediction (THERP)**

Input Factors: According to studies, THERP does not have pre-defined PSFs associated with multiplier. In this method, PSFs value defined by probability of failures for each elements (Kirwan, 1997) (Boring, 2012).
Sector of Origin and Applied Industries: This method was founded and used by nuclear plant industry; it’s also used in both manufacturing, such as offshore and medical sectors (Boring, 2012).
Steps to evaluate HEP: The HEP evaluation is based on the ‘decomposition’ methodology; hence, task breakdown is necessary in order to determine task’s elements. Then, probability

of failure, which consider as PSFs should be assigned to each element. HRA event tree needs to be implemented to evaluate overall HEP (Boring, 2012).
Reported Advantages and Disadvantages: This method is reported as a practical approach; but it has been reported as a time-consuming approach due to extensive resource allocation as well as having a non-clear guideline (Boring, 2012).
Reported validation evidence: Studies showed, THERP was validated by Kirwan et al (1997) at the same nuclear power plant in USA that model was first proposed. There is not any other evidence available to support the model validation (Boring, 2012).

- **Standardized Plant Analysis Risk-Human Reliability Analysis Method (SPAR-H)**

Input Factors: This method includes 8 pre-defined PSFs and multipliers that are classified into actions and diagnosis categories (Gertman et al., 2005).
Sector of Origin and Applied Industries: SPAR-H approach was developed by Gertman et al. (2004) in US nuclear plant. There are no records indicating this method being used in other environments (Calixto, E., Lima & Firmino, 2013).
Steps to evaluate HEP: First, Human Failure events are determined by dedicating proper PSFs into either diagnosis or action tasks and dependency assignments in order to regulate HEP. In this method, nominal HEP for both diagnosis and action failures are 0.01 and 0.001 respectively (Blackman, Gertman, & Boring, 2008).
Reported Advantages and Disadvantages: This method reported as simple and traceable approach, Although, it doesn't have clear PSFs guideline (Whaley et al., 2011)
Reported validation evidence: SPAR-H has a pre-defined multiplier and PSFs but neither values nor the model were reported as being validated (Gertman et al., 2005).

- **Cognitive Reliability, Error Analysis Method (CREAM)**

Input Factors: This approach is based on competence and control differences. The control context is identified by 9 categories of Common Performance Conditions (Hollnagel, 1998).
Sector of Origin and Applied Industries: The CREAM method was implemented in nuclear power plant (Hollnagel, 1998; Schemeleva et al., 2012).
Steps to evaluate HEP: CREAM method calculated HEP based on 7.07*10^{-3}*EXP [-4.9517 9$\left(\frac{\sum \quad Improved}{7} - \frac{\sum \quad Decreasedd}{9}\right)$] formula (Kim et al., 2006).
Reported Advantages and Disadvantages: CREAM method supports both engineers and psychologist's risk concept. But it has not been validated since it is a fairly recent method (Schemeleva et al., 2012)
Reported validation evidence: This method was validated by Collier (2003) in nuclear plant that was firstly proposed. Later Marseguerra, Zio, & Librizzi, (2006) used it in the railway industry. Collier believes that CREAM not working accurately neither in technical nor data gathering. Other researchers also questioned the reliability of this approach (Kim et al., 2006).

- **Quantitative Analysis**

In order to compare selected HRA models quantitatively, sensitivity analyses have been implemented. This analysis includes **OFAT** and **combined PSFs** analysis to determine the impact of PSFs level changes on models' outcome. First, **OFAT** for nominal base cases has been run to assess the impact of PSFs by computing median HEP values. The OFAT analysis demonstrated SPAR-H had the lowest impact, and THERP has the highest impact PSFs assigned to **high** individually. On the other hand, The **OFAT** analysis showed that SPAR-H has the lowest impact, and HEART has the highest impact PSFs assigned to low individually.

Table 1, summarizes the OFAT analysis whether PSFs level assigned to high or low individually associated with their HEP median value.

HRA Models	PSFs level High	HEP median value High	PSFs level Low	HEP median value Low
Highest	THERP	0.67	HEART	0.18
Lowest	SPAR-H	0.0005	SPAR-H	0.004

Table 1-Summary of OFTA Analysis when PSFs level assigned to either high or low individually

Second, **combined PSFs** analysis having all PSFs levels to high and all low to assess the extremes. The combined PSFs analysis showed that CREAM has the highest impact and SPAR-H has the lowest impact when all the PSFs assigned to **high**. In contrast, SPAR-H has the highest HEP with 0.97 impact and HEART showed the lowest impact when all the PSFs assigned to **low**. Moreover, Combined PSFs analysis for nominal showed that THERP and SPAR-H has the highest impacts respectively. Table 2, summarized the combined PSFs analysis to determine the models' responses in extremes PSFs levels, associated with HEP values.

PSFs Level	High-Model	HEP Value-High	Low-Model	HEP Value-Low
High	CREAM	0.99	SPAR-H	0.97
Nominal	THERP	0.229	SPAR-H	0.019
Low	SPAR-H	7E-5	HEART	0.0004

Table 2 - Summary of Combined PSFs Analysis to compare the model's responses in extreme PSFs level

DISCUSSION

Qualitative analysis highlighted that the selected HRA models lack clear guidelines. Therefore, in order to having usable HRA models providing a clear guideline become necessary. Also, All the selected models were developed in the nuclear industry. Therefore, selected models needed broader testing in different sectors to check the models validity. Moreover, there is no paper found to support user reliability, thus further testing will be required. Quantitative Analysis showed selected models varied substantially in their outputs for similar inputs due to lack of PSFs' uniformity. Therefore, further empirically work will be needed to develop better HRA models.

CONCLUSIONS

Qualitative analysis highlighted that the selected HRA models despite fundamental similarities, have lack of uniformity among the pre-defined inputs and un-clear guideline. Also, none of them were reported as the validated models. Quantitative analysis showed selected models provides different responses for the same PSFs level inputs. More objective empirically based models need to be created and validated.

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THE IMPACT OF AGEING ON HUMAN ERROR IN MANUFACTURING SYSTEMS: A SYSTEMATIC REVIEW

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KEYWORDS

Human Factors, Human Error, Human Reliability, Age, Ageing worker, Manufacturing.

SUMMATIVE STATEMENT

Population aging is acknowledged as a global trend, and this trend affects the working population. This paper proposes a framework for addressing the relationship between worker's age and the most famous models and classifications of human error (Rasmussen, 1981; Reason,1990). The framework is based on a systematic literature review concerning the impact of age on human error (HE) in manufacturing systems with the aim of investigating the current state-of-the-art and highlighting the research and practice gaps.

L'incidence du vieillissement sur l'erreur humaine dans les systèmes de fabrication : une revue systématique

MOTS-CLÉS

Facteurs humains, erreur humaine, fiabilité humaine, âge, main-d'oeuvre vieillissante

SOMMAIRE

Le vieillissement de la population fait partie d'une tendance mondiale qui touche la population active. Cette communication propose un cadre pour examiner le lien entre l'âge du travailleur et les modèles et classifications de l'erreur humaine les plus célèbres (Rasmussen, 1981; Raison, 1990). Le cadre repose sur une revue systématique de la littérature portant sur l'incidence de l'âge sur l'erreur humaine dans les systèmes de fabrication afin d'examiner les

connaissances actuelles et de mettre en évidence les lacunes en matière de recherche et de pratique.

PROBLEM STATEMENT

Population aging is acknowledged as a global trend and this trend also affects the working population. For this reason, manufacturing industries are facing major challenges due to the continued ageing of their workforce. In Europe, the working population age trends indicate that the oldest age group (55–64 years) will expand by about 16.2% (9.9 million) between 2010 and 2030, whereas all the other age groups show a declining trend (Boenzi, et al., 2015; Fritzsche, et al., 2014; Kenny, et al., 2016).

For this reason, currently great attention is being paid to the age from scientific community, policy-makers and business leaders. Older workers have more serious, but less frequent, workplace injuries and illnesses than younger ones. Aging is also associated with a progressive decrement in various aspects of human capabilities (motor, cognitive and sensory aspects), that may lead to increase of human errors during the working activity. However, older workers can often compensate for age-related losses with relatively age stable strategies and skills related to their experience, expertise, or learning ability.

Human error is defined as a generic term to encompass all those occasions in which a planned sequence of mental or physical activities fails to achieve its intended outcome, and when these failures cannot be attributed to the intervention of some chance agency (Reason, 1990). The main recognized error taxonomies in the literature are (Di Pasquale, et al., 2016):

1) Model of Internal Human Malfunction (Rasmussen, 1981): differentiates three basic levels of human performance i) skill-based, when automated actions follow an intention (sensory–motor behaviour); ii) rule-based, when there is a procedure or technique guiding the action; and iii) knowledge-based, represented by actions developed to deal with an unfamiliar situation (Skill-Rule-Knowledge model).
2) Model of Unsafe Acts (Reason, 1990): divides human errors in slips and lapses, when an execution failure or an omission occurs, and mistakes, which result from judgement processes used to select an objective, or the means to accomplish it. Reason also highlighted an alternative behavior from a social context, called violation, which emerges from an intentional deviation from operating procedures, codes of practice or standards.

To date, the aging theory has been widely discussed in the literature from a physiological point of view. But little is known about the impact of age on HE, despite of the inevitable role of ageing workers and human errors in manufacturing systems. In fact, chronological age impacts on human reliability and the occurrence of human errors strongly influences system reliability and safety, equipment performance and economic results.

RESEARCH OBJECTIVE/QUESTION

Three research questions are addressed in this study: (1) what is the relationship between age and HE; (2) how and when do human errors due to age affect industrial operations; (3)

and what strategies can be pursued to reduce the negative impacts of age on system performance starting from the older workers strengths.

METHODOLOGY

A systematic literature review, following the guidelines presented by Neumann et al. (2016) and Pires et al. (2015), has been conducted using three scientific databases (Scopus, Web of Science and Engineering Village) to identify peer-reviewed papers that presented evidence on the relationship between ageing and human performance in manufacturing systems. To investigate this relationship, it is necessary to consider research from several disciplines. A set of keywords was prepared for the databases (Table 1). Groups A, B, C and D list keywords related to age, human error, industry type and human field, respectively. The final keywords list used to search consists of all possible combinations of keywords from Groups A, B, C and D using the Boolean operators to make the relationship (AND) and the sum of words (OR) (e.g., Age AND Error AND Manufacturing AND Human).

Table 1. Set of keywords used in the systematic search of Engineering Village, Scopus and Web of Science.

KEYWORDS			
A	**B**	**C**	**D**
Age (*)	Error	Manufacturing (*)	Human
Older (*)	Reliability	Industry (*)	Worker
Senior (*)	Failure	Production (*)	Workforce
Elder (*)	Performance	Assembly (*)	Employee
	Slip		Operator
	Lapse		
	Mistake		
	Mismatch		

Articles that had the searched keywords in its title or abstract and were published between 1996 and 2017 were screened. As restrictions, only articles in English, published in peer-reviewed journals or conferences and with available full text were considered. After running the search on the three databases, all articles were uploaded into a database manager (i.e., Mendeley) and all duplicates were removed.

Papers identified by the systematic review went through two selection processes. The first selection (as a result of reading of the title, abstract, keywords) excluded: a) articles presented only one of the main key concepts (age and human error); b) they did not establish a link between age and human error; c) they were not related to manufacturing environments. The second stage included the reading of the full text and a definitive assessment as function of the exclusion criteria. The references from selected papers were examined as a further source of papers in a “snowball” approach. The selected papers are currently under analysis, through a pre-determined framework, to achieve the research objectives, based on these specific criteria to extract and structure the information:

- Publication year;

- Type of contribution (Development of method/methodology/model, State of the art, Proposition of framework, Other type of contribution);
- Research method (Experimental Research; Simulation, Case study, Literature review, Other type of research method);
- Demographic features;
- Type of human error analysed;
- HF capabilities link to age and human error;
- Age effect on system performance.

RESULTS

The impact of age on HF capabilities has been quantified, as reported in many studies in the psychological, gerontological and medical disciplines that examine how various abilities change over an individual's lifetime (Chan, Tan, & Koh, 2000; Crawford, et al. 2010; De Zwart, Frings-Dresen, & Van Dijk, 1995; Salthouse, 2010; Salthouse, 2012; Shephard, 1999; Silverstein, 2008)

The database search for the systematic literature review resulted in 6521 possible articles. First and second screening and the additional snowball searching led to a final set of only 21 studies. Two articles are conference proceedings whereas the others are published on scientific journals in the engineering, medical and social sciences areas. The final set of papers includes empirical studies and in-depth literature review that aim to establish a link between age and human error. Figure 1 reports the publication distribution over the years.

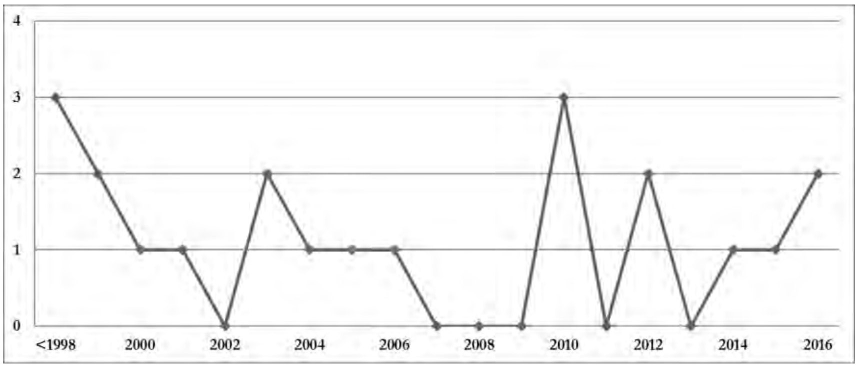

Figure 1: Publication trend by year.

The analysis process, currently underway, is providing evidence of age and human error relationship. Preliminary results show a significant correlation between the human error rate and the operator's age; such correlation is a function of the psycho-physical workload (Börsch-Supan & Weiss, 2016; Fritzsche, et al., 2014; Haji Hosseini, et al., 2012; Pennathur, et al., 2003). Several age-related HF capabilities (vision and hearing loss; decrement of working memory, attention, reaction and response time; physical decline) that affect worker performance and its reliability, have arisen from the systematic review. However, the decrease of HF capabilities is sometimes compensated by the experience, that allows to better manage the performed tasks and reduce the number of human errors (Mehta & Agnew, 2010).

Furthermore, human errors, due to ageing impact, affect industrial operations in terms of safety and system performance. In particular, 11 of the total paper describe the impact of human error on system performance (productivity, quality, efficiency), while 7 papers address the safety issue (occupational accidents, slips, trips and falls) with reference to age.

DISCUSSION

The ageing workforce is considered as productivity, quality and safety risk in manufacturing industries. The systematic literature review provides a first look at the substantial impact that demographic change can have on manufacturing companies. The limited number of selected studies and empirical data in literature is due to the main challenge related to the study of the link between ageing and human error in working context. In fact, human errors are hard to measure directly in manufacturing contexts, because they may cause a quality defect, a productivity loss but also a latent error, which is complex to identify. Furthermore, HEs are influenced by many individual and contextual factors, that may additionally modify the assessment of ageing impact.

The analysis of papers shows that age is highly associated with HE in a way that no simple linear decreasing effect exists and a variety of mediating factors come into play. This outlines the relevance of considering the non-negligible effects of ageing workforce on system performance. For these reasons, the relationship between age and human error must be further explored to help researchers to deeply understand this link and intervene into workplace design and management.

CONCLUSIONS

This paper aims at intensifying the practitioners' and researchers' awareness for the importance of the demographic change in manufacturing systems. As highlighted in the result section, a relationship between age and human error in manufacturing context exists and affects the system performance and worker safety. Accordingly, it is necessary to establish a work environment that considers humans' physical and cognitive features to prevent human errors and to have a program that enhances work performance in preparation for the aging of society. This study motivates future assessment of age affects on HE in manufacturing sector, due to the evidenced gap in literature, providing several research opportunities.

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A CASE STUDY ON THE RELATIONSHIP BETWEEN HUMAN FACTORS AND ENGINEERING METRICS

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KEYWORDS

Performance measurement, indicators, ergonomic reporting, metrics development, macroergonomics

SUMMATIVE STATEMENT

Human factors (HF) metrics in a case organization were observed to be disconnected from the engineering metrics due to HF metrics that focus on health reporting and promotion, operational silos that reinforced perceptions of HF having only a health and safety contribution to an organization, and a lack of predictive measures from HF tools. Five themes for HF metric development and implementation emerged from the qualitative analysis of interactions with the organization - knowledge, connection, support, resources, and communication. The results lead to six recommendations for HF practitioners developing metrics and indicators.

Une étude de cas sur la relation entre les paramètres d'ergonomie et d'ingénierie

MOTS-CLÉS

Évaluation du rendement, indicateurs, rapport d'ergonomie, élaboration de paramètres, marcroergonomie

SOMMAIRE

Dans le cadre d'une étude réalisée en entreprise, on a observé que les paramètres d'ergonomie étaient déconnectés des paramètres d'ingénierie pour les raisons suivantes : l'ergonomie était axée sur la promotion et les rapports en matière de santé, les cloisonnements opérationnels renforçaient les perceptions que l'ergonomie n'apporte qu'une contribution en matière de santé et de sécurité pour l'entreprise, et l'absence de mesures prédictives liées aux outils ergonomiques. À la suite de l'analyse qualitative des interactions avec l'entreprise, cinq thèmes relatifs à l'élaboration et la mise en œuvre de paramètres d'ergonomie sont ressortis : la connaissance, le lien, le soutien, les ressources et la communication. Les résultats ont entraîné la formulation de six recommandations destinées aux praticiens en ergonomie qui élaborent des paramètres et des indicateurs.

PROBLEM STATEMENT

HF is traditionally a health and safety focussed discipline (Theberge & Neumann, 2013) that generates metrics reflecting that focus (Kleiner, 2004). The prevalent use of observational based HF tools (e.g. Takala, et al. (2010)) and a focus on injury outcomes does not appear to align HF reporting metrics and indicators well with organizational decisions and decisions made during engineering design processes (Neumann & Village, 2012). Virtual HF tools are usable in the design process but typically do not provide indicators or metrics in a proper context for non-HF specialists, such as engineers, making business and design decisions. An understanding of how HF metrics relate to engineering metrics is needed to ensure HF is considered in organizational and operational design decisions. Research is also needed to understand the key factors for HF metrics development in order to successfully develop and integrate HF information within engineering design processes.

RESEARCH OBJECTIVE/QUESTION

What are the important factors that affect a) the relationship between HF and engineering metrics, and b) efforts to develop and integrate HF metrics in an organization?

METHODOLOGY

The textual material for this research was obtained from a five year collaborative action research project with a Canadian-based electronics development, manufacturing, and service provider. The project investigated and developed new methods and approaches for integrating HF into production system design in the section of the company providing product development, production system design, and new product realization.

The current study is an explorative action research case study using qualitative data with multiple data sources from over 100 interactions with a variety of stakeholders. Stakeholders had backgrounds in product design, quality, health and safety, among others. Participants included tooling engineers, project managers, production supervisors and managers, senior directors of associated work groups as well as HF specialists, and managers and personnel within environmental health and safety. Data obtained from formal interactions (e.g. targeted interviews and workshops on metrics or related topics) and informal interactions (e.g. general discussions, phone calls, email correspondence where metrics related discussions organically evolved) was documented by field notes and audio recordings.

Company interactions were reviewed for metrics related information from over 360 hours of direct contact time over 137 site visits and 89 phone calls, that resulted in 219 first author and 47 research team member field notes, 106 hours of associated audio recordings, and associated email correspondence. Field notes and relevant audio transcriptions were gathered and analyzed within NVivo (QSR International Pty Ltd). Text was coded in inductive and directed approaches. All text was thematically coded based on the qualitative coding and the inductive analysis approach of Thomas (2006). Data was open coded with respect to information about metrics. Coded data was re-read to refine the focus of the code and similar codes were merged. Research team member and company stakeholder discussions throughout the data collection and analysis provided clarity and verification of the interpretation of the data. Directed coding focussed on the identification of individual metrics, metrics sets and metrics system as defined by Melnyk, et al. (2004).

RESULTS

The observed engineering metrics could be clustered into four categories, which were defined for their reporting on the product design system and production system (Figure):

1. LEADING: reporting the future expectations for the production and product design systems
2. STATUS: reporting on the current state of the production and design systems with information on issues, inventory, and timing of events
3. LAGGING: reflecting the outcomes of the production and product design systems and capturing information on productivity and quality
4. RESPONSE: reporting on what was done in reaction to an incident in the production and product design systems

Clustering HF metrics to match the observed engineering metrics categories identified few HF metrics in the response category and no applicable HF metrics in the leading category. HF metrics reporting on injuries and how the HF group was completing their service of the organization resulted in a greater representation in the status and lagging categories.

Three themes for a disconnection between the engineering and HF metrics emerged: a) HF reporting on health and health promotion that did not relate to the new product realization environment, b) engineering and HF operations silos that reinforced perceptions and knowledge of HF contributions, and c) HF specialists lacking tools to generate predictive measures.

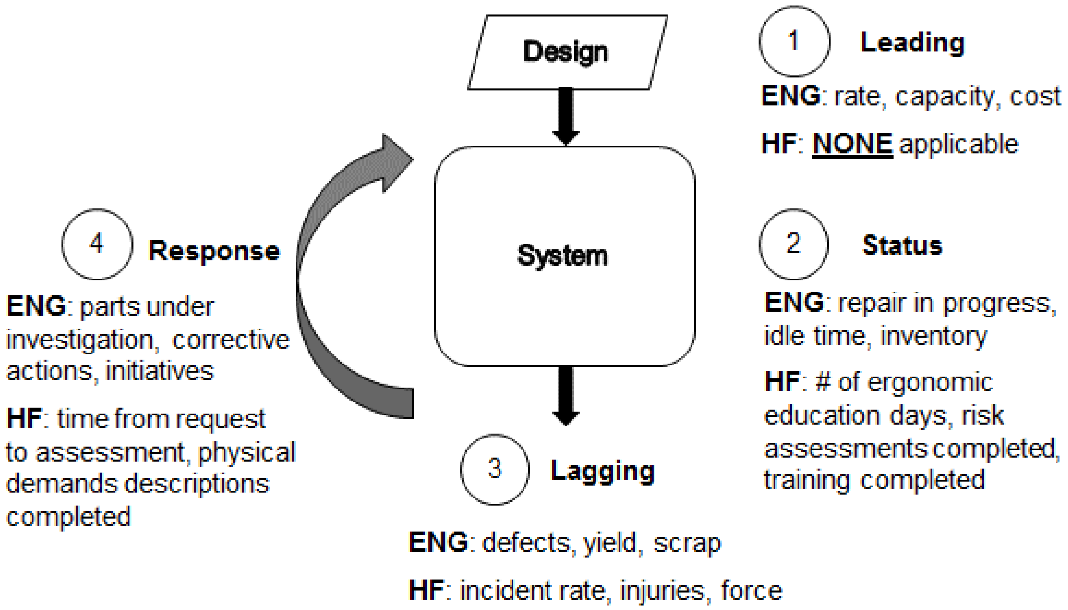

Figure 1. The four categories of engineering (ENG) metrics and indicators that emerged from the review of the case organization as they relate to an adapted model of work systems development and flow of information (see Neumann & Village (2012)).

Qualitative analysis of stakeholder interactions revealed five issues that were applicable to HF metric development and implementation:

a) *knowledge* of the audience involved and their knowledge of the metric information – meaning the need for the metric developer to understand the knowledge and environment of the metric recipient,

b) *connection* of metrics to the audience or organization goals – meaning the need to connect to personal and organization goals, a connection that generates support for the metrics and makes any additional effort to generate the metrics seem worthwhile,

c) *support* of the organization and support from the organization – meaning creating a relevant metric that links to the organization and is desired and accepted by key stakeholders to ensure organizational support for the metric,

d) *resource* availability considerations – meaning create a metrics process that integrates within existing organization processes and employee workload, and is not encumbering on current processes,

e) *communication* of information – meaning use the language of choice of the metrics audience.

DISCUSSION

The stereotypical focus of HF on reporting health and safety risk and outcomes reflects the dissociation of HF information from the engineering process. This finding supports proposed frameworks (e.g. Neumann & Village (2012)), that suggest HF information dissociation from organizational measures and a lack of HF contribution to design and strategy level decisions. Further, the observed HF measures demonstrate the traditional HF measures that Kleiner (2004) identified, and demonstrate the common outcomes of HF practitioner tools (e.g. Takala et al. (2010)). In general, there is a lack of appropriate HF metrics for manufacturing (Neumann, et al., 2013) which is, in part, a function of a lack of HF tools that assess for performance related outcomes.

The lack of predictive HF tools was one of three factors which appeared to affect the ability of HF metrics to provide information that contributes to engineering processes and connects with engineering metrics in the case organization. The two other factors were an observed health focus of HF, and the separation of HF and engineering. A health-only focus of HF is common and further entrenched in organizational culture by ergonomists and HF specialists being frequently located both organizationally and physically in the health and safety or human resources departments of a company (Theberge & Neumann, 2013). Moving beyond the cultural and structural boundaries often necessitates justification of work and a convincing of the target audience (Wells, et al., 2013). A part of convincing audiences is having the ability to relate to the audience, which has been shown to be a means of improving HF integration (Broberg, 2007). HF specialists in the case organization did not initially have tools that allowed this to occur. New tools and approaches were developed as the project progressed which helped to bridge this gap and improve the integration of HF in common organizational processes (see Village, et al. (2014)).

The five metrics issues identified from this HF perspective case share similarity to those reported generally for metrics and performance measurement. Key factors include connecting to business objectives and being cost-effective, clear, and conscious of process resource constraints (e.g. Franco & Bourne (2003)). The support of organization leadership has also been highlighted for performance management (e.g. Bititci, et al. (2006)) and has likewise been reported for participatory ergonomics programs (van Eerd, et al., 2010). The potential for interactions of the highlighted metrics issues, along with the necessity for understanding the goals and needs of individuals involved with the metrics alludes to a non-trivial process to metrics creation and integration. Understanding and coordinating the desires of all actors involved creates the notion that HF metrics need user-centred HF principles applied to their development. A list of recommendations have been developed from the results of this case study (Table 1), though more research is required to establish the generalizability of the observations.

CONCLUSIONS

Metrics observed in an exploratory study of a light assembly case organization demonstrated a difference of focus between engineering metrics and HF metrics. Identified metrics categories of leading, status, lagging, and response showed that HF metrics were predominantly reactive, and less in number, compared to engineering metrics and indicators, with no HF metrics to support product design systems or production system design. The difference in focus can limit the application of HF beyond health and safety and reinforces a limited view of HF / ergonomics. Five issues (knowledge, connection, support, resources, and communication) were identified that can contribute to the development of new HF metrics that can help to integrate HF directly into organizational processes like product design and production system design. The case results lead to six recommendations for HF practitioners to develop metrics and integrate metrics and provide a call for improved HF tools to support metrics development.

Table 10. Recommendations for developing HF metrics based on study results. Contributing results are indicated by [ ] and correspond to where the result can be found.

Recommendation	Supporting Results
1. *Understand other organization processes and identify key milestones to support.* Know what information is important, and when the information is important and most relevant to the audience.	Engineering metrics are focussed on different goals compared to HF metrics. [metrics categories] Knowledge of the metrics audience. [issue (a)]
2. *Be aware of the background knowledge of the target audience.* Determine their understanding of metrics and knowledge of the information that you are able to share.	Views of metrics and metrics definition differ. Knowledge of the metrics audience. [issue (a)]
3. *Educate the audience on the benefits of HF.* Provide education as needed using audience and organization relevant examples. Simultaneously highlight HF as a performance and well-being benefit.	Engineering and HF silos reinforces unhelpful perceptions and knowledge of HF contributions. [theme (b)] Audience knowledge of metric information. [issue (a)]
4. *Be relevant to strategic goals or goals in the organization*. Move HF beyond a health and safety focus and demonstrate HF as a means to system and organization success. Identify key stakeholders for support and gain their support by connecting to their personal or organization goals.	Connect metric content to audience or organization goals. [issue (b)] Support the organization and it will support the metrics. [issue (c)]
5. *Work within existing processes and minimise additional work.* Create metric processes (e.g. HF tools) that integrate within existing work flow or add minimal work. Identify appropriate timing to introduce new concepts and demonstrate the importance to their role or the organization.	Support the organization and it will support the metrics. [issue (c)] Resources are precious so work within stakeholder constraints. [issue (d)]
6. *Create information in a style that is familiar to the audience.* Determine if the audience prefers colours, symbols, or data so that HF information is in a more familiar format and integrates within their traditional thinking.	HF reporting on health and health promotion activities did not relate to the new product realization environment. [theme (a)] Communication with others should be in the language of their choice. [issue (e)]

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Symposium D: Participatory Ergonomics and Design

Symposium D: Ergonomie participative et conception

WHAT ARE THE DESIGN REQUIREMENTS FOR AN ORGANISATIONAL SIMULATION SUPPORT?

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KEYWORDS
Ergonomics, Simulation, Organisational Simulation, Organisational Design

SUMMATIVE STATEMENT
Activity-simulation is a methodology used to provide tools for participative approaches aimed at designing work situations. Generally used in predominantly technical or spatial projects, this methodology can be used in the design of new forms of organisation. It is then referred to as “organisational simulation”. This requires us to define specific requirements, relative to the supports and materials to be used in this context.

Quelles sont les exigences de conception pour soutenir la simulation organisationnelle?

MOTS-CLÉS
Ergonomie, simulation, simulation organisationnelle, conception organisationnelle

SOMMAIRE
La simulation de l’activité est une méthodologie utilisée pour outiller les démarches participatives visant la conception de situations de travail. Généralement utilisée dans les projets à dominante technique ou spatiale, cette méthodologie peut être utilisée pour la conception de nouvelles organisations. On parle alors de « simulation organisationnelle ». Des exigences spécifiques relatives au support de simulation à utiliser dans ce contexte doivent être définies pour cela.

PROBLEM STATEMENT
Ergonomics has long urged consideration of organisation inasmuch as it represents a structuring determinant of human work activity. Here we bring it into play to respond to demands for support to reorganisation projects, or even to help design innovative forms of organisation from start to finish. These demands require responses.

The participation of ergonomics in design projects is based on a tested methodology of work simulation (Daniellou, 2007) which allows employees to envisage future work situations as well as participating in elements of the project. It requires a simulation support in order to “play out” the future activity. In projects which are predominantly spatial or technical, this support is usually a two- or three-dimensional model representing the technical elements of the project (workspace, desktop, tools, interface, etc) which can be presented to workers in order to play out future work, test its characteristics and modify them where appropriate.

In a work organisation design project we therefore have to resort to a methodology of “organisational simulation”. This emerging methodology needs to be formalised. In particular, it requires creative effort on the part of ergonomists to develop and propose simulation supports which make it possible both to represent the organisation to be designed, and to play out the future work. This innovation work is not self-evident, and raises the following questions:

- first, about the organisation: on what dimensions of the organisation is action required? how are they to be represented? how are organisational modifications or contributions to be put on stage?
- then, about the simulation support: what does an "organisation model" look like? what does it represent? what requirements must it fulfil?
- lastly, about the simulation: what activity dimensions have to be simulated? By what "mediation effect" are they operative? what is the structure – particularly social – within which it has to be put in place? for what results?

This article aims to specify the issues and objectives of organisational simulation, to detail the design requirements for a simulation support which are necessary for it to be effective, and to specify the ways in which it is put into practice. It is based on illustrations from interventions whose objective was the design or transformation of work organisations and which enabled us to define the principles of organisational simulation.

METHODOLOGY: IMAGINING THE FUTURE ORGANISATION IN ORDER TO DESIGN IT

In any project, what is at stake for the employees involved is to be able to imagine themselves in a future situation which by definition they do not know at the point when the project begins (Andersen & Broberg, 2015). The main thing for them is to verify that the logic of action which they have developed in their past experience, which constitutes their concrete competence, remains effective in the future situation, possibly at the cost of adjustments or the development of a new logic of action – which itself can be anticipated. When the project is conducted in such a way that this projection is not possible, the "fear of not getting there" arises quite legitimately. Tensions which appear are often interpreted by project leaders as "resistance to change" and this usually leads them to set up a communication plan. But it is by no means unusual for this plan to accentuate the newness of the project, and hence also the "fear of not getting there"!

So for the ergonomist involved in design projects, the objective is specifically to set up a framework which enables employees to see themselves in the future situation at the same time as they participate in the technical and organisational choices involved in the project itself (Garrigou, A., Daniellou, Carballeda, & Ruaud, 1995). One of the main effects is that employees involved in this approach not only build up a detailed knowledge of the project's content (by participating in the choices made concerning it) but also, and above all on the logic of action they will have within that project, before it is even put into action. This necessarily participative approach has been formalised and enriched since the early 1990s in activity ergonomics (Daniellou, 2007). Figure 1 represents a recent practical example (Barcellini, Van Belleghem & Daniellou, 2014).

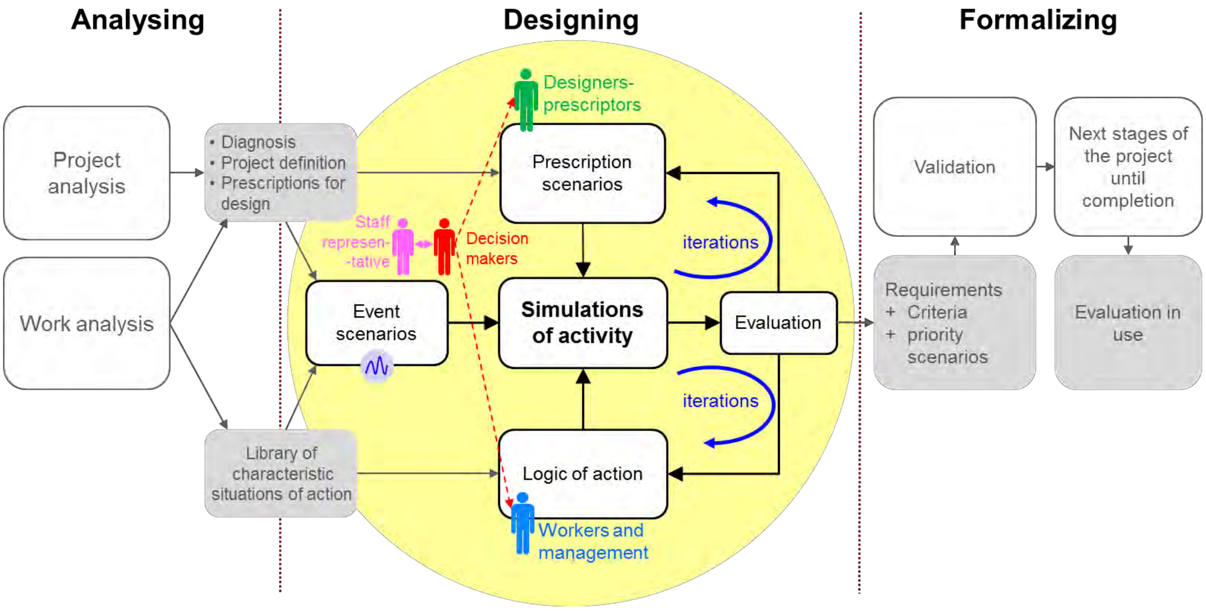

Figure 1: simulation structure at the centre of the way an ergonomics project is carried out (Barcellini, Van Belleghem & Daniellou 2014)

Work simulation is at the heart of this methodology. With the help of a simulation support such as a model or some other intermediary object (Broberg, Andersen & Seim, 2011), it aims to get workers in future work situations to "play them out" in order to test technical and organisational choices which are proposed by designers and/or participants, and formalised as prescription scenarios. This "play" has been found to be particularly rich when workers use an "avatar" to better project themselves into an activity (Van Belleghem, 2012). The avatar is usually a replica of themselves on a smaller scale (for example a Playmobil character or, better, a scale figure) which they can move around an make interact with the project model (e.g. a workspace).

This approach has been widely tested in predominantly spatial and technical projects. But can it be applied to work organisation design projects? Before answering this question we need to clarify what is meant by "work organisation".

Organisation can be defined as a system of formal rules, particularly aimed at the distribution, allocation and coordination of tasks, which enables a socio-technical system to function in pursuit of a given objective. But, thanks to sociology in particular (Reynaud, 1998, De Terssac 1992), we know that this definition does not account for effective organisation. In fact the system of prescribed rules alone never constitutes the organisation of work. Over against it there is the work of organisation, which takes its source from the activity and social interactions between actors, and which produces new rules (informal ones, this time) to deal with the gaps in the formal rules. From this point of view, transforming the organisation cannot be restricted to changing the structure and system of formal rules, but also requires taking an interest in the process which constructs effective rules, articulating formal and informal rules together.

The stakes for organisational simulation can thus be expressed like this: *elaborating formal rules which favour the development of effective rules which are acceptable for the activity.* Doing this means having an adapted simulation support available.

ADAPTED SIMULATION SUPPORT

Elaborating an organisational simulation support requires creativity. In order to help this process, it seems useful to us to define design requirements for the support on the basis of practices carried out (and nowadays mastered) in mainly technical projects. These requirements should enable us to orient our research on innovative organisational simulation supports. We propose three:

- Requirement 1 (Representation): enabling representation and evolution of prescription elements in the form of scenarios,
- Requirement 2 (Modification): enabling collective modification of prescription scenarios,
- Requirement 3 (Simulation): enabling activity simulation.

These requirements are detailed below, and illustrated by interventions which made it possible to elaborate them.

Requirement 1: enabling representation and modification of prescription elements in the form of scenarios

In a mainly technical project, this requirement is met by making a scale model of a desk or space, the design object, usually made of cardboard. In an organisational project this requirement will have to be met by a representation of the structuring formal rules which are the object of design or transformation. For example, bringing two reception teams together as one gave rise to a model functional organigram which made it possible to represent several scenarios, where personnel were allocated to different entities according to their skills, representing them by different colours (cf. figure 2a). Another intervention, dealing with the redefinition of the information-handling process between different departments in a daily newspaper, produced a model logigram of tasks which also enabled exploratory research on several scenarios (cf. figure 2b).

a. Functional organisation model of a new administrative reception service

b. Information treatment process model in a daily newspaper

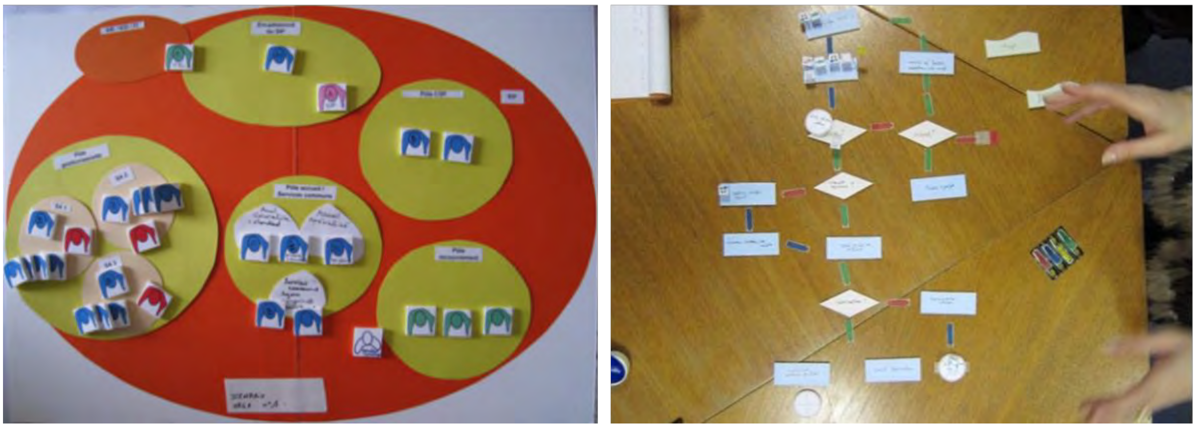

Figure 2: examples of supports enabling representation and modification of organisation rules

Depending on the content of the project, it will be necessary to precisely define the organisational principles brought into play (hierarchical relationships, process, working hours, security rules, etc) and to determine the best way of representing them to facilitate the work of putting them on stage. One must take care to differentiate between fixed principles and those the project seeks to act upon – just as, in a spatial model, we can differentiate between load-bearing walls (glued to the model) and partitions which can be moved (simply pinned on, so that they can be manipulated at will). The issue is to leave the scenario potentialities as open as possible, in a field which is nonetheless circumscribed by limits which are best spelt out when the simulation begins, following analysis of the project and the work, which will have enabled the project's orientations to be (re)defined at the point of diagnosis.

Requirement 2: enabling collective modification of prescription scenarios

Here we must insist on the participative nature of the approach: each actor in the group charged with instructing the project (generall a working group) must be able to be a source of propositions. The support should function as an invitation to this, being accessible to the work collective. In a spatial project, the scale of the model is thus chosen with a view to the possibility the group should have to modify walls, doors, furniture, etc. A scale of 1:50 makes it easy to position workspaces in a tertiary space; a scale of 1:5 makes it possible to see what is in the desk drawers.

In an organisational project, if a model is chosen, care must be taken to ensure that its size and manipulability facilitate collective propositions. So for example the model in figure 2 is A2 sized and every element can be modified manually. The model in figure 3 is made up of kit elements which make it possible to gradually build up a logigram of tasks directly on the meeting-table.

Another intervention, dealing with a major reorganisation of a ministerial HR department of 250 agents, substituted a matrix organigram for a “rake” organigram. This led to developing a model of future entities which was big enough (1m x 1.5m) to position all the planned administrative sectors (cf. figure 3a). Using cartridge paper pinned to the model enabled us to represent functional links between the different entities. These links were proposed, and drawn on the paper, by the ergonomist or by the participants themselves, hence constituting a first scenario (figure 3b). The paper could be taken away and replaced, at the participants’ suggestion, to constitute a second scenario which was significantly different (figure 3c) and which was quickly preferred by the working group. By centralising the flow of files, this scenario was to facilitate activity guidance through the framework structure which all the teams would later benefit from. This prescription scenario was the basis for starting the simulations.

a. Initial model **b. First proposed scenario** **c. Second (chosen) scenario**

Figure 3: modelling and staging ways of dealing with files between entities of an HR department

Requirement 3: enabling activity simulation

This requirement is central to the approach, but also the hardest to meet. Formalising prescription scenarios on a model is not enough for simulation, as it maintains a static aspect which is very far removed from what will be played out for real. A way needs to be found to use the model as a support to mediate future activity. In predominantly spatial projects this mediation can appear quite natural: every activity has a corporal aspect which can easily be represented by shifting an avatar of the operator (a figure, for example) within a model of the future space – for example, when dealing with the food industry, a cook in his/her future kitchen.

But in an organisational project, the dimensions of the activity we seek to simulate do not necessarily relate to an individual’s gestural or postural intentions in a space. Activity simulation, therefore, is not self-evident. For this, we need an avatar to mediate activity.

In video games and on internet, the term “avatar” refers to a character representing a user. But more generally, the term refers to an incarnation (of a god or a person) in an object or animal. Here we want to enable an operator to embody his/her activity through this avatar at the moment of simulation on the model. There is a strong analogy with board games: the avatar is to the model what the pieces are to the chessboard. The player who moves the queen on the squares of the board "is" that queen. The cook moving a figure on the model of the future kitchen "is" in activity. And because s/he is in activity, along with the whole working group they can evaluate the conditions under which their work will be carried out, as they are allowed for by the design choices embodied in the model. There really is embodiment. And without the pawn, there is no game. Without the avatar, no work simulation.

Organisational simulation, then, also needs its avatar. What the avatar will be depends on the dimension of activity which has to be simulated. Here again, creativity is required. For the HR reorganisation project, activity analysis showed that agents dealt collectively with request letters, placing them in cardboard folders of different colours which were then circulated among the different departments concerned. The circulation of these folders obeyed very precise effective rules, although these rules were not formalised in official procedures. So once their importance to collective functioning had been recalled, we had to design a matrix organisation which would allow them to be put into practice in an efficient, fluid manner. We made miniature letters (about 2 x 3cm) on which group participants wrote the headings of different sorts of requests addressed to HR (e.g. secondment request for a category B agent, transfer request for a category A agent, urgent request to recruit an assistant, etc). These letters were then inserted into coloured folders on the same scale. Those folders were our avatars. The simulation could begin.
The "play" consisted of getting agents from different entities to deal with the miniature letters, as they were gathered around the modelled scenario (figure 5c). The letters were moved around on the model according to decisions made at different stages in their treatment (cf. figure 4). At each stage there was a discussion between agents, hierarchy and project leaders about the effective modalities of the procedure. The multiplicity of requests simulated enabled us to verify whether the proposed logic in each case was well adapted to a large number of situations. Conflicts between rules were identified several times, but solutions were quickly found by adjustments either to prescribed rules or to modalities of procedure. These adjustments enabled agents to evaluate how adapted the project was to their logic of action, as well as the expected evolution of that logic in order to be adapted to the future organisation. Even if it does foresee a gap between present and future logic, this process is reassuring for agents, as it simultaneously contributes to measuring the scope of that gap. "Fear of not getting there" then gives way to "the knowledge that is needed to get there".

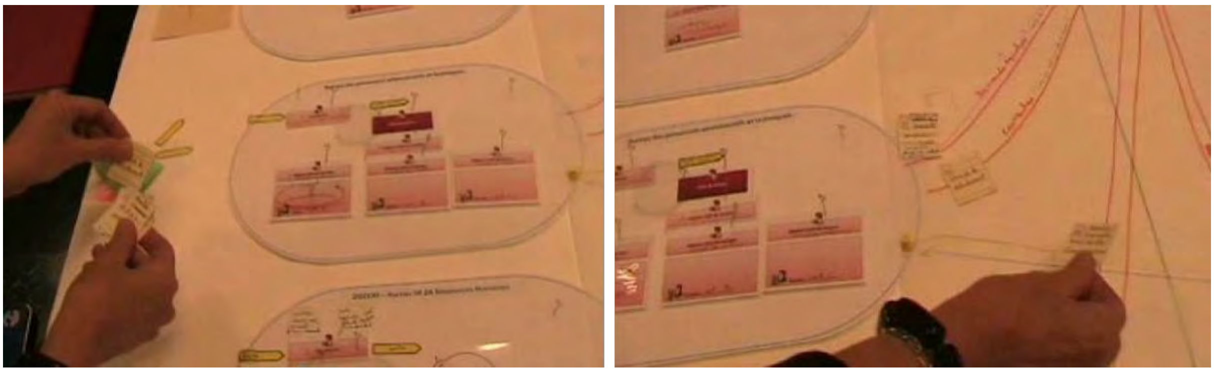

Figure 4: dealing with requests, simulated using avatars of letters

CONCLUSION
What is at stake in organisational simulation is evaluating prescription rules. The interest of the procedure lies in the fact that this evaluation is collective and centred on real, if simulated, work. But the criteria for evaluation are not known in advance: they are built up between participants as the simulations progress. We can then see that these criteria do not only deal with rules and their efficacy. They are based on values, norms of social interactions, subjective representations, arguments about the quality of work and social relationships, etc,

which nurture the project in all its dimensions. The final model bears the marks of these arbitrages, and participants in the process are concerned to preserve them from random modifications in later stages of the project. This really is a matter of “putting the project to the test of activity” when so many projects tend rather to lead to the opposite. This is truly an ergonomic issue.

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A PRACTITIONER'S PERSPECTIVE ON ADDING AN SMS APPROACH TO THE PARTICIPATORY ERGONOMICS PROCESS

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KEY WORDS: participatory ergonomics, safety management system, ergonomics interventions, on-going process, priority action plan

Over time, ergonomic interventions can lose their effectiveness because of a subsequent change in the total work system. To remedy this, a component from the P-D-C-A approach used in a Safety Management System was added to the Participatory Ergonomics Process (PEP) when a new Team (Ergonomics Field Intervention Group) was formed within the City of Vancouver's Park Board. One tool used to ensure that the PEP process continued on an on-going basis was the use of a Priority Action Plan. It lists the action the EFIG had recommended for various pieces of equipment and shows the date by which the identified action should be completed. The Priority Action Plan was reviewed, updated and modified at every EFIG meeting. It was found that adding the step of continuing the EFIG process assisted in identifying unexpected changes. It is concluded that adding a step used in a Safety Management System provided an on-going process to assist in the identification of unexpected changes and resulted in the more effective implementation of ergonomics interventions achieved from a Participatory Ergonomics Process.

Le point de vue d'un praticien sur l'ajout d'une approche par SMS au processus d'ergonomie participative

MOT CLÉS: processus d'ergonomie participative, système de gestion de la sécurité, interventions ergonomiques, un système continu, plan d'action prioritaire

Au fil du temps, les interventions ergonomiques peuvent perdre leur efficacité suite à un changement dans le système de travail. Pour remédier à cela, une composant de l'approche "P-D-C-A" utilisée dans le Safety Management System a été ajouté au Participatory Ergonomics Process (PEP) quand une équipe (Ergonomics Field Intervention Group) a été formée dans la Régie des parcs de la ville de Vancouver. Un outil utilisé pour assurer que la méthode PEP continue de façon permanente a été l'utilisation d'un Plan d'action prioritaire. Il énumère les actions que l'EFIG a recommandé a pour diverses pièces d'équipement et indique la date par laquelle l'action identifiée doit être complétée. Le Plan d'action prioritaire a été examiné, actualisé et modifié à chaque réunion de l'EFIG. On a observé que l'ajout d'une étape pour continuer le processus d'EFIG a aidé à identifier des changements inattendus. On conclut que l'ajout d'une étape utilisée dans le Safety Management System nous dota d'un système continu pour aider à identifier des changements inattendus et a résulté en l'implémentation plus efficace d'interventions ergonomiques réalisées à partir du Participatory Ergonomics Process.

INTRODUCTION:

Federal, State and Provincial governments enact legislation requiring employers to minimize an employee's risk of musculoskeletal injury (MSI). Often the legislation outlines an ergonomics process with the intent of minimizing MSIs through the implementation of preventive and protective measures. The common approach used includes elements of risk identification, assessment and control and the evaluation of the compliance measures taken.

As a component of the Occupational Health and Safety Program at the City of Vancouver workers are encouraged to report their symptoms of musculoskeletal discomfort to their supervisors. Situations associated with an increased risk of MSI also come to the attention of professional staff responsible for occupational health and safety or the specification and/or selection of tools or equipment.

As part of the process to minimize workers' risk of musculoskeletal injury, Teams are formed in a Business Unit and incorporate a Participatory Ergonomics Process to develop and implement solutions. Typically the Team consist of at least one supervisor, some (or all) of the workers who perform the work, appropriate professional staff and the City's Ergonomist. In some cases a Team has a broader mandate, or involves more than one Business Unit, but the key responsibility of identifying and implementing possible solutions is still there.

Within the City of Vancouver the Teams and the issues they address are:

1) The OH&S Committee for Engineering's Parking Operations & Enforcement Branch
2) IT Client Hardware Advisory Panel
3) Facilities Design, Facilities Planning and Development, and Facilities Management
4) Park Board Accessibility and Adaptive Services
5) Park Board Aquatics
6) Engineering's Equipment Services' Tenders for Equipment

PROBLEM

The Teams created within various Business Units identify and implement ergonomics interventions. However, over time, an intervention can lose its effectiveness because of a subsequent change in the total work system.

CONTEXT

At a monthly Joint Health and Safety Committee Meeting, Park Board workers raised a number of issues about the tractors and loaders they operated in order to maintain the City's parks, gardens, golf courses, beaches, boulevards and playing fields. The response by the City's Safety Consultant for Park Board was to request that the four Superintendents of Parks Maintenance ask the workers to list their concerns. The information on the concerns regarding the tractors and loaders in the four Service Yards was compiled (Table 1) and the concerns were then discussed with the City's Ergonomist.

Table 1: The concerns the Equipment Operators reported to their Supervisors regarding the tractors and loaders operated in each of the four Service Yards in Parks Maintenance.

TRACTOR TYPE	CONCERNS
SERVICE YARD A:	
Tractor X	poor back rest (does not adjust/recline) small head room in cabin foot pedal located in uncomfortable position gear shift too close to leg/knee
Tractor Y	uncomfortable seat operator complains of vibration and feeling every bump on the road
Tractor Z	uncomfortable seat less room in the cabin
SERVICE YARD B:	
Tractor X	posture when using controls to operate attachments air loss pressure on seats
Tractor Y	vibration (on hard surfaces and travelling to from sites) distance from seat to pedals
Loader X	distance from seat to pedals
SERVICE YARD C:	
Tractor X	seat uncomfortable
SERVICE YARD D:	
Tractor Y	not suited for continuous road travel (bouncy, noisy)
Tractor Z	seat back not high enough, - no air suspension
Loader Y	hydrostatic pedal angle leads to back problems

ACTION

The City's Ergonomist knew the key role and benefits that a Participatory Ergonomics Process (PEP) has in achieving effective ergonomics interventions. The City's Ergonomist requested that the Safety Consultant for Park Board convene a meeting of the Superintendents so that the Operators' concerns could be discussed. The Ergonomist also requested that the Superintendents bring at least one knowledgeable Equipment Operator from their Service Yard to the meeting.

This PEP initiative in Horticultural Operations needed to work differently than the PEPs in other Business Units. It was realized that an extra component was needed. The difference would be including an overriding concept from the City's Safety Management System (SMS).

In a SMS, a Plan-Do-Check-Act (P-D-C-A) approach is used for achieving Continuous Improvement. At the City of Vancouver, the P-D-C-A approach applies to all parts of the Occupational Health and Safety program, including the ergonomics program.

Further, since the emphasis would be on operational issues within Horticultural Operations, the Team would be called an "Ergonomics Field Intervention Group" (EFIG).

The City's Ergonomist established the Terms of Reference for the Team. It included the step-by-step process that the EFIG - Horticultural Operations would use (Table 2).

Table 2: The eight steps that members of the EFIG - Horticultural Operations were expected to follow. The list was handed out at the beginning of the inaugural meeting.

EFIG STEP 1 – Understand the concerns of the workers
Understand the issues and concerns of the workers who perform the assigned work tasks.

EFIG STEP 2 – Consider the ergonomics risk factors
Management and workers jointly discuss how the risk factors known to cause musculoskeletal discomfort and/or injury affect the workers' ability to perform the assigned work tasks.

EFIG STEP 3 – Consider the total work system
Management and workers jointly discuss if changes to the tools, equipment, work procedures and/or work processes could reduce the risk of musculoskeletal discomfort and/or injury.

EFIG STEP 4 – Identify interventions
Workers and management identify interventions that address the concerns raised and that could reduce the risk of musculoskeletal discomfort.

EFIG STEP 5 – Rank the possible interventions
Both management and the workers rank the feasibility of implementing the interventions that have been discussed.

EFIG STEP 6 – Implement the most feasible interventions
The most feasible and practical interventions are implemented.

EFIG STEP 7 – Evaluate the effectiveness of the changes made
The effectiveness of the interventions implemented to-date is evaluated to ensure that the changes have reduced the risk of musculoskeletal discomfort and/or injury.

EFIG STEP 8 – Continue the EFIG process
Since changes in the tools, equipment, work procedures and/or work processes is an ongoing occurrence, the EFIG process needs to be repeated on a regular basis.

OUTCOMES

The inaugural meeting of the EFIG - Horticultural Operations was held on February 18, 2015.

The Superintendents from the four Service Yards (Evans Yard, Sunset Yard, Jericho Yard and Stanley Park Yard), Equipment Operators from Jericho Service Yard and Sunset Service Yard, the Safety Consultant - Park Board and the City's Ergonomist attended. The Safety Consultant chaired the meeting. At the time of the first EFIG meeting the position of Fleet Supervisor – Parks had not been filled. Once it was filled the successful candidate has attended all subsequent meetings of the EFIG.

A handout covering the eight steps in the EFIG process was provided to each participant. Then the Ergonomist explained each of the eight steps and its importance to the EFIG process. There was agreement to follow the eight steps in the EFIG process. It was also agreed that the City's Ergonomist and the City's Safety Consultant for Park Board would conduct an on-site assessment at one of the Service Yards in order to gain an understanding of the issues and concerns (Step 1).

The on-site assessment was conducted on February 25, 2015 at Jericho Service Yard. The purpose of the assessment was to determine the validity of the concerns and issues raised. The Superintendent of the Service Yard and Equipment Operators were present. The various pieces of equipment for maintaining the City's parks were identified. The Equipment Operators demonstrated how the equipment was used and the issues arising from its use were discussed. Some preliminary measurements were obtained.

The City's Ergonomist prepared a report that outlined the findings and provided recommendations. The report was presented at the second EFIG meeting. Steps 1 to Step 3 were covered in the discussion.

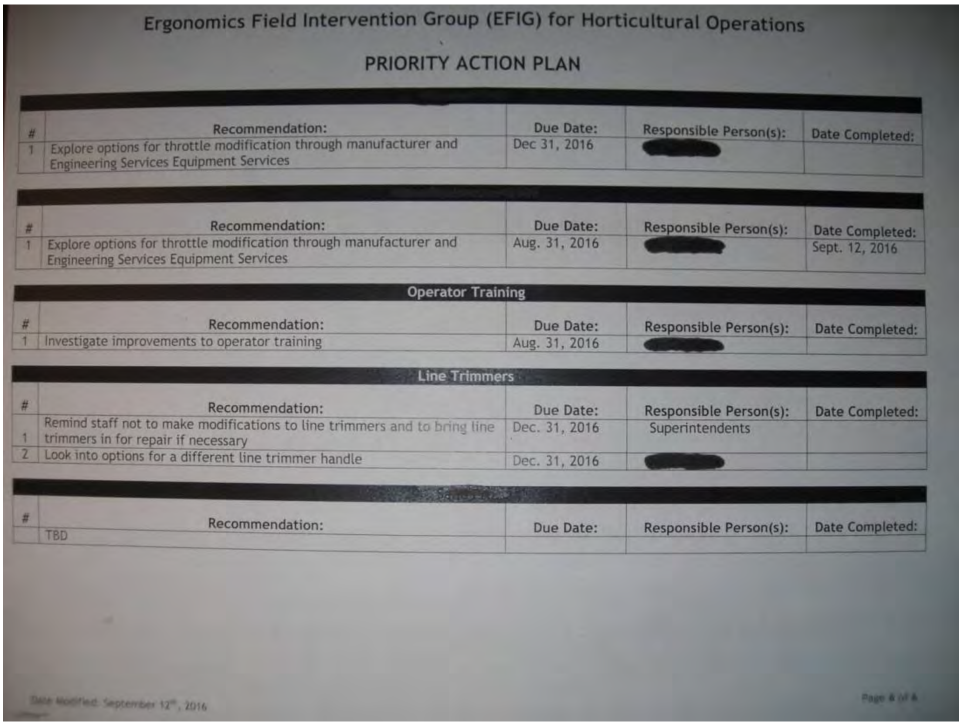
The discussion provided examples of why the workers and supervisors had concerns about the Tractors and Loaders (Step 1). Some issues were evident for all four of the Service Yards while other issues were site-specific. It was evident that the issues raised were complex (Step 2) and difficult to address (Step 3).

Identifying interventions for a seat that is uncomfortable, a cab that limits head room, a foot pedal located in an uncomfortable position or a method for increasing the Operator's field of view around a piece of equipment requires a comprehensive analysis before appropriate interventions can be identified. Since further testing and evaluation of each piece of equipment would be required specific or directive interventions were not always possible (Step 4).

The recommendations provided were often general. Some of the recommendations would identify the need for the development of a business case. The recommendations also included comments on the logistical and maintenance procedures that were used and the need for an ergonomics assessment as part of the review process before a product was purchased.

For the rest of the second meeting the relative importance and the likelihood that a solution could be identified and implemented were discussed (Step 5).

This information was used to develop a Priority Action Plan that contained all of the recommendations identified during the on-site assessment. Some additional recommendations were made and added to the Priority Action Plan. For each item there was a brief description of the recommendation and a Due Date along with the individual(s) responsible for reporting on that item (see example in Figure 1).



Ergonomics Field Intervention Group (EFIG) for Horticultural Operations

PRIORITY ACTION PLAN

[redacted]

#	Recommendation:	Due Date:	Responsible Person(s):	Date Completed:
1	Explore options for throttle modification through manufacturer and Engineering Services Equipment Services	Dec 31, 2016	[redacted]	

[redacted]

#	Recommendation:	Due Date:	Responsible Person(s):	Date Completed:
1	Explore options for throttle modification through manufacturer and Engineering Services Equipment Services	Aug. 31, 2016	[redacted]	Sept. 12, 2016

Operator Training

#	Recommendation:	Due Date:	Responsible Person(s):	Date Completed:
1	Investigate improvements to operator training	Aug. 31, 2016	[redacted]	

Line Trimmers

#	Recommendation:	Due Date:	Responsible Person(s):	Date Completed:
1	Remind staff not to make modifications to line trimmers and to bring line trimmers in for repair if necessary	Dec. 31, 2016	Superintendents	
2	Look into options for a different line trimmer handle	Dec. 31, 2016	[redacted]	

[redacted]

#	Recommendation:	Due Date:	Responsible Person(s):	Date Completed:
	TBD			

Date Modified: September 12th, 2016

Figure 1: The Priority Action Plan lists the action the EFIG had recommended for various pieces of equipment or issue. It is reviewed, updated and modified at every EFIG meeting.

The meeting dates, location and various outcomes from the EFIG discussions are shown in Table 3.

During an EFIG meeting a specific issue or concern could be raised that required additional information. Some of these issues required an on-site assessment by the City's Ergonomist and the City's Safety Consultant for Park Board. Table 4 shows the dates, location and reason for these on-site visits.

Some of the ergonomics interventions could be implemented right away while some required additional investigation and planning before implementation (Step 6). In other cases, it was found that it was not practical to implement an intervention.

The effectiveness of each intervention was informally evaluated to ensure that the changes had achieved the desired outcome (Step 7).

The Priority Action Plan was reviewed, updated and modified at every EFIG meeting (Step 8).

Table 3: The dates, location and outcomes arising from the EFIG - Horticultural Operations.

EVENT	DATE	LOCATION	EXAMPLE OF AN OUTCOME
Meeting # 1	Feb 18 2015	Evans Yard	Ergonomist described steps in EFIG process
Meeting # 2	May 21 2015	Evans Yard	Priority Action Plan prepared
Meeting # 3	June 23 2015	Evans Yard	Mechanics travel to work on Tractor
Meeting # 4	Sept 14 2015	Evans Yard	Relocating the control box in the cab
Meeting # 5	Nov 19 2015	Stanley Park	Addressed Tint on Windows
Meeting # 6	Jan 18 2016	Sunset Yard	Procedure - increasing tension on tractor seat
Meeting # 7	May 18 2016	Jericho Yard	Throttle replaced – other units checked
Meeting # 8	Sept 12 2016	Evans Yard	Installing camera to see what is behind
Meeting # 9	Nov 16 2016	Sunset Yard	Transporting on trailer, raise at CPI meeting
Meeting #10	Jan 31 2017	Stanley Park	Require demonstration before purchase
Meeting #11	March 30 2017	Evans Yard	Height of pull handle for sit-on equipment
Meeting #12	June 14 2017	Jericho Yard	Accelerator Pedal for sit-on mowers

Table 4: The dates, location and reason for the site visits conducted following the identification of issues during the EFIG - Horticultural Operations meetings.

EVENT:	DATE	LOCATION	REASON
Site Visit # 1	Feb 25 2015	Jericho Yard	Report with findings and recommendations
Site Visit # 2	Sept 18 2015	Manitoba Yard	Evaluate height needed to lift Tractor
Site Visit # 3	Nov 26 2015	Stanley Park	Throttle tension on sit-on equipment
Site Visit # 4	Nov 3 2016	Sunset Yard	Determine the best location for camera
Site Visit # 5	Jan 12 2017	Evan’s Yard	Height of control when Operator leaning

DISCUSSION

Organizations develop processes for identifying, developing and implementing ergonomics interventions to minimize a worker's risk of musculoskeletal injury. This certainly applies to the City of Vancouver where all levels of management support the need for the implementation of ergonomics interventions as part of the City's Occupational Health and Safety program.

A factor that influences the effectiveness of ergonomics interventions is the degree of employee involvement in OHS and employee empowerment across the organisation (Bentley and Tappin, 2010). These factors, together with top management commitment, are generally crucial to the success of interventions and, in particular, participatory ergonomics initiatives (Wilson and Haines, 1997).

This was the finding at the City of Vancouver. The ergonomics interventions the Teams identified and implemented resulted in a reduction in the overall number of reports of musculoskeletal discomfort and injuries. However, there could be a change to the tools, equipment, work procedures and/or work processes. When this occurred, it was found that a once useful intervention was no longer effective.

To remedy this, a component used in a Safety Management System was added to the Participatory Ergonomics Process (PEP). The intent was to provide the EFIG with a continuous process for identifying ergonomics interventions and implementing corrective actions that would minimize a worker's risk of musculoskeletal injury and improve operational efficiencies.

Providing an on-going process to the Participatory Ergonomics Process was a natural step. The City of Vancouver uses "Plan-Do-Check-Act" in its Safety Management System (SMS) model for Continuous Improvement (Figure 2). The "Plan-Do-Check-Act" approach is also an established part of the Ergonomics Process (CAN/CSA-Z1004-12). Including the P-D-C-A approach in the PEP would provide an on-going process for addressing changes that occur over time.

It was found that adding Step 8 (Continue the EFIG process) assisted in identifying unexpected changes. It provided the EFIG an opportunity to consider the consequences of any upcoming change in the total work system before the change was implemented and to identify any necessary and appropriate interventions for tools, equipment, work procedures and/or work processes.

Figure 2: The "Plan-Do-Check-Act" process the City of Vancouver uses in its Safety Management System (SMS).

The tool used to ensure that the PEP functioned on an on-going basis was the use of the Priority Action Plan. The Priority Action Plan listed the action the EFIG had recommended for various pieces of equipment or issue and gave the date by which the identified action should be completed. It also listed the individual worker who had volunteered to investigate possible solutions or try a different tool or method, or the group responsible for implementing the recommended intervention. The typical entry when a group was responsible would be the Superintendents. The Fleet Supervisor – Parks was often included since this is the position responsible for equipment purchases.
There were tremendous advantages from having the Fleet Supervisor as part of the EFIG. Including the person responsible for equipment purchases is consistent with van Eerd et al., (2010) who reported that successful PE interventions require the right people to be involved along with the need for clearly defined responsibilities.
At every EFIG meeting the individual(s) responsible for an item would provide an update on the progress to-date. The EFIG would review the outcome, discuss the need for further action and whether the Due Date was still appropriate. The Priority Action Plan would be updated and/or modified accordingly.

The last column of the Priority Action Plan (Date Completed) was only “filled in” when the EFIG agreed that the action had been completed. Even though an item was marked as being “completed” it could come back onto the Priority Action Plan at any time.

Many of the interventions identified, evaluated and implemented by the EFIG – Horticultural Operations would be classified as being reactive on the basis that the issue was raised following reports of musculoskeletal discomfort or injury. However other identified concerns on the Priority Action Plan involved the development of a business case and/or long-term capital expenditures. Examples included a business case for obtaining a trailer to transport a large piece of grass cutting equipment between locations and the long-term planning needed before replacing loaders and tractors.

The EFIG wanted to document the operational requirements and have input on the design specifications for new purchases. For this reason there was no “forward time limit” on the Due Date for completion of that item. It could be five years into the future. This decision was made in order to provide an on-going reminder that action was required and that the work required had not been started yet. This provided an on-going process for identifying changes that still needed to be planned for.

The other aspect of adding the P-D-C-A approach to the PEP was to provide a process for addressing unplanned changes that do occur over time. There are often unexpected changes due to not having or not following written standards, changing expectations, technological changes, changes in the way business is conducted and changes in legislated requirements.

It was found that, by adding Step 8 to the PEP, the EFIG – Horticultural Operations was structured for, and was able to respond to unexpected changes. For example, the on-going review of the Priority Action Plan reminded at least one EFIG member that an operational change had been discussed at a recent Parks Operations Continuous Process Improvement project meeting. As a result the EFIG - Horticultural Operations was informed about and could identify interventions that facilitated the advance planning for the proposed change in routes for various types of grass-cutting equipment.

CONCLUSION

It is concluded that adding a step used in a Safety Management System provided an on-going process to assist in the identification of unexpected changes and resulted in the more effective implementation of ergonomics interventions achieved from a Participatory Ergonomics Process.

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ARTICULATING INTERMEDIARY OBJECTS IN THE DESIGN PROCESS TO ENABLE ERGONOMICS INTERVENTION

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KEYWORDS
Simulation; Workspace Design; Participatory Ergonomics

SUMMATIVE STATEMENT
Ergonomics aims to understand work and transform it. In order to effectively do so, ergonomics takes a design-driven approach. This paper presents how different simulation supports were articulated to incorporate rationales, interests, constraints and expectations of actors into the design process.

Utilisation d'objets intermédiaires dans le processus de conception pour favoriser les interventions ergonomiques

MOTS-CLÉS
Simulation, conception d'espace de travail, ergonomie participative

SOMMAIRE
L'ergonomie a pour but de comprendre le travail et de le transformer. Elle adopte une démarche centrée sur la conception afin de pouvoir réaliser ce travail efficacement. Cette communication présente la façon dont divers outils de simulation ont été utilisés pour intégrer les justifications, les intérêts, les contraintes et les attentes des intervenants dans le processus de conception.

PROBLEM STATEMENT
One of the main challenges for ergonomics intervention is not only to produce knowledge about work situations, but rather transform them. To overcome this, ergonomists become involved in the design process and are then required to look for methods, techniques and tools that may help in the incorporation of workers' activity into the design process.

This ergonomics intervention articulates several viewpoints and mobilizes diverse actors, aiming to influence their representations about work and decision-making processes. The introduction of positive changes in work, is enabled in a first instance, through the construction of interaction spaces in a way which highlights questionings arising from the work activity itself. Bucciarelli (1984, 1988) considers design as a social process, in which actors come from different object-worlds are required to work together to achieve a common goal, thus requiring the incorporation of a range of intermediary objects to enable communication among the different actors of the project. Intermediary objects are artefacts produced and circulated by the actors involved in the design process which can take several forms and can be used with different goals (Vinck, Jeantet, & Laureillard, 1996).

The concept of simulation is broad and with diverse applications, including in the research and practice areas of ergonomics, design and engineering. Thus, this paper utilizes the term "simulation" according to the concept of "simulation situation" presented by (Béguin & Weill-

Fassina, 2002). To these authors, simulation is a situation of exchanges and a process for constructing significations, considering perspectives of knowledge communication (mainly actions and behaviors), transformation and expression.

The scope of this research the discussion of the application of different simulation supports which act not only as a tool for incorporating the work perspective but also having an active role in the social construction of interaction, confrontation and decision-making spaces. This role is aligned with (Maline & Pretto, 1994) who point out simulation as favoring the expression of different participants' needs and acting as a support for a collective reflection.

RESEARCH OBJECTIVE/QUESTION

This paper aims to explore how different simulation supports, employing different intermediary objects, may be articulated by ergonomists in the design process to enable the social construction of spaces of interaction, confrontation, deliberation and decision-making.

METHODOLOGY

The methodological approach taken in this research is a case study and is based in *a posteriori* reflection, aligned with the principles from reflexive practice laid out by (Schön, 1983) which defines the participation of the researcher as an actor directly responsible by the transformation of the object of study. The cases analyzed were taken from a field research in an industry.

Thus, the present research may be separated in two distinct moments: the first of practice (or action) and a second one of reflection (knowledge production). The former refers to the activities of ergonomics consulting carried out in an oil refinery which started in 2007 and lasted for 5 years. The latter is the reflection upon the experiences and data collected during the interventions developed by the main author. The technical consulting team was mainly responsible for carrying out the Ergonomic Work Analysis (Wisner, 1995) and developing conceptual designs of the workplaces and work systems analyzed, aiming to make them more compatible to workers' needs, skills and limitations as well as to improve the organization production and operational results.

To better understand the role of simulation in this process, the authors selected cases where this resource was employed. The number of cases approached should be enough to accurately reproduce the amplitude of the data collected throughout the project. On the other hand, there was a practical need of working with the minimum necessary, to prioritize the required detailing and in-depth analysis and reflections once there were originally more than 200 interventions during the reported five-year period, thus a sample of 4 cases were selected.

RESULTS

A synthesis of the different simulation supports employed in the cases is provided, along with the articulation required to effectively use them to incorporate ergonomics factors into the design process and develop workers' future activity. The intermediary objects analyzed were also determinant to the consideration and crystallization of technical aspects of the context to the solutions developed.

One of the most relevant findings was regarding the diversity of the simulation supports employed in the interventions which enabled the reflection on the applicability of the different techniques and tools used as mediators in the conception stages. A brief description of each simulation support employed is provided on Figure 1.

Technique	Tool	Description
Hand drawings	Paper and writing material	Largely used during meetings and seminars to develop and presented graphically solutions or problems observed.
2D and 3D CAD drawing (CAD)	AutoCAD software	*Computer Aided Design* is a graphical tool used in engineering contexts which allows users to create bi and tri dimensional models with a high level of accuracy.
3D animation and rendering (3DR)	3D Studio Max software	Creation of animations and movies in three dimensions with a moderate to high level of realism.
Digital Human Simulation (DHS)	Jack Tecnomatix software	This digital human modelling software takes into account anthropometry and biomechanical aspects, allowing for a wide range of analysis, both static (posture analysis) or dynamic (analyzing processes and the course of action
Game Engine (GAM)	CryEngine software	Game engines are platforms usually employed in the development of digital, 3D games. This software is characterized by its high graphical quality, interactive resources with the models and the possibility of programming events and answers to users' inputs.
Physical prototyping (PPR)	University's prototyping laboratory	The physical prototype is constructed in 1:1 scale of the designed object, aiming to achieve the desired functional requisites allowing project actors to directly manipulate and test it during the design process, complementing the digital tools employed.

Figure 1. Main simulation supports employed in the conception process

The object of study in the first case was the analyzes and design of several accesses used by operators in a field of fluid storage tanks (oil and derived products). These accesses were distributed throughout the refinery and connected the passageways (avenues, roads, and sidewalks) to the tanks' areas. The main simulation supports employed in this case were CAD models, DHS and game engine environment. The second case dealt with the development of devices in an engineering laboratory in the company. At first, the goal was to meet the recommendations made in an internal audit, which was later expanded to improve the handling and storage of pipeline specimen in the lab, from the perspective of workers' activity. Physical prototypes, CAD models and DHS were employed in this case.

The third case, located in an operational room in an industrial area, arises from a typical ergonomics demand: the analysis and selection of furniture. This demand was reformulated and the problem was tackled in three dependent and concurrent fronts: design of an interface mask to a control panel, modifying the physical structure of the panel console to better accommodate workers' lower limbs and the analysis, selection and tests of suitable chairs for the operation of the console panel. In all the fronts, physical prototypes, CAD models and DHS were employed as simulation supports. Finally, the fourth and last case differs from the others since it is a completely new situation to be designed. Also, the dynamics of the ergonomics intervention were substantially different: the ergonomics team was involved in the initial stages of the design process of the new facilities, especially participating on the design of a platform for chemical products supply to a tank on the effluent treatment plant. In this case, it wasn't possible to employ physical prototypes, thus being restricted to the CAD models, DHS and Design Reviews meetings and tools (DRV). Figure 2 synthesizes some of the different simulation supports employed in the four cases.

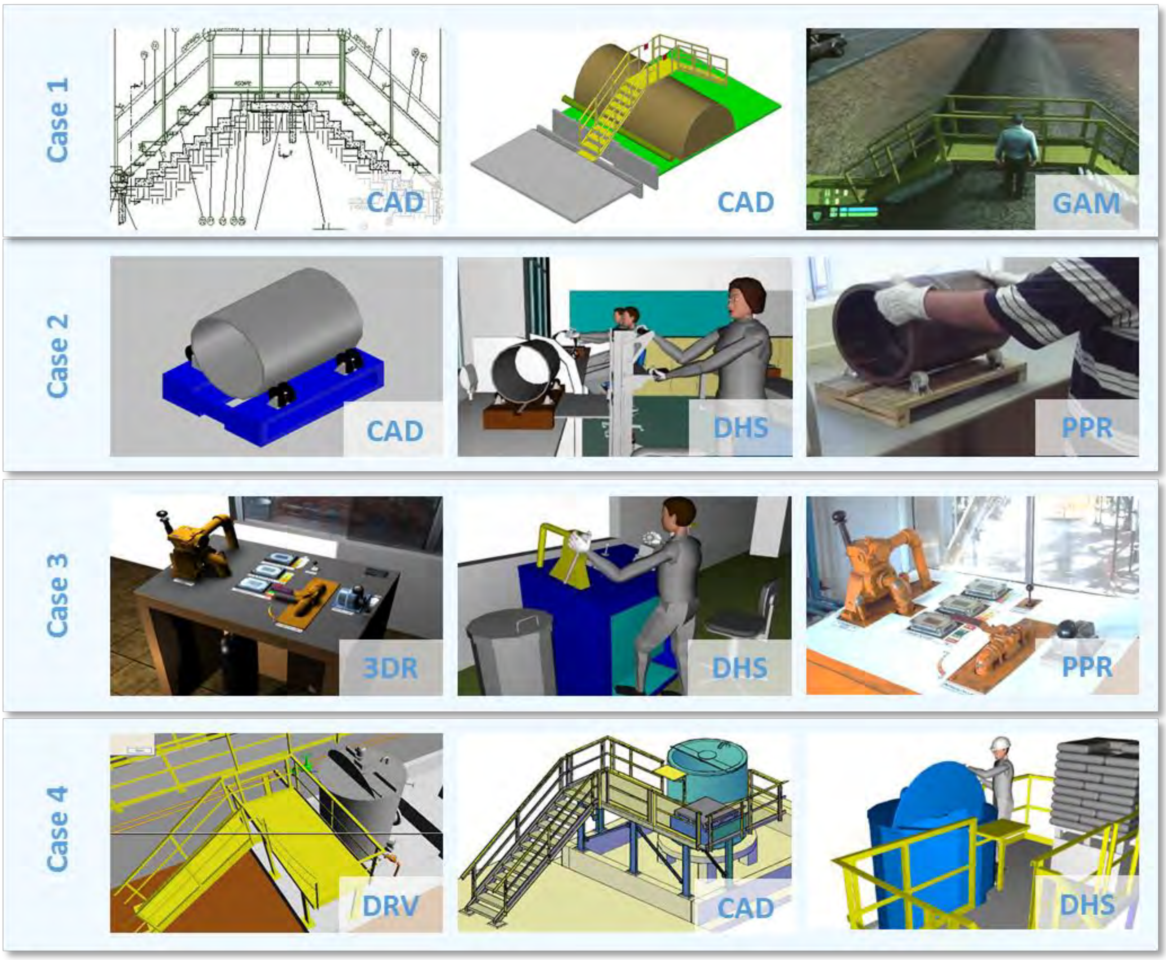

Figure 2. Main simulation supports utilized in the cases. Adapted from Braatz & Menegon (2016).

DISCUSSION

In the selected cases, it was observed how the different simulation support which were articulated throughout the design processes contributed to incorporate aspects of the analyzed activities and develop workers' future activity. These supports we also fundamental to consider and allow for the technical aspects to become evident in the developed solutions. This aims to achieve not only the idealistic and desired answers from each of the rationale involved in the design process, but rather to make clear the technical feasibility, characteristics and limitations of the elements present in the solution and in the design process itself.

The dynamics of usage and development of the simulation situations became also evident in each case. There were situations where a specific support was indispensable (such as the use of physical prototypes in two of the cases) and in other moments, the team had autonomy to select which intermediary object to employ in the simulation situation (e.g. choosing between the GE or DHS in one of the cases). Similarly, there are situations where negative assessments regarding the design object can be quickly addressed and redesigned with the help from the utilized supports; in other cases there is a clear need to terminate the current simulation situation to allow for new analysis and developments which culminate in improved designs and then a new simulation situation is set up.

In this context, it's interesting that the participants in the conception processes have at their disposal a series of simulation supports which may act as intermediary objects in their different roles and expression forms (Braatz, 2015). Then, it's possible to define which ones to use considering the context, participants, design goal, available resources and situation complexity. The developments point towards a proposition that the simulation supports act as knowledge objects (already employed by engineers and architects) which have specific functions helping to reduce the dichotomy between technical and social aspects in the design process. The diversity of intermediary objects highlighted by (Vinck et al., 1996) characterized by its positioning among several elements, actors or design stages comprise broadly drawings, files and prototypes which mark the transition from on stage to another, circulate from one group to another or even among several actors. However, these objects located among actors are expanded by (Vinck, 2009) where the author states that contrarily to the concept of boundary objects, the notion of intermediary objects is still in its infancy, leaving it open to researchers the interpretative structure given, i.e., whether or not the objects are going to be interpreted by different actors, or be a driver of standardization or even if they should cross distinct social worlds.

An important characteristic of the intermediary objects, goes back to their usage and roles they might take. For instance, an object might be considered “open” when it allows for a diversity of actions, previously designed or not (thus having a divergent focus); or they can be considered “closed” when the action allowed is restricted and controlled (thus having a convergent focus). These focuses are important once they allow the insertion of the intermediary objects throughout the design process, from its beginning to its conclusion. During the initial phases, it is necessary that the objects employed allow the integration of the different knowledge and know-how of the participants to explore the problem and possible solutions, based on what is desirable (highlighting the designing action on the object). In the final stages, the challenges are of another kind, since the object are employed more with the intention to validate the proposed solution, controlling the next steps and the implementation stage of the project (prevailing the coordination function of the project). Figure 3 illustrates the articulation of these simulations and the different focus of the objects throughout the development of the project.

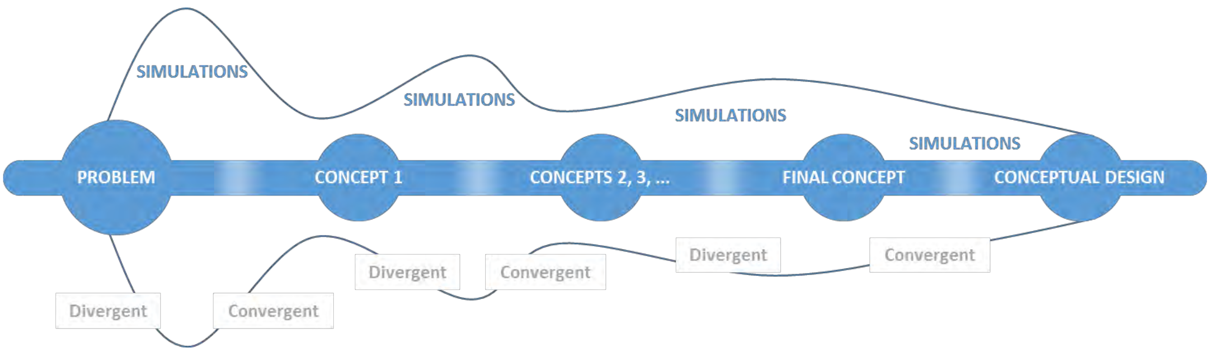

Figure 3. Simulations and intermediary object focus in the design

The articulation illustrated in Figure 3 is a conceptual proposition on the usual development of the design processes and the use of the intermediary objects. Nonetheless, there should not be any impediments to employing more than a single-focused intermediary object. It is possible, even in the initial phases of the design process, that employing a closed intermediary object could be useful to define concepts and guide the subsequent developments. Searching for better solutions, in a macro perspective, converges to a conceptual design that crystalizes it. However, during the design process this search also takes a divergent fashion, allowing for novel concepts proposition, prototyping and simulation.

As explored in the cases presented in this paper, the number of concepts generated and the way they will diverge or converge cannot be predicted in advance due to the intrinsic uncertainties associated with the conception process. The final concept achieved should also be prototyped and simulated, not aiming to generate new propositions (which could happen), but as a final validation step among the participants of the design process and other interested parties. After the validation and with the final concept well defined, the conceptual project may be specified for implementation. Thus, employing these objects supports the design activities (designing) and the management of the conception process (coordination).

CONCLUSIONS

According to (Vinck et al., 1996), intermediary objects to conception are part of an objects production during the design process of different natures with the goal to be evaluated, discussed and modified. Such objects, which may be drawings, blueprints, physical models, reports, among others, also act in the sense of becoming instruments of coordination among the different specialties involved during the development due to the definition of temporal milestones to the project. Utilizing different technologies and techniques may increase the effectiveness of ergonomics incorporation to the design process, if it occurs in a structured, articulated and conscious way. Simulation may be then employed as an instrument oriented to the object (design action of the technical system), to the other (coordinated action) and to self (once it creates a space for development, learning and transformation).

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WORKSPACE EXPERIMENTS: A JOURNEY ON PLANNING PARTICIPATORY DESIGN

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KEYWORDS
Workspace design, user involvement, participatory process

SUMMATIVE STATEMENT
This paper presents a resource material in planning and performing participatory workspace design processes. This material brings up design dialogues into focus and gives insights on how to stage them, bridging the gap of merging user involvement with the well-defined design work-practice.

Expériences en milieu de travail : le chemin emprunté pour planifier la conception participative

MOTS-CLÉS
Conception d'espaces de travail, participation des utilisateurs, processus participatif

SOMMAIRE
Cette communication présente le processus participatif utilisé pour élaborer un document de planification et de conception d'espaces de travail. Le document explique comment établir et utiliser des dialogues liés à la conception et la façon de combler les lacunes en fusionnant la participation des utilisateurs à des pratiques de conception bien définies.

PROBLEM STATEMENT

The concept of participatory design and user involvement is well known and discussed among researchers (Simonsen and Robertson, 2013), and there is a widespread interest in implementing it in major building and construction projects. Nevertheless, it is also often difficult to translate the contributions from users to workspace design that seriously take on board the employees' specific work practices as a platform for a desired change. There is a need for a tool that manages to travel into a well-defined design work-practice and merge with it.

Design dialogues set the stage and employees, management and design practitioners are brought together to explore opportunities on the basis of the professional experience they each represent. Different materials (or objects) can help planning and performing participatory design processes. Several researchers have studied which kind of objects can be found in design processes (Ewenstein and Whyte, 2009) and others have attempted to characterize different objects in relation to how well they function (Broberg et al., 2011).

RESEARCH OBJECTIVE/QUESTION

We developed a resource material to merge user involvement within current designers' practices when designing new workspaces. The aim was to test and experiment how a participatory prototyping process can help developing such a material aimed at architects and other participants on workspace design projects.

METHODOLOGY

We developed the resource material through a participatory "prototyping process", that is through a mutual learning process taking place in a cooperative design setting. The material was gradually built during a research project, including three workshops emphasizing joint exploration by architects, consulting engineers and health & safety consultants (Figure 1).

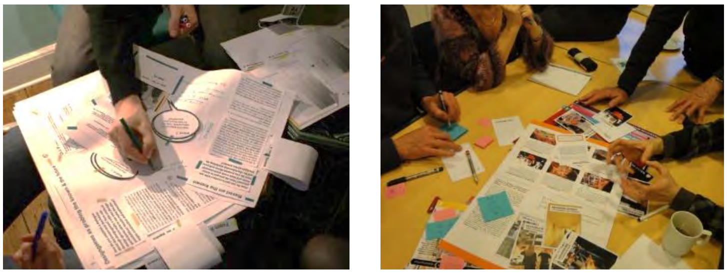

Figure 1 – Prototyping process over the workshops

This method was used because we could discuss, explore, and try out various aspects of the new resource material with its prototypes and thus mediate communication among the different participants of the process, content and format being gradually developed through participation.

RESULTS

The result was a flexible resource material for designers as a tool to help building a participatory process specifically for each project (Figure 2). The material consists of a toolbox containing: 1) three booklets, 2) "playing" cards, 3) a game board, and 4) a leaflet explaining the main process the tool aims at bringing participants through. The booklets are the core of the toolbox and they aim at giving ideas and inspiration on methods and activities that can be part of the participatory process. The cards and the game board aim at making the use of the resource material a participatory and interactive activity in itself. The leaflet provides some guidance the participatory planning.

Figure 2 – Final prototype for the resource material

DISCUSSION

As we see it, the resource material was well accepted during a training section and some participants were happy they in fact used the time during the session to solve some planning issues for their projects. The material became an asset that streamlined the planning of a participatory process while putting the key themes within user involvement and workspace design on the agenda. It still has room for improvements, but it is a good starting to introduce participatory methods into the design practices and to facilitate the planning for such activities.

CONCLUSIONS

The task of involving users in design processes is not easy and it can be a challenge to merge these activities. The resource material helps staging the interventions and activities and preparing the materials to be used. On a long term, we see the resource material as an open source, where new methods and inspiring ideas can always be added.

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LEARNING FROM PARTICIPATORY DESIGN PROJECTS ACROSS INDUSTRIES

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KEYWORDS
Participatory design; framework; work systems interaction.

SUMMATIVE STATEMENT
A preliminary framework for participatory design projects (PDP) was developed based on a retrospective analysis of five PDPs across different industries. The framework may serve as a guidance for planning and conducting PDPs.

Apprendre des projets de conception participative réalisés dans diverses industries

MOTS-CLÉS
Conception participative, cadre de travail, systèmes de travail, interaction des systèmes de travail

SOMMAIRE
Un cadre préliminaire lié aux projets de conception participative (PDP) a été élaboré à partir d'une analyse rétrospective de cinq PDP dans diverses industries. Ce cadre pourrait s'avérer utile en vue de la planification et de la réalisation de PDP.

PROBLEM STATEMENT

A growing number of experiences with participatory design or participatory ergonomics projects have been gained within the field of macro-ergonomics. It is suggested that the Participatory Ergonomics Framework (PEF) validated by Haines et al. (2002) needs to be updated based on these experiences and hence more focused on design activities.

RESEARCH OBJECTIVE/QUESTION

The objective of this study was to update and design-orient the PEF based on experiences with PDPs within the last ten years.

METHODOLOGY

Five participatory design projects across different industries were systematically analyzed and compared in order to develop a framework pointing to supportive theory and practical guidance for ergonomics practitioners. The five PDPs were based in the following industries: construction, public service, food processing, and two healthcare projects (Broberg 2006 and 2010; Seim & Broberg 2010; Broberg et al. 2011; Broberg & Edwards 2012; Conceicao et al. 2013). The starting point for the analysis was the notion of work systems meeting each other in the intervention into design projects by ergonomists/researchers.

RESULTS

The nine dimensions and categories in the framework by Haines et al. (2002) are still relevant. However, they are not entirely oriented towards design projects and the framework do not include the dynamics between the ergonomist/researcher and the design activities going on in a company. It is suggested to add the following dimensions to the PEF: Involved work systems, type of interaction between the ergonomist work system and the company design work systems, transfer and integration of results from PDPs into the overall design project in the company.

DISCUSSION

The proposed update of the PEF introduces a dynamic understanding of PDPs by the notion that PDP’s may be seen as interactions between different work systems, including those of the ergonomist/researcher, company designers, consultants, and technology suppliers. By an initial mapping the relevant work systems, the intervention by ergonomists may be better planned and better ensure a real impact on the overall design project. This is of importance because many PDPs have an intermittent and temporary character. The notion of interaction between different work systems also allows for theories on how ergonomists/researchers can impact design projects by facilitating participatory schemes.

CONCLUSIONS

This study suggested an updating of the PEF in order to include the dynamics between an ergonomist work systems with its own goals and rationale and a number of company work systems involved in design projects and having other goals and rationales. The updated framework is aimed at guidance in planning and conduction PDPs.

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Symposium E1: Rasmussen Revisited 1 Human Factors, Accidents and Error

Symposium E1: Rasmussen revisité 1 : facteurs humains, accidents et erreurs

PROTOTYPE TO FINAL PRODUCT: A CONTRIBUTING FACTOR CLASSIFICATION SCHEME TO SUPPORT THE APPLICATION OF RASMUSSEN'S ACCIMAP METHOD

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KEYWORDS
Rasmussen; systems thinking; reliability; validity; incident classification

SUMMATIVE STATEMENT
One factor potentially limiting the uptake of Rasmussen's (1997) Accimap method by practitioners is the lack of a contributing factor classification scheme to guide accident analyses. This presentation describes the development and validation of a contributing factor classification scheme designed for led outdoor activity domain. The implications for the design and development of contributing factors classification schemes are discussed.

Du prototype au produit final : un système de classification des facteurs contributifs pour appuyer l'application de la méthode ACCIMAP de Rasmussen

MOTS-CLÉS
Rasmussen, pensée systémique, fiabilité, validité, classification des incidents

SOMMAIRE
L'absence d'un système de classification des facteurs contributifs pour guider les analyses d'accidents constitue un facteur qui pourrait limiter l'adoption de la méthode Accimap de Rasmussen (1997) par les praticiens. La présente communication décrit l'élaboration et la validation d'un système de classification des facteurs contributifs conçu pour le secteur des activités de plein air, et aborde les répercussions sur la conception et le développement de ce type de système.

PROBLEM STATEMENT
Rasmussen's Accimap accident analysis method has been criticised as analysts must use a "bottom-up" coding approach to identify contributing factors and relationships from the incident data. This creates concerns regarding its reliability and validity, and makes it difficult to produce useful summaries of multiple incidents and implement within incident reporting systems.

RESEARCH OBJECTIVE/QUESTION

This study evaluates the intra- and inter-rater reliability and criterion-referenced validity of a contributing factor classification scheme developed to support the use of Accimap by led outdoor activity (LOA) practitioners.

Development of the classification scheme involved adapting Rasmussen's framework to describe the "LOA system" and the development of a set of codes to populate the levels. The codes for the classification scheme have two levels: the system level describes the actors, artefacts and activity context in terms of 14 codes; the descriptor level breaks the system level codes down into 107 specific contributing factors. The version of the classification scheme that was evaluated in this study was developed a revised in a series of previous studies (Goode, Salmon, Lenne, & Finch, 2014; Salmon, Goode, Lenné, Finch, & Cassell, 2014; Salmon, Williamson, Lenne, Mitsopoulos-Rubens, & Rudin-Brown, 2010; Taylor, Goode, Salmon, Lenne, & Finch, 2015).

METHODOLOGY

A test-retest study design was used. Eleven LOA practitioners used the classification scheme on two separate occasions (Time 1 and Time 2) to code a pre-determined list of contributing factors identified from the same pre-selected, indicative four incident reports.

The participants included 10 males and 1 female, with an average age of 42 years (SD = 5.74, range 31 to 48). On average, participants had 17 years' experience in the LOA sector (SD = 6.48, range 5 to 25 years). All participants held a managerial role in their organisation with direct responsibility for safety management (e.g. risk manager, program manager, senior teacher, director of outdoor education).

Criterion-referenced validity was assessed by comparing the codes selected by LOA practitioners to those selected by the method creators. Reliability and validity was assessed for coding at the system level and descriptor level of classification scheme using the Index of Concordance. A criterion of 70% was adopted as an acceptable level of agreement.

RESULTS

Mean intra-rater reliability scores at the system (M = 83.6%) and descriptor (M = 74%) levels were acceptable. Mean inter-rater reliability scores were close to acceptable for both coding attempts at the system level (M_{T1} = 68.8%; M_{T2} = 73.9%), but not the descriptor level (M_{T1} = 58.5%; M_{T2} = 64.1%). Mean criterion referenced validity scores at the system level were acceptable (M_{T1} = 73.9%; M_{T2} = 75.3%), and close to acceptable for the descriptor level (M_{T1} = 67.6%; M_{T2} = 70.8%) for both coding attempts.

DISCUSSION

Overall, the results indicate that the system level of the classification scheme is reasonably logical and parsimonious, but further clarification of the descriptor level is required. The findings suggest a solution to the common problem of designing a scheme that is both sufficiently detailed for detecting problems and preventing future incidents based on the intended context of application.

CONCLUSIONS

Although the study illustrates the challenges associated with designing a valid, reliable and useful classification scheme, the results support the conclusion that the scheme is now ready to be deployed (with some constraints and additional training) in practice.

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'RASMUSSEN VS. THE REST'

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SUMMATIVE STATEMENT: This presentation aims to present work-in-progress, the aim of which is to compare the work of the Danish Safety Scientist Jens Rasmussen with other prominent researchers from the 1970s, 80s and 90s (e.g., Barry Turner, James Reason, Aaron Wildavsky). The presentation will also serve as an introduction to the 'Rasmussen Revisited' symposium at ODAM 2017 and take stock of developments in attempts to progress the legacy of Rasmussen's work (e.g., plans to publish a book based on his work).

Rasmussen par rapport au reste

SOMMAIRE : Cette communication a pour but de présenter des travaux en cours, qui consiste à comparer les recherches du scientifique en sécurité danois Jens Rasmussen avec ceux d'autres éminents chercheurs des années 1970, 1980 et 1990 (p. ex., Barry Turner, James Reason, Aaron Wildavsky). Elle sert également d'introduction au symposium intitulé «Rasmussen revisité» dans le cadre de l'ODAM 2017, et fait le point sur l'évolution des tentatives visant à faire progresser l'héritage des travaux de Rasmussent (p. ex., l'intention de publier un livre qui reposera sur ses travaux).

PROBLEM STATEMENT/RESEARCH OBJECTIVE / QUESTION: What are the unique characteristics of Rasmussen's approach towards safety science? How does this compare with the work of other significant researchers including Barry Turner, James Reason and Aaron Wildavsky? What research questions remain from his work and how can these be addressed in future work on accident analysis and investigation?

METHODOLOGY: The paper will summarise current work by the author which seeks to use a framework to compare Rasmussen's work against that of the others. The framework covers, amongst other things: key influences (e.g., Cybernetics, ecological psychology, cognitive psychology); theoretical orientation (e.g., control engineering, cognitive science, and organisational sociology); methodology (e.g., laboratory experiments, naturalistic observation, protocol analysis); outcomes (e.g., new methods, new theories of safety).

RESULTS/DISCUSSION/CONCLUSIONS: The presentation will focus on a comparison between the work of Rasmussen and some of his contemporaries (Turner, Reason and Wildavsky). Four specific themes are utilised in order to compare the two researchers: (1) Both Turner and Rasmussen shared an interest in applying ideas and concepts from cybernetics. Turner for example, used cybernetics in his theory of 'Man-Made Disasters' to explore further the breakdown of order within organisations (e.g., discussions centred on 'anti-tasks' and 'negentropic' processes). Cybernetics (e.g. the work of Norbert Wiener and Stafford Beer) also played an important role in Rasmussen's mindset, as for instance in his description of micro and macro components of complex systems. Secondly, the four researchers applied very different, but complementary methodological approaches towards complex work environments. Turner devoted much of his career in using and developing 'Grounded Theory'. Rasmussen developed a much broader approach to the study of complex work environments, one that involved the development of a suite of new methods (e.g., Cognitive Work Analysis, Accimaps), but also and perhaps crucially, the development of new ways of modelling complexity and what might be characterised as 'normal error'. Reason's early work was experimental and then expanded out to include diary studies and field studies. Wildavsky's work was primarily conceptual and grounded within political science and public policy Finally, the paper will reflect on a much wider parallel within the work of the researchers, namely the extent to which they were shaped by their application of 'sociological' (e.g., Weberian 'ideal types' - Turner) as compared to 'psychological' (e.g., Reason and Norman's work on error taxonomies - Rasmussen) frames of reference and world-views. The presentation will conclude with a brief discussion of how the Rasmussen/Turner/Reason/Wildavsky comparison might be extended to include other researchers (e.g., Charles Perrow, Scott Sagan).

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MORE CONVERTS INTO RASMUSSEN? – IMPACT OF A STORY-BASED ANIMATION ON SYSTEMS SAFETY

[Symposium: Rasmussen revisited at ODAM2017]

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Un plus grand nombre de convertis à Rasmussen? L'impact d'une animation vidéo racontant un événement sur la sécurité des systems

SOMMAIRE : Cette recherche vise à évaluer l'impact d'une animation vidéo de 10 minutes portant sur deux points de vue divergents d'un accident de traversier survenu en Corée du Sud. La vidéo a été produite pour faire connaître la sécurité des systèmes et diffuser le contenu auprès d'un plus vaste auditoire.

PROBLEM STATEMENT: Our understanding of how complex systems fail has made huge progress over the past sixty years from Heinrich's domino model to present-day thinking on systems safety, to which Jens Rasmussen made huge contribution. The lack of awareness of systems safety among many stakeholders in the society often leads to a counter-productive blame culture, as shown in the aftermath of the South Korea ferry accident and many others. Therefore, there is an urgent need to educate/communicate the latest systems safety thinking to a wider audience.

RESEARCH OBJECTIVE / QUESTION: This research aims to evaluate the impact of a ten minute story-based animation, Two Contrasting Views of the South Korea Ferry Accident, which was produced and disseminated to introduce systems safety to a wider audience.

METHODOLOGY: Data was collected and analysed from multiple sources: digital analytics (# of views, average view duration, geographic location and demographics of viewers) and qualitative comments (online and emails). Online questionnaire was also used with 112 Chinese and 39 British to investigate whether the animation changed their views on accident causation and accountability.

RESULTS:
The animation was created from the close collaboration between a human factor research team and an animator. Three main messages on systems safety were included in a real accident scenario: i) complex interactions between contributing factors rather than simple linear interaction; ii) human as asset rather than threat; iii) just culture rather than blame culture. Since the official roll-out on 13th July 2015 (1.5 years so far), the animation has been viewed approximately 30,000 times around 70 different countries for 2 min 55 sec average view duration. The animation received positive comments declaring that they will use the animation for student teaching, professional training and client discussions. Some urged that people at all levels should watch and digest it. Surprisingly, the responses from Korean audience were more negative than elsewhere criticising it for misrepresenting the causes of the accident and giving unfair excuses to those involved in the accident. From the

online questionnaire, significantly increased awareness of system issues was found in both Chinese and British participants. However, it was found that British participants were more optimistic about lessons learned from holistic accident investigation and just culture helping improve safety while Chinese participants were more skeptical about the importance of accident investigation and still believed in importance of holding people accountable.

DISCUSSION:

Two possible explanations for the more critical responses from Korean/Chinese viewers might be a pre-existing hierarchical culture of Chinese/Korean society and post-traumatic stress at the Korean society level in the aftermath of the accident. First, South Korea and China have a culture that is characterised by relationships ordered by status and a strong sense of shame. In such a culture, holding people accountable by blaming them is widely-accepted and considered effective. On the other hand, a more complex, counter-intuitive and paradoxical systems safety concept might have been a challenge to be accepted. Second, the politicized aftermath with various versions of conspiracy theories on the accident in Korea could have made the Korean public weary of listening to another version of explanation about the accident through our story-based animation.

CONCLUSIONS:

This study shows that use of new media (animation, film, etc) can be effectively used to disseminate important systems safety messages to a wider audience. However, a careful consideration should be given to duration of animation, cultural background of target audience and choice of the story.

ASSESSING TASK COMPLEXITY BY USE OF RASMUSSEN'S DECISION LADDER: MODEL AND ITS APPLICATION TO RECOVERY FROM HEALTHCARE ADVERSE EVENT

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KEYWORDS
Task complexity; Decision ladder; Jens Rasmussen; Adverse event recovery; Dialysis

SUMMATIVE STATEMENT
This paper describes applications of a recently developed task complexity model of cognitive load and performance based on a systematic task analysis using the *Decision Ladder* (Rasmussen, 1986). The model is applied to two cases of recovery from adverse events occurring during dialysis therapy where it is shown that it succeeds in detecting bottle-necks in cognitive operations.

Évaluer la complexité des tâches au moyen de l'échelle de décision de Rasmussen : un modèle et ses applications pour se remettre d'un événement indésirable associé aux soins

MOTS-CLÉS
Complexité des tâches, échelle de décision, Jens Rasmussen; récupération d'un événement indésirable, dialyse

SOMMAIRE
Cette communication décrit les applications d'un modèle de complexité des tâches récemment élaboré sur la charge cognitive et le rendement reposant sur une analyse systématique des tâches au moyen de l'échelle de décision de Rasmussent (Rasmussen, 1986). Le modèle a été appliqué à deux cas de récupération d'un événement indésirable au cours d'un traitement de dialyse. Il a démontré qu'il est possible de détecter ce qui fait obstacle aux fonctions cognitives.

PROBLEM STATEMENT

The key research question of this study is: how may we measure and assess the cognitive complexity of a safety-critical task, and use the results to improve systems resilience in a healthcare organisation.

INTRODUCTION

In modern high-risk sectors, it is of critical importance not only to eliminate risk factors, but also to build *resilience* into the work setting. This paper addresses *task complexity* as a dimension in task analysis that may be used both to optimise organisational performance (e.g., productivity and safety) and to provide perspectives on enhancing resilient abilities of the work system. For instance, results of task complexity analysis may contribute to work design and re-design to increase the ability to respond to critical events; to monitor ongoing developments; and to anticipate future threats and opportunities – which have been suggested as essential abilities in sustaining systems resilience (Hollnagel et al., 2006). One of the aims of using task complexity analysis is to simplify the task structure so that one can effectively address the actual, the critical and the potential (Hollnagel, 2011). The assessment is also expected to provide valuable suggestions for changing to a more resilient organisation by applying the analysis to positive experiences – i.e., learning from things that went right.

There have been a number of methods and models developed for measuring task complexity in various domains (e.g., Liu & Li, 2012). In most previous studies, task complexity has been measured by some overall characteristics – such as the number or variety of task elements, ambiguity or dynamic nature, and cognitive/physical load or demand for the task. The present study aims at applying task complexity assessment to systems design or redesign to make component tasks – be they daily routines or unexpected, irregular activities – simpler and more workable; this, in turn, may be expected to increase system resilience. Therefore, our approach is to measure complexity of a task and its sub-tasks by synthesising complexity factors of relevant properties based on cognitive task analysis. For this purpose, we can find it useful to apply the well-known approach of Cognitive Task Analysis developed by Jens Rasmussen.

This paper exemplifies the use of the model by showing its application in the dialysis setting. In Japan, 320,448 persons (0.25% of the population) received regular dialysis therapies in 2014 – a number that increases by about 4,000-6,000 patients per year (Masakane et al., 2017). When dialysis patients undergo dialysis, their blood is circulated into the external equipment for purification, and this process is more likely to lead to a critical event than most other types of therapies when something goes wrong, e.g., blood leak and sudden machine failure. The patient must stay long and frequently in a hospital or clinic – typically receiving four-hour therapy three times per week. Therefore, since the patient is exposed to a highly safety critical procedure over and over and for extended periods, careful safety management is of critical importance. Moreover, external factors may increase risks. E.g., the 2011 Tohoku Earthquake damaged not only clinical equipment and functions, but an electricity blackout affected many dialysis facilities for several hours (even many days near the seismic centre). In such cases, patients must be quickly and appropriately managed to protect against severe disturbances – including recovery from undesirable events or conditions –, and clinical systems must be sustained to continuously operate therapies and treatment after the disruption. Therefore, dialysis facilities belong to organisations that must ensure and sustain resilience capabilities to protect patients against harm during unexpected disruptions.

METHODS AND APPLICATIONS

Task analysis

In this study, task analysis is performed to describe cognitive operations, their properties and the flow of operation, following the scheme of the Decision Ladder model (Rasmussen, 1986): Activate, Observe, Identify, Interpret, Evaluate, Define Task, Formulate Procedure, and Execute. An operation flow is exhibited as transitions of operations which compose a task under study. Each operation is assessed based on: (i) characteristics of its data processing activities, (ii) the in- and out-states of knowledge resulting from the data processing, (iii) its step position properties in the Decision Ladder step, and (iv) its unique label (brief description of the operation). For instance, three properties are captured for an operation at the Observe step, in which data required for later steps are obtained: information type, applied procedure, and obscurity level. Information type is determined from the following categories: indicator (e.g., indicator of dialysis machine), physical object (e.g., blood circuit), human (e.g., patient) and environment (e.g., around dialysis bed). Obscurity of information is classified into four levels: definite, quantitative, quantitative and indefinite.

An operation at the step Identify – which makes mapping from a set of required data or information to states of the system or affairs – is analysed in terms of three properties: the number of information sources required, time-band (or tense) identified or estimated, and applied identification method. The time-band is classified into three categories according to the definition of Situation Awareness (Endsley, 1988): present, present + past, and present + future. An identification method can be selected among the following five categories according to Rasmussen's (1986) classification: simple transformation, topographic search, pattern recognition, decision-table look-up, and hypothesis and test. Properties and their categories analysed in this study are shown in Table 1 for all Decision Ladder steps.

Task complexity measurement
Task complexity is assessed in terms of step-based complexity, task-flow complexity and overall complexity based on the results of the above task analysis. In the step-based complexity, unit complexity is calculated for each operation as a product of complexity factors of assigned categories to the properties relevant to the Decision Ladder step. In this study, values of unit complexity factors (also for other factors and weights) were determined by expert judgement of five dialysis professionals – three technologists and two nurses – as shown in Table 1. Complexity factor in each property is represented in terms of a factor (multiple) of the simplest category as 1.0. For instance, the factor for observation of human-type information, i.e., 2.0, is indicated as twice as complex than that of the simplest type, i.e., indicator-type information.

Table 1. Analysed properties of each Decision Ladder step and their assigned complexity factors

Step (Object analysed)		Properties	Categories complexity factors				
Activate (Information)	(1)	No. of information pieces (IPs)	1	2	3+		
			1.0	1.5	2.0		
	(2)	IP connection type	OR	AND	conditional		
			1.0	1.5	2.0		
Observe (Information)	(1)	Information types	Indicator	Physical obj.	Human	Environment	
			1.0	1.5	2.0	2.5	
	(2)	Applied procedure	Snap-shot	Monitor	Change rate		
			1.0	1.5	2.0		
	(3)	Obscurity level	Definite	Quantitative	Qualitative	Indefinite	
			1.0	1.5	2.0	2.5	
Identify (System states)	(1)	No. of information sources	1	2	3+		
			1.0	1.5	2.0		
	(2)	Time band	Present	+Past	+Future		
			1.0	1.5	2.0		
	(3)	Identification method	Simple trans.	Topographic	Pattern recog.	Decision-table	Hypoth. & test
			1.0	1.5	2.0	2.5	3.0
Interpret (System goals)	(1)	No. of system states	1	2	3+		
			1.0	1.5	2.0		
	(2)	State-consequence	One-to-one	Same direct.	Harmonious	Conflict	
			1.0	1.5	2.0	2.5	
	(3)	Interpretation method	*Same as Identification method*				
Evaluate (System goals)	(1)	No. of system goals	1	2	3+		
			1.0	1.5	2.0		
	(2)	Certainty of goal-state relationship	One-to-one	Deterministic	Probabilistic	Complicated	Unknown
			1.0	1.5	2.0	2.5	3.0
	(3)	Evaluation method	*Same as Identification method*				
Define task (Task)	(1)	No. of system states	1	2	3+		
			1.0	1.5	2.0		
	(2)	System state-task connectivity	Fixed	Strong coupling	Loose coupling	Unknown	
			1.0	1.5	2.0	2.5	
Formulate procedure (Procedures)	(1)	Control mode	Fixed	Selective	Numerical	Discrete control	Continuous
			1.0	1.0	1.5	2.5	3.0
	(2)	No. of candidate procedures	One or a few	Limited	Unlimited		
			1.0	1.5	2.0		
	(3)	Task-procedure connectivity	One-to-one	Fixed	Loose coupling	Variety	
			1.0	1.5	2.0	2.5	
Execute (Motor movement)	(1)	Time constraint	Any time	Large window	Sort window	Exact	
			1.0	1.5	2.0	2.5	
	(2)	Required precision	No action	Any time	Wide range	Narrow range	Immediately
			0.0	1.0	1.5	2.0	2.5

We propose that two types of complexity measures shall be made when a set of unit complexities are aggregated into a step complexity and further as overall task complexity: potential complexity and actual complexity. *Potential complexity* is referred to as complexity under all possible conditions regardless of occurrence probability. In order to manage all possible events appropriately under any circumstance, one must learn and obtain knowledge and skills for all the operations comprising the task. Accordingly, the potential complexity can be measured as a sum of unit complexity for all unit operations in the step. In contrast, in an actual performance, a part of possible operations are made each time of event occurrence. Therefore, a mean complexity of actual operation performance – this index is referred to *actual complexity* – is defined as a weighted sum of unit complexity for all operations at a step, given an occurrence probability for each unit operation. Overall complexity, which refers to the complexity of the entire task, can be defined by a one-dimensional index of task complexity as a weighted sum of step-based complexity. The overall complexity can also be applied to both potential and actual complexity. In calculation of actual overall complexity, step-based complexity must be adjusted by multiplying a rate of stay at each step, which can be derived from the transition matrix between steps. A weight of each step can be estimated as a factor by estimating how many times a unit operation at the particular step is more complex than that of the Activate step, assuming the simplest unit operations at both steps. In this study, we used the following factors: 1 (Activate), 10 (Observe), 20 (Identify), 30 (Interpret), 50 (Evaluate), 15 (Define task), 10 (Formulate procedure) and 5 (Execute). The task-flow complexity assesses processing flow during the task performance as percentage of skill-, rule- and knowledge-based performance (Rasmussen, 1986), based on step sequences and short-cuts in the Decision Ladder.

Applied cases
We applied the task complexity model to two recovery cases from adverse events during haemodialysis therapy. The first case is blood leak from a dialyser during haemodialysis therapy ("dialyser leak" in short). In this and related cases, an event is usually noticed by a warning alarm of blood leak, and in rare occasions during monitoring parts of the dialysis machine, e.g., dialysate line. Then, dialysis staff observes a patient and dialysis machine including dialyser, and the staff member detects blood leaking from the dialyser. In some cases, it is difficult to detect the blood leak by direct observation. In this case, the staff will try to detect the leak by using urine occult blood reaction test. The staff member will search for causes of the blood leak. In general, assuming the blood filled in the circuit at leakage is infected, the blood, circuit and dialyser must be disposed. Continuation or halt of the therapy is determined, primarily depending on percentage done of therapy before the leakage, patient states, etc. When restart of the therapy is decided, a new dialyser and circuit are prepared and installed to the dialysis machine. The rest part of dialysis therapy is then restarted. In recent years, this kind of events rarely occur because of the high reliability and quality of dialysers and other materials, and they seldom bring a patient to this type critical adverse event.

In the other case ("needle removal"), a centesis needle is accidentally removed from a patient's hand, where the immediate cause may be inappropriate centesis and/or the patient's own act of removal. This, in turn, leads to loss of patient blood. This event is usually detected by a bubble sensor warning (air in blood), the patient will shout out or the staff, monitoring the patient, will notice this. Any delay in detection will often bring a patient into a critical situation such as cardiopulmonary crisis due if there is a substantial loss of blood. Depending on the patient situations and the severity of the event, the staff members involved are more likely to perform operations in a knowledge- and rule-based manner such as interpretation about effects of interruption of dialysis therapy, setting new goals for emergent treatment and interpretation of future system states.

RESULTS
Based on the task analysis of recovery operations from the dialyser leak event, complexity analysis has been made by applying the task complexity model. A summary of the complexity analysis results for the dialyser leak event is shown in Table 2. From step-based actual complexity, on the one hand, it is seen that complexity is moderately balanced between steps except for Activate. This may imply that the task structure is practically well functioning in the current, expected situations. On the other hand, potential complexity is biased rather on the steps of Observe and Formulate procedure. This may indicate that the complexity of the present task for the recovery process from dialyser leak is largely attributed to operations at these two steps. Relatively low complexity of operations at Identify and Define task may suggest that the recovery task can be performed in a routine-based manner.

Task and complexity analysis was also performed for the other recovery case, i.e., centesis needle removal, although no detailed result is shown here. Comparative results of task complexity between the two cases are shown in Table 3. The results indicate a recovery task from the needle removal is overall about 1.8 times higher in actual complexity and 4.0 times in potential complexity than the dialyser leak task. The difference between the two cases was partly derived from operations at steps of Interpret and Evaluate in the needle removal case. In other words, knowledge-based performance, i.e., processing sequence of Identify, Interpret, Evaluate and Interpret, contributed to higher task complexity in the recovery from the needle removal event. In other steps except for Activate and Execute, step-based potential complexity was higher in the needle removal than the dialyser leak case. However, mean actual complexity over all steps, excluding Interpret and Evaluate, was almost same for the two cases (1.2 times higher in the needle removal). Actual complexity was even higher in the dialysis leak case at Formulate procedure and Execute.

Table 2. Complexity analysis of recovery from dialyser leak event

Steps/Operations		Rate of operations	Unit/Step complexity	Potential complexity	Actual complexity
<<Activate>>			1.00	1.00	0.20
Act-1	Activation of event to be tackled	0.20	1.00		
Act-2	Activation initiated by previous cycle	0.80	0.00		
<<Observe>>			77.50	775.00	174.25
Obs-1	Observation for confirming event	0.25	15.75		
Obs-2	Observation for cause investigation	0.25	9.00		
Obs-3	Information seeking blood reaction test	0.05	3.00		
Obs-4	Observation for continuation of dialysis	0.25	22.75		
Obs-5	Observation after restart of dialysis	0.20	27.00		
<<Identify>>			18.75	375.00	83.50
Ide-1	Identification of dialyser leak	0.25	2.00		
Ide-2	Identification of causes by visual check	0.20	2.25		
Ide-3	Event dentification by blood reaction test	0.05	2.00		
Ide-4	Decsion of continuation of dialysis	0.25	5.00		
Ide-5	Check of progress after restrat of dialysis	0.25	7.50		
<<Define task>>			6.75	101.25	16.71
Def-1	Task definition for examination of dialyser leak	0.33	1.50		
Def-2	Task definition for disposing blood & materials	0.33	3.00		
Def-3	Task definition of post-treatment after restart	0.33	2.25		
<<Formulate procedure>>			69.38	693.75	114.47
Pro-1	Procedure formulation for blood reaction test	0.33	12.50		
Pro-2	Proc. formulation for disposing blood & materials	0.33	45.63		
Pro-3	Proc. formulation of post-treatment after restart	0.33	11.25		
<<Execute>>			56.00	280.00	37.25
Exe-1	Stopping blood pump	0.25	1.50		
Exe-2	Performing occult blood reaction test	0.05	13.00		
Exe-3	Making restart of blood pump	0.20	2.00		
Exe-4	Disposing blood & materials at leak	0.15	31.50		
Exe-5	Restart of dialysis therapy	0.20	2.00		
Exe-6	Performing post-treatment after restart	0.15	6.00		
		Overall complexity		2226.00	426.38

DISCUSSION

This paper proposed two types of task complexity measures from different perspectives. Actual complexity assesses mean complexity at the time when a task is performed in an expected, averaged condition. In this sense, there is not a large difference in task complexity between the two cases examined in this study when the task is actually performed, unless there is a huge loss of patient blood, in which case the patient enters a severe condition. Potential complexity aggregates degrees of complexity for all operations that a task must be performed under any condition. Accordingly, all possible operations must be enumerated in conditions as many as one can (practically) consider. Complexity scores are summed up on the basis of the perspective that even rare operations must be performed in an unexpected, emergent situation. The operations captured in this way, considering the actual knowledge, skills, etc. involved in the operations, form the total capability of a given system or an organisation. Therefore, potential complexity may be more likely to correspond to an impediment factor against systems resilience. High potential complexity at steps of Observe and Formulate procedure (cf. Table 3) may suggest the need for introducing alternative information sources to facilitate simple, quick observations, and for aggregating subtasks to reduce their number and hence complexity and, in turn, strengthen resilience against any future crisis. The comparative results of the two cases suggest, although no robust conclusion can be made unless more cases are tested in a future study, that complexity task analysis may be a structured method for identifying points at which the safety of work systems may be improved.

Table 3. Comparisons of task complexity between dialyser leak and needle removal

	Potential complexity		Actual complexity	
Step	Dialyser leak	Neddle removal	Dialyser leak	Neddle removal
Activate	1.00	1.00	0.20	0.20
Observe	775.00	1740.00	174.25	223.13
Identify	375.00	1150.00	83.50	121.95
Interpret (1)		1500.00		99.23
Evaluate		1225.00		99.23
Interpret (2)		810.00		65.61
Define task	101.25	352.50	16.71	26.32
Formulate procedure	693.75	1578.75	114.47	103.27
Execute	280.00	472.50	37.25	30.56
Overall complexity	2226.00	8829.75	426.38	769.49

CONCLUSIONS

In this study we have built a task complexity model based on results of cognitive task analysis. Jens Rasmussen developed several useful models and methods which are applicable to task analysis for modern cognitive work like clinical and therapeutic tasks in healthcare. We have created a model of assessing task complexity from a practical and resilient point of view, i.e., actual complexity and potential complexity, by the use of Rasmussen's Decision Ladder model, and have suggested its implications for improving system resilience.

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Symposium E2: Rasmussen Revisited 2: Human Factors, Accidents and Error

Symposium E2: Rasmussen revisité 2 : facteurs humains, accidents et erreurs

BEYOND THE INTERFACE: USING EID TO DESIGN RAIL LEVEL CROSSING ENVIRONMENTS

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KEYWORDS
Ecological interface design, railway level crossings, transport, safety

SUMMATIVE STATEMENT
The ecological interface design (EID) philosophy is one of Rasmussen’s core legacies. EID was applied to develop a novel railway level crossing environment. The work demonstrated that EID can be applied beyond computer-based interfaces to the design of physical environments.

Au-delà de l’interface : utilisation de la conception d’interface écologique pour concevoir des passages à niveau

MOTS-CLÉS
Conception d'interface écologique, passages à niveau, transport, sécurité

SOMMAIRE
La philosophie liée à la conception d'interface écologique (EID) est l'un des principaux legs de Rasmussen. L'EID a été appliquée pour concevoir un nouvel environnement de passages à niveau. La recherche effectuée a démontré que l'EID pouvait être appliquée au-delà des interfaces informatiques et servir à la conception d'environnements physiques.

PROBLEM STATEMENT
Crashes at railway level crossings are of international concern, particularly those in rural areas that have no active warnings (e.g., flashing lights or boom barriers). This work examined whether Cognitive Work Analysis (CWA; Rasmussen, Pejtersen & Schmidt, 1990; Vicente, 1999) and ecological interface design (EID) could be used to develop revolutionary, low-cost interfaces at railway level crossings. EID takes the ecological constraints identified in CWA and uses Rasmussen’s (1983) skills, rules and knowledge (SRK) framework to design interfaces which enable their users to operate at all levels of cognitive control, thus enabling adaptive behaviour.

RESEARCH OBJECTIVE

EID was developed for the design of computer-based interfaces. Our objective was to explore whether EID could be applied to the design of a physical environment; in this case railway level crossings.

METHODOLOGY

CWA was applied to describe the functioning of RLXs in Victoria, Australia (see Salmon et al., 2016 for details). Following this, seven researchers experienced in CWA and railway level crossing safety identified the key constraints that impact the decision-making of road users and train drivers at railway level crossings. Next, using the SRK framework, they considered how each key constraint could be made visible to users.

RESULTS

The outcome was an EID-based design concept for rural railway level crossings (Figure 1) that included features such as: a static field of safe travel using road markings; the use of mirrors to reflect the image and horn of approaching trains; and roadside and trackside poles to assist judgements of speed and distance of vehicles. Experimental evaluation using driving simulation has suggested the potential effectiveness of the crossing above the existing standard design.

Figure 1. Approach to the EID railway crossing design concept as shown in driving simulator

DISCUSSION

This study demonstrated that EID can be used for the design of physical environments. Further research should focus on comparing the effectiveness of this design concept to existing RLX configurations in the field. Further, the concept should be compared to other novel designs developed using design approaches other than EID.

CONCLUSIONS

Our work has demonstrated the utility of EID for the design of system elements beyond computer-based interfaces. This is important for the use of CWA in domains such as road and rail safety where the physical environment is an important influence on behaviour.

ACKNOWLEDGEMENTS

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Is the AcciMap Method an effective approach for analysing Adverse Events in the National Health Service, Scotland?

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KEYWORDS
AcciMaps, Patient Safety, Systemic Models, Risk Management, Accident Models

SUMMATIVE STATEMENT
The AcciMap method was utilized and evaluated by NHS participants based on the survey adapted from a previous study (Underwood et al, 2016). The results obtained indicate the need for further studies on improving the validity and reliability of the method.

La méthode AcciMap est-elle efficace pour analyser les événements indésirables dans le service national de santé de l'Écosse?

MOTS-CLÉS
AcciMap, sécurité des patients, modèles systémiques, gestion des risques, modèles d'accidents

SOMMAIRE
La méthode AcciMap a été utilisée et évaluée par des participants du service national de santé au moyen d'un sondage adapté à la suite d'une étude antérieure (Underwood et coll., 2016). Les résultats obtenus révèlent que d'autres études sont nécessaires afin d'améliorer la validité et la fiabilité de la méthode.

PROBLEM STATEMENT
Despite the benefits of adopting systems thinking approach in analysing adverse events, there remains an existing gap between academic research and practical utilisation of systemic based methods like AcciMaps in safety-critical systems (Underwood & Waterson (2013); Underwood & Waterson (2014)). This is particularly evident within the healthcare system who are still relying on the use of linear and event based techniques (Qureshi, 2008).

RESEARCH OBJECTIVE/QUESTION
The study focuses on the evaluation of the AcciMap method on a medical case study analysis by participants of the National Health Service (NHS), Scotland.

METHODOLOGY
The training workshop was organised by the Healthcare Improvement Scotland (HIS), a national body responsible for reviewing, learning from incidents and report improvement. Invitations were sent to participants via email and subsequent information regarding the

workshop and consent forms were also sent to them. There were fifteen (15) participants in total including special NHS boards (3) and territorial NHS boards (8) out of 14 boards in Scotland. Their job specializations include risk management and clinical governance. They were all experienced in incident investigation in their respective boards and have demonstrated knowledge in the use of different Root Cause Analytical techniques. However, none of them had utilised the AcciMap approach in their respective boards.

The training workshop was designated for a three–hour period with the introduction to the AcciMap method (Rasmussen & Svedung, 2000) with the second aspect focused on the analysis of a clinical case study (Chassin & Becher, 2002). The participants were divided into three teams (A, B and C), each receiving training materials and guidelines based on Branford's standardized AcciMap format (Branford et al, 2009). The questionnaire was adapted from a previous study (Underwood et al, 2016) with the author's permission. The survey composed of twenty–two (22) questions focusing on key aspects of the evaluation including usability, graphical representation, and validity as shown in Appendix A. The questionnaire was distributed to the participants after the duration of the exercise. They were not under any obligation to fill the survey.

Focus group discussions took place immediately after the analysis of the case study and was audio recorded to capture themes. Each team's AcciMap outcomes and safety recommendations were reviewed for similarities and differences. In addition, specific aspects of the AcciMap method were discussed including advantages, disadvantages, and applicability in clinical investigations as well as areas for future improvement.

RESULTS

Survey results and focus group discussions based on their AcciMap results are discussed below:

Survey Results: Out of fifteen (15) participants, only thirteen (13) filled the questionnaire and returned it after the workshop. There were also two missing records on the data that was provided by two participants on questions 13 and 20 The mean and standard deviation values for the survey data are shown in Appendix B. The minimum and maximum values represent the lowest and highest values on the likert scale (from "strongly disagree" (0) to "strongly agree" (6)) used to rate each question. From the survey, 76.9% of participants were familiar with the concept of "systems thinking". However out of 10 participants that knew about systems thinking, only 3 of them were vaguely familiar with the AcciMap method. Three groups were generated from questions 1 and 2 indicated below:

Group 1: Familiar with "system thinking" and unaware of AcciMap method (with sample size 7);
Group 2: Unfamiliar with "system thinking" and unaware of AcciMap method (with sample size 3);
Group 3: Familiar with "system thinking" and aware of AcciMap method (with sample size 3).

The levels of satisfaction regarding the AcciMap method are different between each groups identified (see figure 1). In addition, group 1 seems to indicate the best level of satisfaction on the use of the systemic approach. An Analysis of Variance (ANOVA) analysis was also performed to gain insight on the differences in satisfaction from three groups regarding the knowledge of the systems thinking approach and their awareness of the AcciMap approach.

The results indicated in table 1 suggests that there is no evidence to reject the null hypothesis and hence no evidence of any differences amongst the groups.

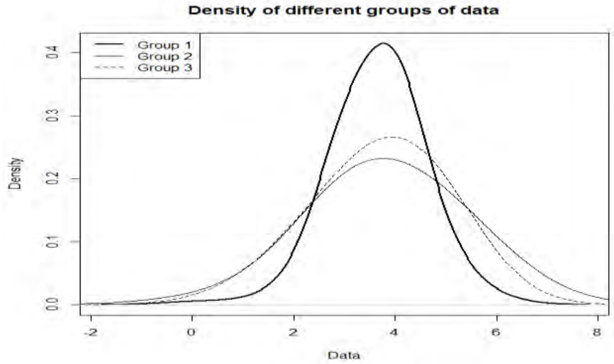

Figure 1: Density of the three groups relating to questions 1 and 2

Table 1: ANOVA table for three groups

Analysis of Variance Table					
	Df	**Sum Sq**	**Mean Sq**	**F value**	**P-value**
Group	2	1.488	0.74406	0.7531	0.4718
Residuals	296	292.456	0.98803		

Based on the exploratory analysis of the responses, many participants considered AcciMap to be a suitable method for analysing accidents (Question 4). There was also a majority agreement regarding the method's ability to represent causal relationships between different levels (Question 8) and as well as promoting collaboration (Question 17). Of interest is their response to questions relating to AcciMaps effectively analysing contributing factors based on different issues; technical components (Question 6a), human factors issues (Question 6b), organisational issues (Question 6c), environmental issues (Question 6d) and external issues (Question 6e). There was a mixture of participants who agreed and other who gave neutral responses to the above issues. However, there was a disagreement from one participant regarding the method's ability to effectively analyse factors relating components. A disagreement was also found regarding effectively analysing issues relating to external issues by another participant. There were also mixed responses from participants regarding the AcciMap method being a time-consuming process and the sufficiency of the training for effective use (Question 21 and 22). The overall satisfaction regarding the use of the AcciMap as shown in figure 2 shows the density line skewing to the right indicating a large probability of satisfaction.

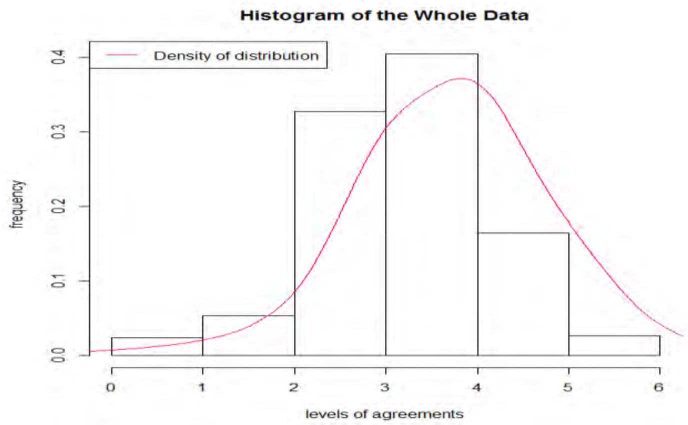

Figure 2: Histogram of the survey data from participants

AcciMap Results: Each of the teams (A, B and C) analysed and produced their respective AcciMap results using the guidelines in training manual as well as the table of contributing factors at different levels of the AcciMap structure (Branford et al, 2009). Figure 3 shows of the AcciMap result of team A from the case study. The AcciMap results of team B and C are shown in Appendices C and D respectively. While the contributing factors table served as a guide in the analysis, the participants determine factors based on the evidence in the report as well as inferences. For example, Team A's AcciMap output indicated some factors that were not considered by other groups. This point was very particular at the higher levels (Organisational and External levels).

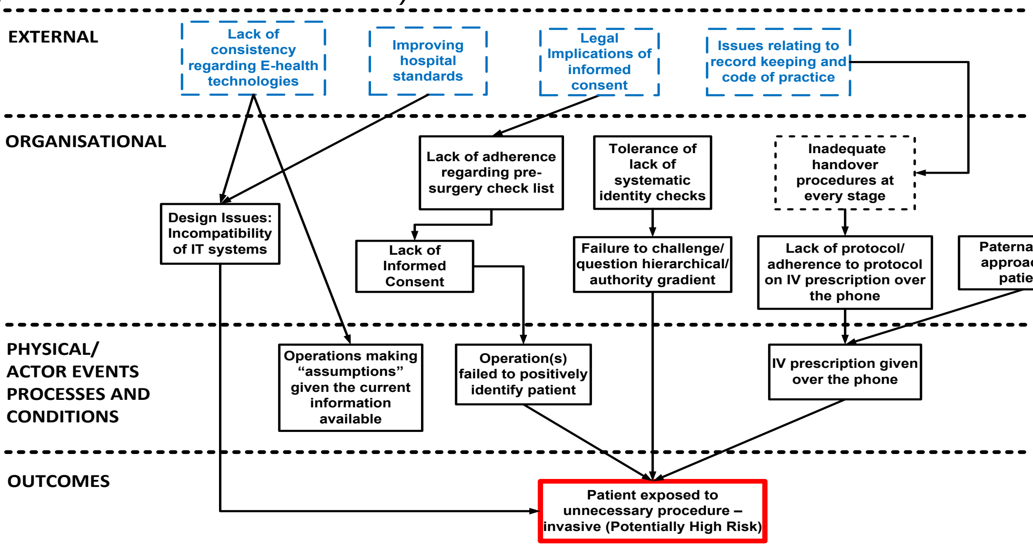

Figure 3: AcciMap output (Team A)

It should be noted that the broken boxes in the output indicates possible contributing factors but with no clear evidence. While the results indicated the method to be highly subjective, there were similar factors each of the groups identified. These factors may have used different wording but they conveyed similar meanings. For example, at the organisational level, the teams similarly identified issues relating to *"handover processes"*, *"auditing"* relating to consent forms and *"communication"* regarding computer systems (IT systems). At the external level, each team had varying factors but two teams (B and C) identified similar factors pertaining to *"waiting times/list"* and *"targets"*. From the results, each team provided safety recommendations as shown in table 2.

Table 2: Recommendations of Teams A, B and C

TEAM A	TEAM B	TEAM C
1.) Full review of systems. 2.) Implementing safety briefing surgical pause handover.	1.) Process for patient consent must be robust and unless completed procedure must be halted. 2.) This process should be audited. 3.) Patient information systems must be able to share information. 4.) Compatibility of systems needs to be reviewed.	1.) Implementation of safety briefs to support development of a safety culture. 2.) Implementation of consent policy.

DISCUSSION

The case study was intended to give participants the opportunity of utilising a systemic method that they were not familiar with, or used for accident analysis in their respective boards. Based on the survey results and group discussions, specific aspects of the method usage criteria are discussed.

1.) **Usability:** Despite their first time use of the AcciMap model, the results suggests a general understanding of the use of the method. Because of the time restriction of the exercise, the participants did not have the opportunity of revising their outcomes which also suggests that more time is needed for AcciMap analysis. From both the survey and group discussions, participants indicated neutral responses regarding how easy it is to understand the AcciMap method (Question 11) and how applicable it is for incident investigation in their NHS boards (Question 10). This suggests more training is needed with the use of cases within their practice. There was a general agreement amongst participants from each team regarding the ease of the use of the AcciMap (Question 15) although there were six (6) neutral responses.

2.) **Graphical Representation:** From the survey results and discussions, there was a majority agreement on the method for communicating contributing factors that lead to the negative outcome (Question 18). Another participant also noted that the ability of the method to graphically represent contributing factors promote discussions at the managerial level. However, only one participant disagreed with the method due to the outputs being potentially complicated. Another notable aspect of the evaluation was whether a timeline could be incorporated in the analysis (Question 5). This is a fact because the current iteration of the AcciMap method does not incorporate timeline of events that occurred with the actors involved at different levels. This point was also noted in the Underwood et al (2016) study using a different systemic method (STAMP) involving participants investigating a railway incident.

3.) **Validity:** Relating to the survey results, participants produced mixed responses (there was a general agreement) on the method's ability to effectively analyse factors relating to external, technical, organisational, and human factor issues. During the discussions, participants further noted the method's ability to show interaction of contributing factors between different AcciMap levels allows for understanding of how they led to the outcome. Although we also noted differences between the survey results and the group discussions regarding those set of questions (Questions 6a to 6e). Considering that this was their first attempt in using AcciMaps, the validity of the produced will need to be further examined especially as to the factors that actually contributed to the outcome. One of the ways this can be achieved is by participants being more skilled and experienced in the use of AcciMaps for accident analysis. To further improve face and content validity, one of the participants indicated the need for a structured process within the AcciMap method that categorises contributing factors in a similar way to the fishbone technique, one of the commonly used techniques in NHS boards.

4.) **Reliability:** The study shows the subjective nature of the AcciMap method. This is especially affected by the level of skill and experience of the participants' first time involvement of this study. Despite the varying outcomes from the teams, there were similarities regarding contributing factors identified and where they were placed in each AcciMap level. Also the number of contributing factors identified by each team relating to the adverse event was also varied. Safety recommendations developed from their analyses also showed some similarities. For example, the implementation of "safety briefs" as part of improving safety culture (teams A and C) as well as reviewing and implementing "consent policy" (team B and C). While the survey did not focus on assessing the reliability of the method, it is a very important characteristic that needs to be further enhanced to be considered a viable tool for investigating incidents in the healthcare domain.

While our objectives for the workshop were achieved within the time allotted, there were several limitations of the study. This includes the amount the time needed to train the participants in other aspects of the Risk Management Framework (RMF). The case incident used also did not explicitly contain substantial evidence especially as to the systemic causes at the higher levels (Organisational and External). This is most likely to affect the results produced even though the teams where encouraged to make inferences. In addition, while the participants completed their AcciMap outcomes during the allocated time, it was not sufficient for them to review and make any need additions or changes to their results.

CONCLUSIONS

The acceptance and adoption of the AcciMap method for analysing clinical incidents in the NHSScotland will depend upon the enhancement of the method's reliability and validity (both face and content validity). This step is very critical in producing consistent and valid results for developing counter measures. This direction could potentially help contribute to the awareness of the practical advantages of systemic based methods incorporating system's thinking as a way of improving patient and system safety. Future studies will focus on the application of a health-based taxonomy of contributing factors within the AcciMap format to address and enhance the reliability of the AcciMap method.

ACKNOWLEDGEMENTS

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APPENDIX

Appendix A: AcciMap Evaluation Questionnaire

Your Name (Optional):
Your Participant Number:
Your Team Number:

Before attending the introductory AcciMap training workshop

Q1.) Were you familiar with "systems thinking"?	Yes [ ]	No [ ]
Q2.) Where you aware of the AcciMap method?	Yes [ ]	No [ ]
Q3.) Had you previously used AcciMap method in your NHS board before?	Yes [ ]	No [ ]

Questions on the use of AcciMaps

The following is a set of statements about using the AcciMap method. For each statement please say whether you:
[6] – Strongly agree [5] – Agree [4] – Slightly agree [3] – Neutral [2] – Slightly disagree
[1] – Disagree [0] – Strongly disagree

Put a tick in the appropriate box

	Strongly Disagree			**Neutral**			**Strongly Agree**
Q4.) AcciMap is a suitable method for analysing accidents	[0]	[1]	[2]	[3]	[4]	[5]	[6]
Q5.) AcciMap effectively describes the timeline of events leading to the accident	[0]	[1]	[2]	[3]	[4]	[5]	[6]
Q6.) AcciMap effectively analyses the contributing factors to an accident from:							
a) Technical components e.g. hardware, software	[0]	[1]	[2]	[3]	[4]	[5]	[6]
b) Human factors issues e.g. workload, fatigue	[0]	[1]	[2]	[3]	[4]	[5]	[6]
c) Organisational issues e.g. policies and procedures	[0]	[1]	[2]	[3]	[4]	[5]	[6]
d) Environmental issues e.g. climate and noise levels	[0]	[1]	[2]	[3]	[4]	[5]	[6]
e) External issues e.g. lack of oversight, budget allocation	[0]	[1]	[2]	[3]	[4]	[5]	[6]
Q7.) AcciMap provides a comprehensive description of an accident	[0]	[1]	[2]	[3]	[4]	[5]	[6]
Q8.) AcciMap effectively represents causal relationships between each levels	[0]	[1]	[2]	[3]	[4]	[5]	[6]
Q9.) AcciMap accurately identifies the causes of an accident	[0]	[1]	[2]	[3]	[4]	[5]	[6]

Q10.) AcciMap can be applied to analyse any type of accident in NHS trust	[0]	[1]	[2]	[3]	[4]	[5]	[6]
Q11.) AcciMap is an easy method to understand	[0]	[1]	[2]	[3]	[4]	[5]	[6]
Q12.) The terms and concepts used in the AcciMap method are clear and unambiguous	[0]	[1]	[2]	[3]	[4]	[5]	[6]
Q13.) It is easy to identify contributing factors that led to the accident	[0]	[1]	[2]	[3]	[4]	[5]	[6]
Q14.) It is easy to identify unsafe decisions that led to the accident	[0]	[1]	[2]	[3]	[4]	[5]	[6]
Q15.) AcciMap is an easy method to use for accident analysis	[0]	[1]	[2]	[3]	[4]	[5]	[6]
Q16.) AcciMap is easy to use in a team-based analysis	[0]	[1]	[2]	[3]	[4]	[5]	[6]
Q17.) AcciMap promotes team collaboration during analysis	[0]	[1]	[2]	[3]	[4]	[5]	[6]
Q18.) AcciMap's graphical diagram is a useful communication tool	[0]	[1]	[2]	[3]	[4]	[5]	[6]
Q19.) It would be easy for me to become skilled at using AcciMap method	[0]	[1]	[2]	[3]	[4]	[5]	[6]
Q20.) AcciMap analysis can be completed in an acceptable timescale (within a few hours of the training workshop)	[0]	[1]	[2]	[3]	[4]	[5]	[6]
Q21.) AcciMap method is time consuming	[0]	[1]	[2]	[3]	[4]	[5]	[6]
Q22.) I received sufficient introductory training in the use of the AcciMap method to effectively use this method.	[0]	[1]	[2]	[3]	[4]	[5]	[6]

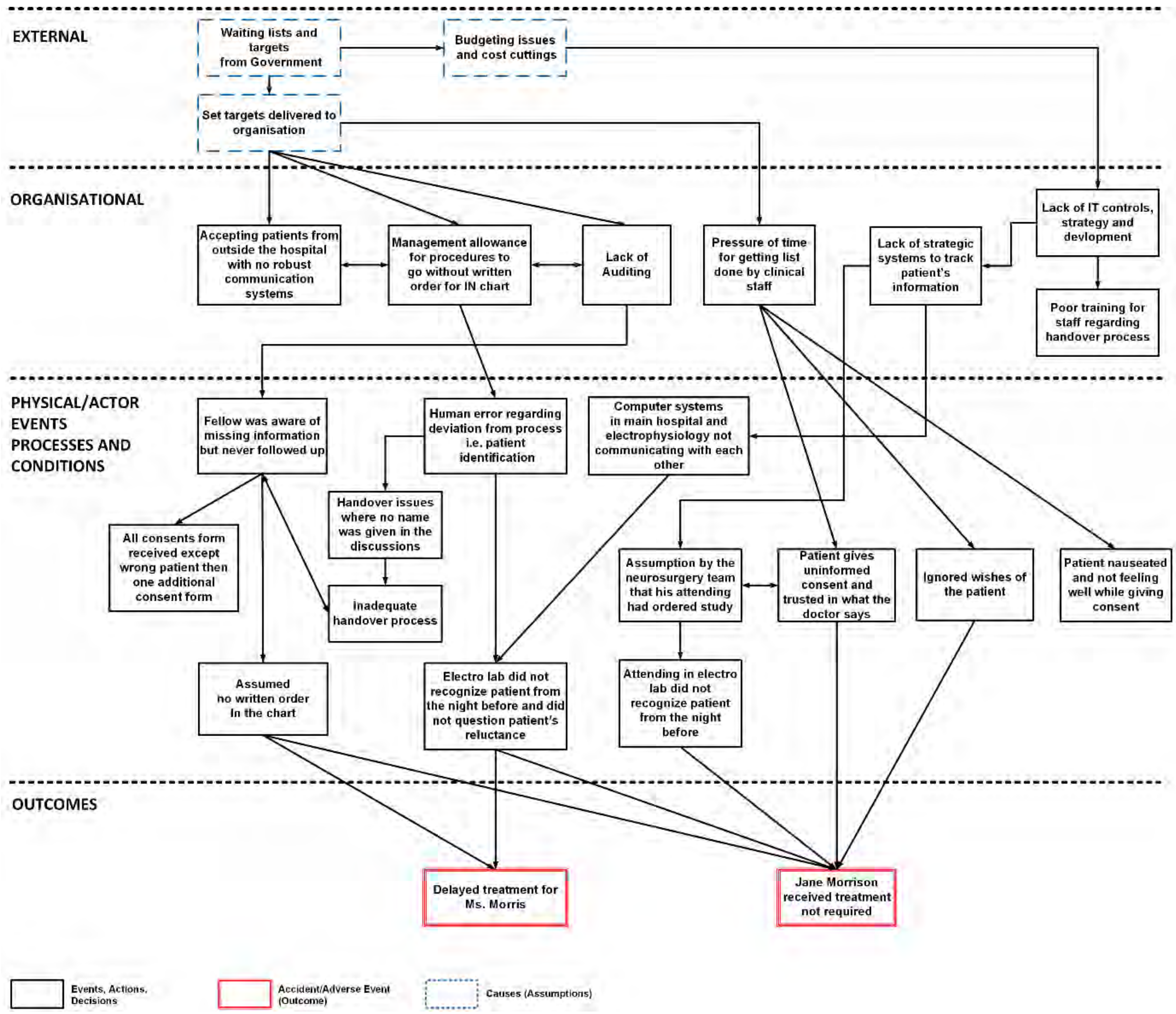
Any other comments

Appendix B: Descriptive Statistics (Questions 4 to 22)

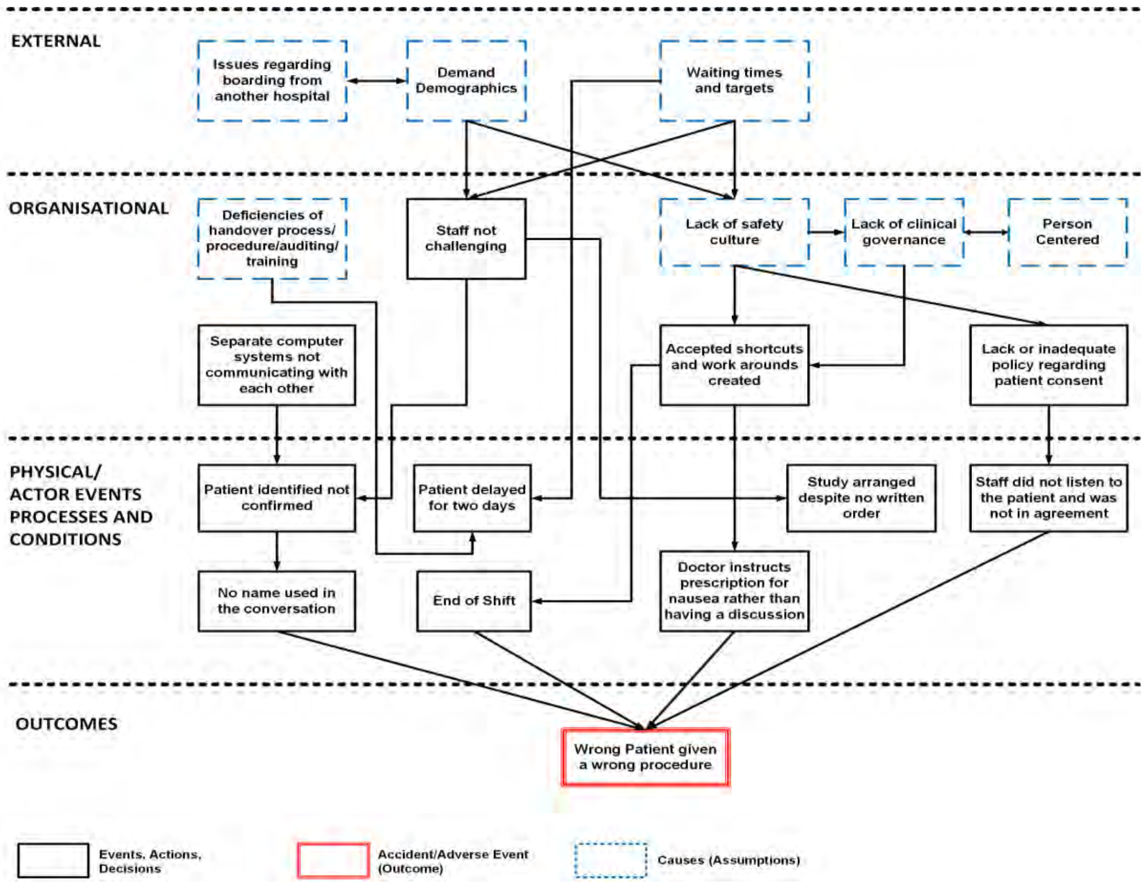
Question	N	Min	Max	Mean	SD
4.) AcciMap is a suitable method for analysing accidents	13	3	6	3.92	.862
5.) AcciMap effectively describes the timeline of events leading to the accident	13	0	3	2.23	1.013
6 a.) AcciMap effectively analyses the contributing factors to an accident from Technical components	13	3	5	3.62	.650
6 b.) AcciMap effectively analyses the contributing factors to an accident from Human factor issues	13	2	5	3.54	.776
6 c.) AcciMap effectively analyses the contributing factors to an accident from Organisational issues	13	3	5	3.77	.725
6 d.) AcciMap effectively analyses the contributing factors to an accident from Environmental issues	13	3	5	3.54	.660
6 e.) AcciMap effectively analyses the contributing factors to an accident from External issues	13	0	5	3.54	1.198

7.) AcciMap provides a comprehensive description of an accident	13	1	6	3.62	1.261
8.) AcciMap effectively represents causal relationships between each level	13	3	6	4.38	.870
9.) AcciMap accurately identifies the causes of an accident	13	3	6	4.23	.832
10.) AcciMap can be applied to analyse any type of accident in NHS boards	13	2	6	3.54	1.266
11.) AcciMap is an easy method to understand	13	3	6	3.85	.987
12.) The terms and concepts used in the AcciMap method are clear and unambiguous	13	3	5	3.77	.725
13.) It is easy to identify contributing factors that led to the accident	12	3	5	3.83	.718
14.) It is easy to identify unsafe decisions that led to the accident	13	2	5	3.62	.768
15.) AcciMap is an easy method to use for accident analysis	13	3	6	3.85	.987
16.) AcciMap is easy to use in a team-based analysis	13	3	5	3.92	.641
17.) AcciMap promotes team collaboration during analysis	13	2	5	4.08	1.115
18.) AcciMap's graphical diagram is a useful communication tool	13	2	5	4.38	.870
19.) It would be easy for me to become skilled at using AcciMap method	13	3	6	4.15	.987
20.) AcciMap analysis can be completed in an acceptable timescale (within a few hours of the workshop)	12	3	5	3.75	.754
21.) AcciMap method is time consuming	13	1	5	3.08	1.038
22.) I received sufficient introductory training in the use of the AcciMap method to effectively use this method	13	1	4	3.00	.913

Appendix C: Team B AcciMap Result



Appendix D: Team C AcciMap Results


EXTERNAL
Issues regarding boarding from another hospital
Demand Demographics
Waiting times and targets
ORGANISATIONAL
Deficiencies of handover process/ procedure/auditing/ training
Staff not challenging
Lack of safety culture
Lack of clinical governance
Person Centered
Separate computer systems not communicating with each other
Accepted shortcuts and work arounds created
Lack or inadequate policy regarding patient consent
PHYSICAL/ ACTOR EVENTS PROCESSES AND CONDITIONS
Patient identified not confirmed
Patient delayed for two days
Study arranged despite no written order
Staff did not listen to the patient and was not in agreement
No name used in the conversation
End of Shift
Doctor instructs prescription for nausea rather than having a discussion
OUTCOMES
Wrong Patient given a wrong procedure
Events, Actions, Decisions
Accident/Adverse Event (Outcome)
Causes (Assumptions)

TAXONOMIES OF HUMAN ERROR AND TASK CONDITIONS – FOUNDATIONS AND USE

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Taxonomie de l’erreur humaine et des conditions de travail – fondements et utilisation

ABSTRACT
In much of his work, Jens Rasmussen was concerned with taxonomies of human error (with or without scare-quotes) and the factors that underlie and shape human performance. It seems that his earliest reference to taxonomies was in a technical report (Rasmussen, 1974) describing the need for designing control room display interfaces to be “properly matched to the characteristics of human mental data processing”. He observes that incident and accident analyses typically present a simplistic picture of so-called human error and argues that to “improve system reliability, more integrated consideration must be given to human errors during system design and operation”. Discussing the possibilities for developing methods for predicting human reliability, he argues, (following Meister, 1971) that this would require empirical data on the reliability of the individual sub-task together with information on task and situational factors – a requirement he seems to deem largely unrealistic. Still, he does sketch a programme for collecting and analysing performance data, but notes:

> “Before a large-scale collection of human failure data is planned, it is necessary to formulate taxonomy of tasks and work conditions related to different modes of mental activities, and to verify the foundation by careful analysis of the work conditions in process plants and by analysis of detailed post-event records from the same plants”.

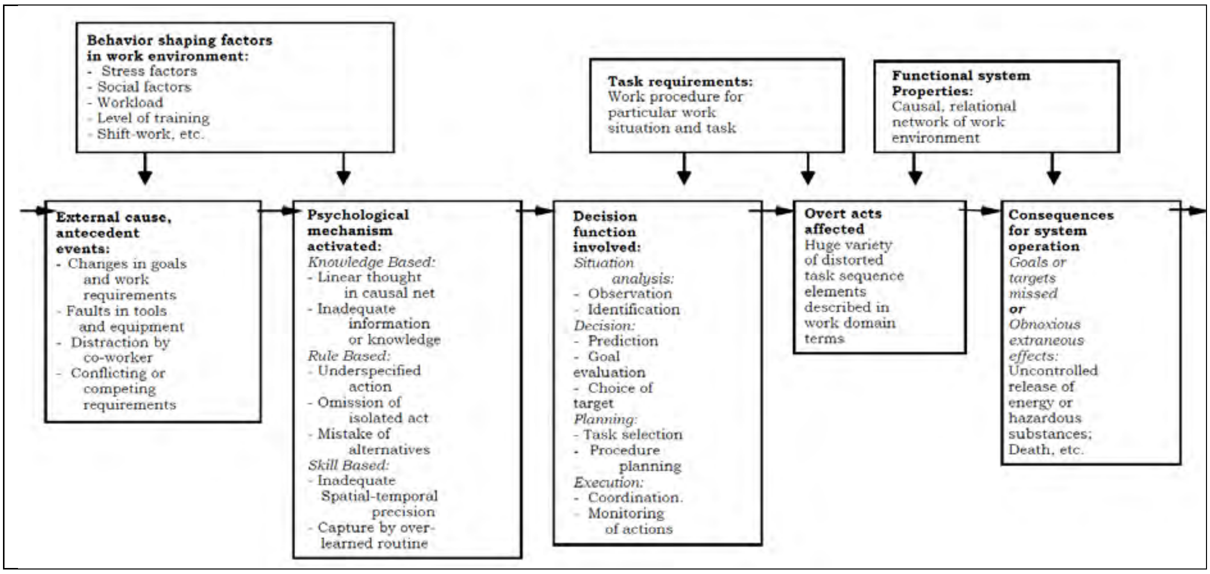

Fig. 1 Multi-facet taxonomy for description and analysis of events involving human malfunction (from: Rasmussen, 1982)

In the late 70's and early 80's, Rasmussen then developed his "multi-facet taxonomy for describing events involving human malfunction", which has inspired a large number of authors developing and applying error classification systems.

In this presentation, we describe the theoretical foundations behind major taxonomies and review some recent results on their use, including issues of validity and interrater reliability showing how the "multi-facet taxonomy" formed the background of the taxonomies that formed the framework of the AcciMap approach in Rasmussen

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Symposium E3: Rasmussen Revisited 3 - Human Factors, Accidents and Error

Symposium E3: Rasmussen revisité 1 : facteurs humains, accidents et erreurs

SYSTEMIC FACTORS IN THE INVESTIGATION OF RAILWAY OCCURRENCES IN SOUTH AFRICA

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KEYWORDS
Rail, railway occurrences, Rasmussen's (1997) Risk Management Framework, complex systems, accident investigations

SUMMATIVE STATEMENT
Railway occurrences in South Africa remain high, despite the Regulator and railway operators investigating occurrences. This research explores why this is the case. Rasmussen's (1997) Risk Management Framework is used to illustrate the railway hierarchy in South Africa and how the different levels influence the effectiveness of the accident investigation process. The results highlight how systemic factors inherent in the bigger rail socio-technical system impact on the investigation process, the reliability and accuracy of the findings, and the appropriateness of the recommendations. These factors contribute to the recurrence of railway accidents and highlight how the investigation of accidents is an example of a complex system on its own.

Les facteurs systémiques dans les enquêtes d'accidents ferroviaires en afrique du sud

MOTS-CLÉS
Train, accidents ferroviaires, cadre de gestion des risques de Rasmussen (1997), systèmes complexes, enquêtes d'accidents

SOMMAIRE
Malgré les enquêtes d'accidents menées par l'organisme de réglementation et les opérateurs ferroviaires, les accidents ferroviaires demeurent toujours élevés en Afrique du Sud. Cette recherche explore les raisons de cette situation. Le cadre de gestion des risques de Rasmussen (1997) a été utilisé pour illustrer la hiérarchie ferroviaire en Afrique du Sud et la façon dont les différents niveaux influencent l'efficacité du processus d'enquête d'accident. Les résultats mettent en lumière comment les facteurs systémiques, qui sont inhérents au grand système sociotechnique ferroviaire, influencent le processus d'enquête, la fiabilité et l'exactitude des résultats, et la pertinence des recommandations. Ces facteurs contribuent à la répétition des accidents ferroviaires et démontrent comment une enquête d'accident présente un exemple de système complexe à lui seul.

PROBLEM STATEMENT
There is a need to understand how effective interventions are within the railway industry in addressing critical occurrences. A failure to identify what really happened may be a possible reason for the number of recurrences. The primary aim of an investigation is to uncover the events at all levels of the system and to identify remedial actions to prevent a recurrence. *If accidents are being investigated, why then do the number of occurrences remain largely unchanged?* It is proposed that there are factors inherent within the railway system that influences the effectiveness of the investigation process and therefore its objectivity, quality accuracy, validity, and reliability.

In South Africa, there are on average 4500 railway occurrences annually resulting in fatalities, injuries, damage to rolling stock and the environment. South Africa's rail network includes a mix of both freight and passenger rail with accidents resulting in social, moral and financial consequences. South Africa's railway has been underdeveloped and neglected due to a number of years of underinvestment in rail. This is attributed to the historical context of the country that has also resulted in a shortage of railway skilled professionals.

South Africa's unenviable railway safety record warrants further analysis, with the Railway Safety Regulator (RSR) acknowledging that one of its safety interventions is to investigate railway occurrences as part of its mandate to oversee railway safety. While railway operators are obligated to report, and investigate all occurrences to the RSR, the RSR investigates occurrences that have led to major loss, for example fatalities, injuries, major damage to property, and those that attract media attention. The RSR maintains that the purpose of its investigations is to identify the immediate and root causes and prevent recurrences (RSR, 2015). In striving to ensure railway safety, the RSR's vision for the period of 2015-2020 is to aspire to achieve zero occurrences (RSR, 2015). While this is a positive progression, it is argued that this may be a major feat given the high occurrence rate and inherent complexities of a rail socio-technical system, further emphasising the importance of addressing this research problem.
This research is important not only because of the existing problem in South Africa (with regards to railway safety performance trends), but also due to the existing literature on accident investigations. A number of important studies examining accident causation have been produced. Much of this work tends to focus on the accident itself, determining the events leading up to the accident and more recently what factors within the system contribute to accidents. While work exists on the investigation of accidents, little attention has been given to *the investigation process of accidents as a complex system* in its own right. This work examines the system of accident investigations as a complex system and not the accident itself. A systems approach applied to the investigation process of accidents is important as systemic factors influence the effectiveness (accuracy, quality, reliability, validity and objectivity) of the investigation process, and therefore its outcomes (findings and recommendations).

RESEARCH OBJECTIVE/QUESTION

Rail has the potential to play an important role in the sustainability of transport within South Africa. The benefits of rail include: creating economic growth, reducing congestion on roads, providing mobility to citizens and contributing to re-industrialisation. For rail transport to play a vital role in society, the primary and overall requirement is that it is a safe mode of transport.

A critical review of the literature, in terms of accident investigation theory, indicates that the current research targets various approaches, methods and models to determine why accidents occur; from a human, technical, or system perspective. The literature focusses on accident causation by addressing the system and its role in contributing to such events. However, very little critical analysis exists on the actual investigation process of accidents as a complex system in its own right, and its contributory role in the ongoing high number of accidents.

This research illustrates how the complexity of the South African railway system, combined with systemic factors impacts on the entire accident investigation process. It focusses on the system of accident investigations and not the accidents themselves. Adopting a systems approach allows for a holistic and comprehensive identification of the external and internal parts or components within and between organisations, their interactive nature, feedback and interdependence, in addition to the role of the environment influencing the investigation system's performance. Rasmussen's (1997) Risk Management Framework provides the theoretical framework for this research and is operationalised for the South African railway system. The identification of the systemic factors influencing the investigation system will not only benefit the railway industry but will also contribute to accident investigation theory by providing an alternative approach.

This research addresses the problem statement by stating that the effectiveness of the investigation process of occurrences contributes to the accuracy, validity, quality, objectivity and reliability of the findings, recommendations and the number of occurrences. *It is therefore hypothesised that there are systemic factors influencing the investigation process of occurrences in South Africa.* This indirectly contributes to the high numbers of occurrences as symptoms and unsuitable recommendations are identified resulting in latent conditions remaining unnoticed. Deficiencies in the investigation system limit the effectiveness of the entire investigation process from achieving its objectives, offering an explanation for why railway safety trends remain unchanged in South Africa. This may be true for other countries that demonstrate similar safety performance trends. Furthermore, this is despite interventions that are put in place by various levels in the socio-technical system to reduce occurrences, fatalities and injuries.

The objectives of this research are to understand what systemic factors (challenges / pressures / frustrations / obstacles) influence the investigation process of railway occurrences and therefore its effectiveness. Adjustments to Rasmussen's (1997) Risk Management Framework are made to operationalise it to the South African railway system, and the system of accident investigations. Systemic factors for each level of the system impacting on the effectiveness of occurrence investigations are highlighted in this research emphasising the complexity of the accident investigation system.

METHODOLOGY

The levels in Rasmussen's (1997) Risk Management Framework served as sources from which the data was collected for this research. In this research the system of interest is the system of accident investigations and not the accident itself. In order to contextualise Rasmussen's (1997) Risk Management Framework to suit the South African railway context, adjustments to the levels were necessary. Rasmussen (1997) states that the exact number of levels and references of each level can vary depending on the system being studied. There were a few difficulties in doing this, particularly at the Management and Staff levels. The *Staff* level generally refers to operational front line staff, for example a train driver or signaller. In this study looking at the investigation system, the Staff level refers to the individuals who conduct investigations. However, investigators were also *Management*, as was identified in the railway company (operator) who did not have appointed investigators, but by virtue of being a Manager could investigate. This is a finding in itself, given the skills and competencies required to be an investigator and whether the Managers are equipped with such. Operational front line staff are not responsible for the investigation process as their role in occurrence investigations is to act as witnesses. They do not play any role in the administration and organisation of investigations. Operational staff in the investigation system act as informants. Other witnesses observed in the observations also acted as informants in this study and in the review of the accident investigation reports. This is because of their involvement in the incident and the part they played in conveying (or not) information. Informants formed part of the secondary data gathering. In terms of the *Work* level in the system of accident investigations, this refers to the actual work of conducting an investigation or inquiry.

An additional adjustment to Rasmussen's hierarchy in this research was the inclusion of the *Public* as a level in the system of accident investigations. Rasmussen's (1997) Risk Management Framework does not include the public as an actual level but makes reference to public opinions and pressures influencing the system (dynamic force) at a Government level. Public opinion regarding railway safety was deemed an important level to include in this research and is represented by way of the media. The role of society, represented by the public is acknowledged as an external pressure that can force the Government to introduce legislation and control the practices of safety. However, in this research the inclusion of the public as part of the system of accident investigations gives more impetus to the public to increase pressure on the Government. With reference to the system of accident investigations, the demands of the public on the Government are that accident investigations should be thorough, effective and independent. This is important to not only curb the number of accidents, but to ensure that the many citizens relying on rail transport to commute to work, or customers transporting freight, can do so safely. Furthermore, the purpose of including the public as a level rather than an outside pressure is because the author believes that the role of the public is far greater than just an external pressure especially in South Africa. The socio-economic conditions and the historical context have resulted in many people relying on the South African Government to provide safe and reliable transport after years of underinvestment, segregation and the deterioration in rail infrastructure. Furthermore, the increase in urbanisation has resulted in greater demands for rail transport as a mode of travel to get to work (DoT, 2015). The inclusion of society as part of the system of interest can therefore play a more significant role in determining the systems performance. An additional reason for including the public (represented by the media) as a level on its own is because the media influences the severity and level of an occurrence investigation. Governance documents at the Regulator and the railway company selected revealed that if an occurrence receives media attention and public outcry that this increases the level of severity of the investigation. In other words, the occurrence is deemed more serious than may have originally been classified. The public (represented by the media) therefore is an important decision maker in the system of accident investigations.

A qualitative multi-method approach was adopted in this research. Data was collected from each of the levels in Rasmussen's (1997) Risk Management Framework. A print media analysis was conducted on media reports relating to railway accidents for the period of 2008 to 2013. The purpose of this method was to determine if railway occurrences are reported on in the South African media, and if so, what information is reported on to inform the public about railway safety. The data collected from this method represented the public and society. One way that the public can be informed about railway occurrences and railway safety is through the reporting of these in the media. It is proposed that if the public are not adequately informed about railway occurrences and railway safety, then public opinion and pressure will not be strong enough to influence the South African Government to control the practices of safety. Furthermore, if railway accidents and incidents are reported on in the public domain, what information is provided to society? Is society acceptably informed by the media about the state of rail safety as a mode of transport? Moreover, is the media even aware themselves of the state of railway safety in South Africa in order to sufficiently inform the public? In terms of the next levels, data was collected from the South African Government, the Regulator and an operator. Semi-structured interviews were conducted. A Government official at the Department of Transport (DoT) responsible for rail was interviewed in addition to 11 investigators at the RSR and 11 Managers at the railway operator. The duration of the interviews was on average 1 hour and 30 minutes. Investigation files, including accident reports were analysed at the RSR and the operator. Governance documents (legislation, policies, procedures and standards) relating to occurrence management were analysed for all levels of the system to determine if what happens in practice is as per the policy requirements. Lastly observations of actual inquiries conducted by the RSR and the operator were observed. Thematic content analysis on the interview and the media data was conducted to identify the themes emerging from the data. Data from all the methods were compared and verified against each other using triangulation. Triangulation is beneficial as the verification of the data helps to improve the validity of the information, which is particularly important in qualitative research. The advantages of adopting qualitative research using a multi-method design provided the researcher with an in-depth understanding of the railway system and the intricacies within a "system of systems".

RESULTS

Railway occurrences and safety were reported in the media and 133 media articles were identified. Operational occurrences were reported on the most, followed by security incidents and then reports relating to regulation. This was expected as operational occurrences are more newsworthy and would be perceived by the media to hold more risk to the public due to resultant fatalities and injuries. In terms of the number of occurrences reported on in the media compared with the annual statistics reported by the Regulator there was a major discrepancy. The media analysis revealed that the media isn't appropriately informed about railway occurrences. If this was to change, and the media reported more on railway occurrences, then this would be a challenge for the Regulator and the operating company. Both organisations indicated they do not have current capacity to investigate every occurrence. Constraints within each organisation already limit the number of occurrences each organisation is able to investigate, exacerbating the complexity of the accident investigation system. These constraints may also be reasons for why the media (and the public) are not acceptably informed about railway occurrences, as the organisations would not be able to cope with the demands of increased media and public pressure. Thematic content analysis on the media data resulted in 15 main themes, with 14 of the themes containing sub-themes. The theme of *investigations* were the most reported theme as most articles stated that the occurrence would be followed by an investigation or reported that an investigation would be conducted. The *type of occurrence* was the second most reported theme and supports the finding of operational occurrences being reported on the most. Level crossing events and collisions were the most reported occurrences. The third most reported theme was e*conomic* and this related to the reporting of the costs of occurrences both direct and indirect costs.

The results from the governance document analysis, the review of the investigation files, the interviews and the observations illustrated a number of systemic factors that influence the manner in which occurrences are investigated. A number of themes emerged from the data and were verified against the data from the different methods. For example what happened in practice, as observed, and reported in the interviews was not always as per the governance document requirements. The systemic factors highlight how the bigger rail socio-technical system has a number of challenges, constraints and pressures that influence the performance of the accident investigation system and therefore its effectiveness in identifying what happened and what can be done to prevent recurrences. Systemic factors identified in this researched included: no National Rail Policy, limited resources to investigate, shortage of skilled investigators, absence of investigator training, non-compliance to governance documents, an underinvestment in rail, financial constraints, and a blame culture.

Similar findings were identified from the different methods. Systemic factors, challenges and constraints influencing the investigation process were identified for each level of the system. The results from all of the methods were integrated and summarised in an Accimap. The Accimap graphically illustrates the systemic factors impacting on the effectiveness of the accident investigation process, its outcomes (findings and recommendations), and the recurrence of accidents.

DISCUSSION

The media, representing the public, are an important decision maker in the system of accident investigations. The media analysis illustrated that although railway accidents are reported, the number of reports were substantially fewer than the number of occurrences reported annually by the RSR. Therefore the public (and the media) are not acceptably informed about the state of railway safety in order to pressure the South African Government to improve railway safety. The Government (represented by the Rail Branch in the DoT) in the investigation system plays no role in the actual investigation of occurrences, and in general does not actively participate in railway safety. No National Rail Policy in South Africa and generic legislation that is not well understood at the highest levels of the system are examples of systemic factors. Constraints and challenges at this level in the investigation system impacted on the next level of the system, the RSR. The results demonstrated very little vertical integration between the different levels below the Government level, and also up to the Public level. This had an impact of the investigation system's performance in addition to that of the bigger rail socio-technical system. The RSR lacks autonomy and is not an independent investigating body, despite it advocating that it is. The reporting structures in the DoT are a contributing factor to why railway operators do not take the Regulator seriously. For example, a major passenger rail operator and the RSR both report to the Minister of Transport highlighting a conflict of interest. A number of systemic factors were identified that impact on the effectiveness of the investigation process but also the validity, reliability, objectivity and accuracy of the findings and recommendations from the investigation reports. A lack of resources, in terms of staff, investigating equipment, and financial resources impacted on the quality of the investigations; exacerbated by investigators who did not have the necessary competency and experience. Similar findings demonstrated at the Regulatory level were identified for the next level in the system, the Company. Similar systemic factors included no formally appointed investigators, no investigation training, conflicting goals of safety and productivity, time pressures, time delays in commencing with the inquiry and the relationships within and between the different levels of the system. At the both the Regulator and Company level in the investigation system it was evident that a just culture does not exist despite this being a requirement of a national railway standard.

The Accimap highlights that the effectiveness of the occurrence investigation process is influenced by decisions makers and events from all levels of the bigger rail socio-technical system. It can be confirmed that constraints and challenges higher up in the system influence the actual process of conducting investigations with a greater impact on the lower levels of the system where it is mandatory to investigate all railway accidents. The bigger rail socio-technical system influences its nested systems of which one is the system of accident investigations. The system of accident investigations is an example of a complex system in its own right.

CONCLUSIONS

The results indicate that there are a number of systemic factors influencing the effectiveness of the investigation process of railway occurrences in South Africa. The systemic factors, displayed in an Accimap, are inherent within and between the different levels of the investigation system. The accident investigation system is an example of a complex system in its own right with system principles such as integration, feedback, demands, resources, constraints and flow of information all evident from the results in this research. It can be concluded that the investigation system's complexity is influenced by disjointed system of systems where the performance of other systems, the context, conflicting goals and organisations' commitment to safety influences the investigation system from achieving its objectives. That is objective, valid, reliable, accurate and quality investigations. Thorough investigations should lead to the establishment of accurate findings and recommendations that are appropriate and are implemented for change to occur. A learning culture within the South African railway system needs to be encouraged in order to maintain safety and to prevent recurrences. Systemic factors collectively behave to influence the effectiveness of the investigation process, but also on the bigger rail socio-technical system which impacts on the safety, reliability and efficiency of the South African railway system. This research contributes to a deeper understanding of the nature of accident investigations and provides a useful and novel application of Rasmussen's framework. Recommendations for thorough, independent investigations and focussing on a systems approach are essential to reducing the 4500 occurrences that occur annually in South Africa. It is recommended that an independent national transportation body be established in South Africa that is appropriately independent and funded to ensure accidents are investigated and recurrences prevented. Furthermore, a just culture should be adopted by all levels of the system to facilitate a reporting and learning culture.

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THE OBLIQUITY STRATEGY AS A MEANS OF OVERCOMING THE "DRIFT TO UNSAFE STATES" EFFECT

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Summative Statement
Rasmussen suggests that many actors, operating separately to optimise their own portion of the operations system, cause a "drift to unsafe states" (DTUS) effect. Human Factors (HF) in design – because of its proven ability to improve many aspects of sociotechnical systems - can help counter this trend by unifying design objectives like quality, productivity, and employee wellbeing. By connecting their health agenda to other actors' goals (goal hooking) the OHS agenda can be furthered to a greater extent than an exclusive focus on safety – posing an obliquity strategy for achieving safer workplaces.

La stratégie d'obliquité comme moyen de surmonter l'effet de « dérive vers un état dangereux »

Sommaire
Rasmussen révèle que de nombreux intervenants, fonctionnant indépendamment pour optimiser leur propre partie du système opérationnel, provoquent un effet de « dérive vers un état dangereux ». En raison de son efficacité prouvée pour améliorer de nombreux éléments des systèmes sociotechniques, l'intégration de l'ergonomie dans les activités de conception pourrait aider à contrer cette tendance en unifiant les objectifs de conception comme la qualité, la productivité et le bien-être des employés. En reliant les préoccupations de la santé aux objectifs d'autres intervenants (unification des objectifs), il serait possible de développer davantage le programme de SST, au lieu de se concentrer exclusivement sur la sécurité, ce qui entraînerait une stratégie d'obliquité dans le but d'obtenir des lieux de travail plus sécuritaires.

Problem statement
Rasmussen suggests that organisations inevitably drift towards unsafe states (Rasmussen, 1997) – the DTUS effect - as a variety of actors, each trying to optimise performance in their own domain, fail to consider the system level safety impacts of the improvement efforts they propose. Part of this problem is the emergent nature of work systems, which are the product of decisions made by different groups working on different sub-systems. This disaggregation compromises a systems perspective in workplace design. Similarly, typically safety-oriented ergonomics programs, pursuing a single goal, struggle to affect this development process and continue to operate in a retrofitting corrective mode – where changes are most difficult and expensive to implement. This furthers the isolation of the wellbeing agenda as managers question the value of this separate improvement agenda. HF, by its definition, is more systems oriented, but the perception of "ergonomics" as safety oriented (Theberge and Neumann, 2013) has limited its uptake. A broader, more robust approach to ergonomics is needed.

Research Question
How can ergonomists help counter the tendency for organisations to drift to unsafe states?

Methodology
This is a conceptual paper drawing on the theorization of Rasmussen and secondary use of empirical studies published in the literature.

Results

Managing the DTUS effect is difficult as strategic decisions made throughout the product and process design affect ergonomics for operators (Neumann et al., 2002; Neumann et al., 2006). Ergonomics, applied at all stages of design, has been shown to help improve performance including quality, reliability and productivity (Goggins et al., 2008) as it "spans the gap" between operations management and human resource management concerns (Neumann and Dul, 2010). Ergonomics' ability to improve worker health may also be a means to stimulate customer demand (Dixon et al., 2017; Neumann et al., 2014). The perception of HF/Ergonomics as safety focussed has limited its application in OS design (Theberge and Neumann, 2013). Contributing directly to the primary goals of designers, and using tools and approaches familiar to those actors has been shown as a good way to gain support for the application (Village et al., 2014a; Village and Neumann, 2014). We know HF has the ability to contribute beyond just health issues to address other to company strategies (Dul and Neumann, 2009), and once managers understand this contribution (Village et al., 2016) they begin to include HF aspects in their normal design and process improvement work (Village et al., 2014a; Village et al., 2015). Adapting existing familiar engineering tools seems to help engineering teams apply HF knowledge in their system design work (Village et al., 2014b). A variety of simulation technologies are available to support HF in the design of operations systems (Perez, 2011; Perez and Neumann, 2015). Including HF in each development groups' work routines provides a unifying control – a systems view - over design that can help reduce the DTUS that occurs when goals are pursued separately. By helping actors in the organisational network achieve their goals with HF, ergonomists can create a platform for a more coherent, user centred view of the operational development process.

Thus an oblique strategy – focussing on the performance goals of organisational actors rather than just on the safety agenda – can open new opportunities for ergonomics to support safer design. To do this ergonomists need to connect their HF work more closely to company strategies (Dul and Neumann, 2009).

Discussion

The obliquity strategy forms a complement to conventional safety-oriented practices. There is a shortage of tools and methods to support decision makers across the organisation to understand how their choices may affect both employee wellbeing and performance. One challenge remains the emergent nature of the working environment and strategies are needed to identify and handle critical interactions between choices made in different parts of the system while still in the design stage.

A number of social structures inhibit the adoption of the obliquity strategy. The university education system fosters isolated knowledge sets in different disciplines with little training for humans given to engineers (Neumann et al., 2015), and little training in systems design given to health professionals. Once trained, professionals in the workplace are further socialised into their organisational silos which tend to be focussed on singular goals or isolated sub-systems that lead to the DTUS (Kaghan and Bowker, 2001; Neumann and Village, 2012; Neumann and Winkel, 2006; Rasmussen, 1997, 2000). Similarly research-funding structures that emphasise single-goals or single disciplines can suffer from myopia, resisting funding novel projects that span outside their "fence". This makes research on such boundary spanning oblique approaches difficult to pursue. The obliquity strategy, which aims to goal-hook broadly across the organisational system to achieve a safety be design effect, takes time to achieve (Neumann et al., 2009; Village et al., 2014a) and some funding programs lack sufficient length to achieve meaningful organisational change. Understanding how to foster the obliquity strategy requires deep study of ongoing processes using approaches such as action research which are less familiar to experimentally trained researchers who are judging research applications (Neumann et al., 2012), creating a further barrier to studying the obliquity strategy. This paper argues that the oblique approach to the safety agenda, can achieve better safety results than solely direct approach and that, through the unifying impulse of ergonomics, help overcome the DTUS to achieve more human centred operations systems. Applying this in practice requires new collaborations and approaches that draw on HF as well as engineering and industry specific knowledge in more cohesive ways.

Conclusions

An obliquity strategy has the potential to overcome the DTUS effect noted by Rasmussen by contributing to multiple goals simultaneously. This can help overcome the effects of dis-integrated improvement efforts. Ergonomics, with its ability to help further multiple goals can pose a key element of the obliquity strategy and better support safety in design than a direct mono-goal approach to safety.

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Technical Session 14: Design & Macroergonomics

Séance technique 14: Conception et macroergonomie

A CHAIR ASSESSMENT MODEL FOR ORGANIZATIONAL BENEFIT, SAFETY AND ASSET MANAGEMENT

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KEYWORDS
Ergonomic task chair, safety, life cycle, predictive analytics, chair systems

MAIN MESSAGE
The ergonomic office chair is the most important “work tool” determining a worker’s seated productivity in conjunction with the computer (and workstation). It can be said the chair is foundational to good seated workstation ergonomics. Yet, the office task chair is so misunderstood, undervalued and probably the least appreciated asset employers purchase. Until now, there has never been a way to inventory and measure chair quality and competency for ongoing use in the workplace. The goal of the chair assessment system (CAS) model is to help employers manage their chair assets as a system by providing an objective measure to determine whether to keep, repair or replace chairs and then fit employees for ongoing safety, comfort and productivity.

Un modèle d’évaluation de chaises pour assurer les avantages, la sécurité et la gestion des actifs de l’organisation

MOTS-CLÉS
Chaise de bureau ergonomique, sécurité, cycle de vie, analyse prédictive, système de chaises

MESSAGE PRINCIPAL
La chaise de bureau ergonomique est l'outil de travail le plus important qui détermine la productivité du travailleur lorsqu'il est assis devant l'ordinateur (et le poste de travail). On peut dire que la chaise est l'élément de base pour une bonne ergonomie du poste de travail. Pourtant, la chaise de bureau est considérablement incomprise et sous-évaluée et constitue probablement l'acquisition d'actifs la moins appréciée par les employeurs.
Jusqu'à ce jour, il n'y a jamais eu d'outils qui permettaient d'inventorier et de mesurer la qualité et l'efficacité des chaises en vue d'une utilisation continue dans le milieu de travail. L'objectif du modèle d'évaluation de chaises est d'aider les employeurs à gérer leur actif de chaises en tant que système en fournissant une mesure objective pour déterminer s'ils doivent conserver, réparer ou remplacer les chaises puis en adaptant les chaises pour la sécurité, le confort et la productivité des employés.

PROBLEM
Few employers, if any, use an organizational or systems approach to managing chairs as an asset in the workplace. In addition, employers do not recognize or track when employee chairs are at the end of their life cycle (Figure 1) keeping them far too long, exposing themselves and their employees to increased liability, reduced productivity and increased risk for seated musculoskeletal disorders leading to workers’ compensation claims.

The problem is a combination of both employer and employee lack of awareness and understanding of the value and importance of ergonomic chairs in the workplace. Starting with how to select chairs for the workforce and demonstrable willingness to invest in quality chairs as an important asset that contributes to employee health and productivity.

Missing is an objective methodology regarding how to determine whether to keep, repair or replace and fit office task chairs once they are in the workplace. The tests in ANSI/BIFMA X5.1 -2017 Office Chairs standard are intended to assess the performance of new products only. They are not intended to assess a product that has been in use. Essentially, there is no way to objectively assess a chair through its lifecycle to identify proactively when to repair it before the warranty ends or when to remove it from circulation before catastrophic failure.

Figure 36. The Chair Life Cycle model developed by Worksite International, Inc.

CONTEXT

The furniture industry has developed widely accepted ergonomic guidelines for new chairs. Most notable are the BIFMA G1 - 2013 Ergonomics Guideline - Ultimate Test for Fit and the newly released ANSI/BIFMA X5.1 - 2017 Office Chairs. These guidelines are intended to standardize on chair safety and design so they fit most individuals. The standard defines specific tests, the laboratory equipment that may be used, the conditions of tests, and the minimum acceptance levels to be used in evaluating general-purpose office chairs. However, there is no system in place to evaluate chairs once they are brought into and used over time in the workplace.

ACTIONS

Research was conducted over a 6-year period from 2010-2016 to develop a chair assessment system (CAS) model to coincide with the ergonomic chair life cycle (keep, repair, replace and fit). The CAS consists of an Excel data table and an Excel assessment tool along with a chair fitting form to offer predictive analytics for chair decision makers.

After the initial idea was developed and applied in a large organization, additional trials were performed over the last 2 years to test, validate and improve the CAS Excel tool design and functionality.

To utilize the CAS, each appropriate chair in the work area is evaluated (inspected) using 6 primary criteria. A chair ID is established combined with other identification to include name of end user, location of chair, department and date of assessment. The chair manufacturer, name or chair model, date of manufacturing or shipping date and number of shifts the chair is used. The primary criteria assessed include:

1. Age of chair
2. Shifts used
3. Cushion and Fabric Quality
4. Operational Mechanics
5. Chair Comfort (perceived)
6. Overall Quality and Competency

Criteria 3-6 require the evaluator to rate the chair based on a three-point rating scale of good, fair or poor following inspection and observation of each criteria. Whenever possible, the end user participates in selecting the chair perceived comfort rating. Criteria 3-6 offers descriptive terms to select from that best describes the condition of the chair at the time. The information is entered onto the Chair Assessment Tool (CAT), which is then input to the Chair Assessment System Excel sheet for calculation using a proprietary algorithm to determine the score of the chair.

For easy scoring, the algorithm is translated to three responses:

1. Keep the chair
2. Repair the chair
3. Replace the chair (then fit for a new chair)

Each chair score is color coded on the CAS Excel datasheet. A dashboard is created automatically for further sorting of the data to give the employer a better sense of the quality and competency of their chairs by manufacturer and by location/department.

OUTCOMES

As an example, a small company participated in using the CAS. Select chairs were evaluated using the criteria described above to inventory and assess chair quality and competency to provide the employer with the information needed to determine which chairs can remain in operation, which need to be repaired (while under warranty) and which should be removed due to risk of failure or harm to the user.

The CAS Excel spreadsheet (Figure 2) is presented below as an example of an organization (USA Coffee) with 21 employees using a variety of chairs. Data is entered on the Chair Assessment Tool (not shown) and then imported into the CAS Excel database to track chair inventory, quality and competency of each chair assessed. Chairs in poor condition based on the categories described above are shown in red. Chairs in fair condition that would benefit with some degree of repair and are likely still under warranty are shown in yellow. New chairs and chairs continuing to be in good condition overall with little concern are shown in green.

Figure 37. The Chair Assessment System Excel database.

The Worksite International, Inc. Chair Assessment System©

mployer: USA Coffee | Purchasing or Facilities Contact: Allison Heller-Ono | Phone: 831-646-8724 | Email: allisonh@worksiteinternational.com
Address: 1213 Miles Ave | City: Pacific Grove | State: CA | Zip: 93950 | Chair Evaluator: Allison Heller-Ono

ID	Eval Date	Chair Assigned To Last,First Name	Chair ID	Cubicle Number	Department	Location	Chair Manufacturer	Chair Model	Chair Year	Multi-Shift Use	Cushion/ Fabric Quality	Operational Mechanics	Comfort (Perceived)	Overall Quality and Competency	Comments	Image	Age of Chair	Total Score	Keep	Repair	Replace
1	12/7/2015	Unknown	AW1	AW1	Beach	Torrance	Raynor	Conference	Unknown	1 Shift (8 h	Fair	Fair	Fair	Fair	excessively worn seat cushion		Unknown	9		Repair	
2	12/6/2015	Unknown	SS1	SS1	Beach	Torrance	Raynor	Conference	Unknown	1 Shift (8 h	Fair	Fair	Poor	Poor	failing cylinder		Unknown	11		Repair	
3	12/6/2015	Unknown	AS1	AS1	Beach	Torrance	Raynor	Plush	2014	1 Shift (8 h	Good	Good	Good	Fair			New	5	Keep		
4	12/6/2015	Unknown	DN1	DN1	Beach	Torrance	Raynor	Conference	Unknown	1 Shift (8 h	Fair	Poor	Poor	Poor		C:\Use	Unknown	12			Replace
5	12/6/2015	Unknown	JR1	JR1	Beach	Torrance	Raynor	Conference	Unknown	1 Shift (8 h	Fair	Poor	Poor	Poor			Unknown	12			Replace
6	12/6/2015	Unknown	AM1	JR1	Beach	Torrance	Raynor	Conference	Unknown	1 Shift (8 h	Fair	Poor	Poor	Poor			Unknown	12			Replace
7	12/6/2015	Unknown	SD1	SD1	Beach	Torrance	Raynor	Conference	Unknown	1 Shift (8 h	Good	Good	Good	Good			Unknown	5	Keep		
8	12/6/2015	Unknown	VS1	VS1	Beach	Torrance	Herman Miller	Aeron	Unknown	1 Shift (8 h	Good	Good	Good	Good			Unknown	5	Keep		
9	12/6/2015	Unknown	MB1	MB1	Beach	Torrance	Raynor	Plush	Unknown	1 Shift (8 h	Good	Fair	Poor	Fair			Unknown	9		Repair	
10	12/16/2015	Unknown	JM1	JM1	Indoor	Anaheim	Chinese Import	Large Execu	Unknown	1 Shift (8 h	Fair	Fair	Fair	Fair			Unknown	9		Repair	
11	12/6/2015	Unknown	JS1	JS1	Indoor	Anaheim	Chinese Import	Large Execu	Unknown	1 Shift (8 h	Poor	Poor	Poor	Poor			Unknown	13			Replace
12	12/6/2015	Unknown	GM1	GM1	Indoor	Anaheim	Chinese Import	Mesh Back	2015	1 Shift (8 h	Good	Good	Fair	Fair	Good support		New	6	Keep		
13	12/6/2015	Unknown	MW1	MW1	Indoor	Anaheim	Chinese Import	Large Execu	Unknown	1 Shift (8 h	Poor	Good	Fair	Fair			Unknown	9		Repair	
14	12/6/2015	Unknown	KK1	KK1	Indoor	Anaheim	Chinese Import	Large Execu	Unknown	1 Shift (8 h	Fair	Good	Good	Fair		C:\Use	Unknown	7	Keep		
15	12/6/2015	Unknown	NN1	NN1	Indoor	Anaheim	Chinese Import	Large Execu	Unknown	1 Shift (8 h	Poor	Poor	Poor	Fair			Unknown	12			Replace
16	12/6/2015	Unknown	GM2	GM2	Indoor	Anaheim	Chinese Import	Large Execu	Unknown	1 Shift (8 h	Poor	Poor	Poor	Poor			Unknown	13			Replace
17	12/6/2015	Unknown	MF1☐	MF1	Indoor	Anaheim	Chinese Import	Large Execu	Unknown	1 Shift (8 h	Poor	Poor	Poor	Poor			Unknown	13			Replace
18	12/6/2015	Unknown	AB1	AB1	Indoor	Anaheim	Chinese Import	Large Execu	2004	1 Shift (8 h	Poor	Poor	Poor	Poor			Old	14			Replace
19	12/6/2015	Unknown	VL1	VL1	Indoor	Anaheim	Chinese Import	Large Execu	Unknown	1 Shift (8 h	Poor	Poor	Poor	Poor			Unknown	13			Replace
20	12/6/2015	Unknown	JW1☐	JW1	Indoor	Anaheim	Chinese Import	Large Execu	Unknown	1 Shift (8 h	Poor	Poor	Poor	Poor			Unknown	13			Replace
21	5/8/2017	Unknown	AH1	AH1	Indoor	Anaheim	Raynor	Plush	2012	2 Shift (8 h	Poor	Fair	Poor	Poor	excessively worn seat cu	C:\Use	Mid	12			Replace
22	5/21/2017																Old				
[illegible]		Total																[illegible]	5	5	11

The CAS database is also translated into a color-coded dashboard (Figure 3) to act as a visual interface that provides at-a-glance views into key measures relevant to the type of chairs the employer has, the location of the chairs and the quality and sustainability of the chairs. The CAS dashboard provides visualization to help focus attention on key trends, comparisons, and exceptions regarding the chair asset management program.

The CAS dashboard identifies at least twelve chair trends for anyone in the organization who needs to be aware of and manage the chair fleet program. This might include safety and risk managers, EH&S, facility managers, purchasing managers, budget managers, ergonomics teams and others in the organization with an interest in understanding the state of chair asset management relative to employee health, safety and productivity.

The CAS dashboard identifies trends in:

- The number of chairs by manufacturer/model type
- Assessment totals and the number to keep, repair and replace
- Assessment totals by department/location
- Age of chair by manufacturer/model
- Cushion/Fabric quality by manufacture/model and by department/location
- Operational mechanics quality by manufacture/model and by department/location
- Comfort (perceived) by manufacture/model and by department/location
- Overall quality by manufacture/model and by department/location

DISCUSSION

Using the example company (USA Coffee), the employer can specifically identify chair concerns by person, by department and by location which chairs are holding up the best, which are perceived as most comfortable, which require repair and or replacement and many other trends, comparisons and exceptions in their chair program. Chairs scored in the green were acceptable for ongoing use. Chairs scored in yellow indicate they needed some degree of repair under warranty (as applicable). Chairs scored in the red, allowed the

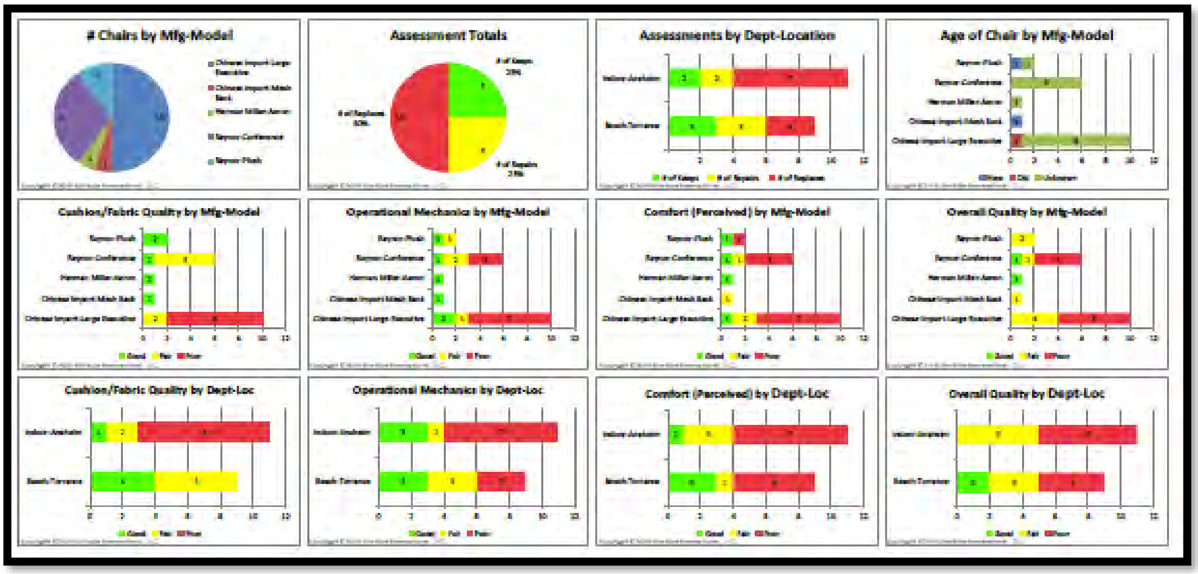

Figure 3. The Chair Assessment System dashboard helps to focus attention on key trends, comparisons and exceptions in the chair fleet.

employer to identify the chair for removal, to effectively budget for replacement and perform a chair fitting with the employee.

The Chair Assessment System easily removes bias from a process often riddled with favoritism or some degree of workplace social hierarchy where certain employees receive new chairs because of status in the organization, a work injury or because their neighbor received a chair. While it may be appropriate to provide new chairs in some circumstances, many times, the current chair simply is not adjusted correctly or set for best fit. Inventorying and assessing the chair for comfort and fit is part of the chair asset management process.

The CAS helps to identify based on objective, measurable evidence whether to keep, repair or replace a chair and then fit for a new one because it has reached the end of its lifecycle or offers an inadequate fit. Through the inventory process, employees learn about the features and functions of their chairs, how to adjust for fit and comfort as well as determine if the chair is a poor fit for them.

Furthermore, this system helps employers to see what chairs are working well for the organization by looking at the perceived comfort of the ratings; further helping to assign chairs more effectively, rather than the “willy-nilly” approach employers typically apply. For example, the petite female in the large, oversized chair and the large male or obese employee in a significantly undersized chair. Typically, there is no rhyme or reason behind the mismatch of chairs in an organization, especially those with multiple types and sizes of chairs accumulated over time.

Most importantly, the CAS identifies when a chair needs repair or is at the end of its lifecycle and should be removed from operation. This is a critical issue as chair cylinders are likely to fail (begins to sink or rise and fall on its own) over time when not properly maintained or the chair exceeds its use time (beyond warranty), adversely affecting employee ergonomics, posture and comfort at the workstation. Employers routinely leave “money on the table” because they rarely effectively use the chair warranty as it is described and intended to repair or replace parts.

Cost Benefit

A good ergonomic chair is an investment costing on average between $350.00 and $850.00 and expected to last approximately 10 years or more. Investment in the chair assessment system costs literally pennies per chair compared to investing in a new chair, especially when it is not necessary. Employers routinely discard chairs perceived as broken or a poor fit simply because they don’t understand how to adjust or use the chair properly; fail to use the warranty or select incorrect chairs for employees.

It is estimated utilizing the chair warranty has an expected cost saving of at least 50% over buying a new chair. By repairing an existing chair as part of a preventive maintenance program, it extends the life of a good quality chair another 3-5 years that would have otherwise been determined to be replaced without the CAS data.

It does take time to evaluate and document the status of each chair. A chair assessment takes approximately 6 minutes using the CAT followed by brief data entry into the CAS Excel sheet. This time is well spent given the outcome.

In regard to the cost-benefit, the chair assessment system is an affordable, asset management strategy designed to optimize operational chair performance, minimize whole life costs and support an organization’s corporate health and safety goals.

CONCLUSION

Based on numerous trials in the workplace, feedback from industry leaders and practitioners, the chair assessment system provides practical and informative,predictive analytical data in a simple and easy to use format allowing employers to better understand chairs as a system. The CAS shows how employers must take the time to inventory and assess task chairs for safety, health and productivity impact.

"The chair assessment system is a great tool for front line supervisors, managers, etc. to use to get a handle on chairs. It is clear and easy to use.".

Cindy Burt, MS, OTR/L, CPE

The chair assessment system is an effective way to assure employee seated work health and chair satisfaction through the life cycle of chair use. Using an inventory and asset management system to measure task chair quality and competency helps employers and practitioners determine the most effective chairs in the workplace, which need to be repaired and which should be replaced to minimize risk, liability and exposure to seated work discomfort. By doing so, thousands of dollars can be saved by reducing work injuries and improving employee health and productivity.

For more information about the Chair Assessment System described in this paper, please contact http://www.worksiteinternational.com/Chair-Assessment-System.html

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ERGONOMICS AND DESIGN EDUCATION: EXPERIENCES FROM THE DEVELOPMENT AND APPLICATION OF A WORKSPACE DESIGN WORKSHOP

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KEYWORDS
Ergonomics education, Engineering Design, Game-based learning

SUMMATIVE STATEMENT
Ergonomics and design education poses a series of challenges to educators and students. A workspace design workshop was developed and held in several contexts. This experience highlights benefits of a practical approach to ergonomics and design education.

Formation en ergonomie et conception : une expérience axée sur l'élaboration et l'application d'un atelier portant sur la conception d'un espace de travail

MOTS-CLÉS
Formation en ergonomie, conception technique, apprentissage par le jeu

SOMMAIRE
La formation en ergonomie et en conception présente divers défis pour les éducateurs et les étudiants. Un atelier de conception de l'espace de travail a été élaboré et organisé dans plusieurs contextes. Cette expérience souligne les avantages d'une approche pratique à l'égard de la formation en ergonomie et en conception.

INTRODUCTION

Ergonomics is an essential element to the formation of production engineers. Production Engineering in Brazil is a very popular career due to its broad field of activities, ranging from finance and economics, to production planning and control. Among the various subject areas regarded in the production engineering education, the area of Design and Technology congregates disciplines as product design, factories planning and design, work design and, of course, ergonomics.

Historically, the human factors and ergonomics field in Brazil has been strongly influenced by the Francophone ergonomics research, centered on the concept on activity (Daniellou & Rabardel, 2005). Topics covered on an ergonomics course in higher education usually follow the ergonomic work analysis methodology (EWA) (Wisner, 1995), which culminates in the ergonomic action.

In this context, ergonomics is regarded as a design discipline, which must be accounted for in the design processes of products, workspaces and facilities, focusing in two closely related outcomes: health, safety and well-being of workers and users and systems' operational performance (Dul et al., 2012).

However, challenges arise in the ergonomics teaching and learning processes in higher education. In a survey performed by (Eroglu, Cifter, & Ozcan, 2013) with 79 students of industrial design related higher education courses, students' dissatisfaction with their ergonomics education mainly related to the insufficiency of applied studies during the course. As noted by (Tempelman & Pilot, 2011) students in design courses struggle to bridge the gap between theory and practice, which can also be seen in ergonomics courses. Nonetheless, the theoretical concepts are paramount for a solid understanding of ergonomics and its development but they may seem elusive for students when they are asked to put them into practice. Furthermore, differences among students' interests, motivation and maturity levels must also be overcome as pointed by (Jones, 1999).

The closer interweaving of theory and practice suggested by (Tempelman & Pilot, 2011) is one of the possible strategies deployed to make the learning process more effective and engaging. The experience described by (MacKie, 2011) shows how a practical assignment (designing a personal vehicle) could help students assimilate concepts of anthropometry and at the same time apply them to a concrete challenge. The hands-on approach reported by (Jones, 1999) allowed students enrolled in an introductory course in human factors and ergonomics to experience the concepts presented in the lectures in a fun and engaging environment.

Recent developments in education research and practice specially those related to the use of games and game-like applications and activities present yet another alternative to bring meaningful experiences, linking concepts and practice, to the classroom. The game-based learning (Kirriemuir & McFarlane, 2004) initiative aims to create environments where games and game-like content can be used by educators to enhance knowledge acquisition and skills' practice, involving students in problem-solving activities while making the learning process fun and engaging. Considering the ubiquity of technology and the ever-growing exposure of students to it, since their young years, and the substantial differences in thinking and information processing of this "digital natives" generation (Prensky, 2001), this idea becomes even more relevant and worth further investigation.

RESEARCH OBJECTIVE

In this paper, we present and discuss the experience of developing and employing a workspace design workshop to support ergonomics and design learning in higher education and specialization courses. Bridging the apparent distance between the abstract and conceptual underlying issues discussed in ergonomics theory and the pragmatic, empiric and objective nature of design practice, is one of the most salient challenges faced in ergonomics education. In this context, we explore the benefits and shortcomings of employing the workspace design workshop pointing to potential future development paths to improve ergonomics education.

METHODOLOGY

The creation of the workshop was guided through the game-based-learning (GBL) theory, incorporating mechanics such as competition, rounds, feedback, cooperation and points. The activity aims to consolidate concepts related to ergonomic work analysis and workspace design.

The development process of the workspace design workshop (WDW) initiated with the adaption of a real-life ergonomics intervention experienced by one of the authors during his work at an oil refinery in Brazil as an ergonomics consultant. The creation process of the activity span for more than three-years in an iterative and interactive process, with several intermediary versions and pilot tests that culminated in the consolidated version of the WDW that is reported here.

The main goal of the activity is to simulate the role of an engineer in the process of analysis and conception of a local control room (LCR) in a large scale continuous process industry. Based on the information available the participants must propose a redesign of the LCR to contemplate operators needs in terms of health, safety and well-being as well as their operational performance. The participants are divided in groups (up to 5 people) which compete to achieve better solutions while attaining to the stipulated budget goal.

Participants receive a “design kit” composed by a game board (where they will sketch their new layout proposals), a budget spreadsheet (listing all available furniture and equipment they may buy to incorporate in their proposals) and additional textual information (in the form of a synthesis of the ergonomic work analysis performed by an ergonomist in the area).

In total, three sessions of the consolidated version of the WDW were held, with a total of 82 participants. Workshop session 1 was held in the context of the ergonomics course in a professional master program on Production Management, with 39 participants. Sessions 2 and 3, were held with undergrad students in the Production Engineering education, with respectively 20 and 23 participants each. All sessions were essentially identical and were held in the first semester of 2016.

The WDW session takes 4 hours, requiring two facilitators. The workshop is divided in three main phases, namely “Levelling”, “Designing” and “Reflecting”. In the first stage, the facilitators briefly present the context and current situation of the area, and explain to the groups the workshop dynamics. After this initial step, the teams receive their “design kits” and then discuss among the team members the issues and improvements that can be proposed. This stage has 3 rounds, at each round the teams consolidate a layout proposal and the correspondent budget spreadsheet and submit them to the facilitators’ evaluation. The facilitators evaluate the layout proposals quantitatively and qualitatively in terms of their resolution of the issues highlighted in the presentation of the case and support materials, following a systematic evaluation guideline, assigning points to the teams’ proposals. After this evaluation and the feedback to the groups regarding their score and position compared to the other groups, another round starts and the groups have a chance to improve their proposals and reflect about what aspects of workers’ activity must be considered when redesigning their workplace. After the last round, the facilitators guide a discussion about the design process experienced by the participants, the concepts involved and how they related to the actual design proposals.

After the workshop, participants were asked to answer a feedback questionnaire comprised of seven closed questions and one open question to assess how they perceived the experience in terms of learning and applying the ergonomics concepts. Data was collected from the workshops (scores achieved by each group in each rounds).

RESULTS

The scores achieved by each group during the rounds of the workshop were plotted in a box-plot diagram an are shown in Figure 1. The three main vertical sections of the diagram correspond to the workshop session analyzed. In each workshop section, there are three subdivisions: the 3 rounds. Each point corresponds to a group in its respective workshop.

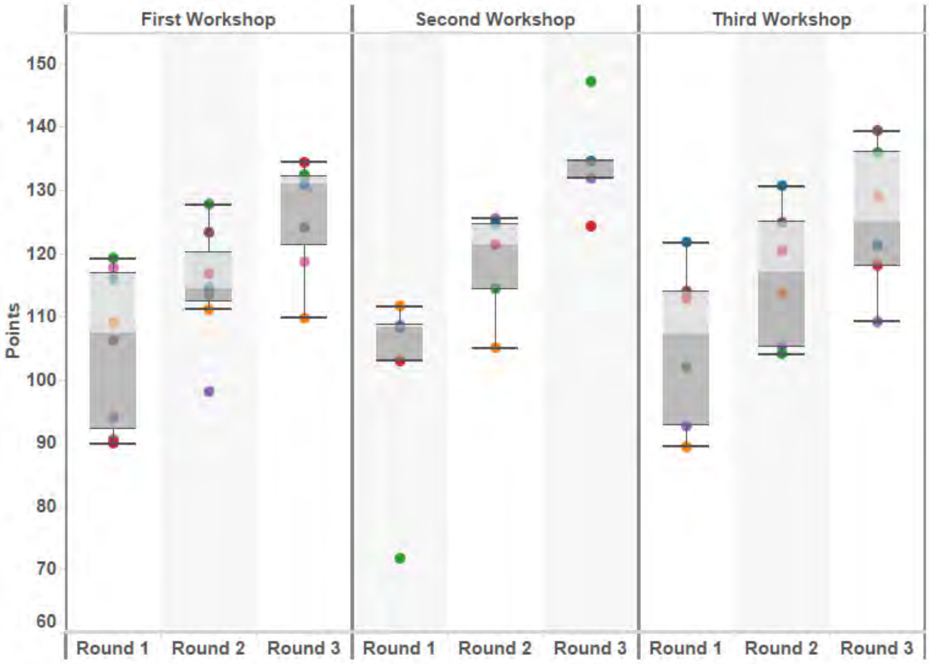

Figure 1. Box-plot diagram of the performance of each group at each round of their respective workshop sessions

It is possible to verify a consistent increase of groups points during the rounds of the workshop. The iterative and interactive nature of design itself is incorporated in the WDW through the rounds system allowing for the groups to progress over time, forcing them to try to better understand the situation presented and to construct links from theory to practice that allowed them to propose new layouts of the area.

The feedback questionnaire was composed of two main parts: the first one focusing on the participant profile and previous knowledge on the topics and the second one regarding their perception on the effectiveness of the activity as a learning instrument in the ergonomics education. The total number of responses of the questionnaire was n=82.

The participants average age was 25.6 ± 4.9 years. Regarding their level of instruction, the majority of the participants 50.0% (n=41) were undergrad students, 48.8% (n=40) were enrolled in a professional masters program and 1 person had already completed graduate school. The participants' background education was mainly related to engineering (production engineering had 62%, n=51 and other engineering another 14%, n=11). Completing the first part of the questionnaire, three questions aimed to the determine the previous knowledge and involvement of the participants with the EWA methodology, engineering design projects and gamified learning activities. The questions and their answers' analysis are shown in figure 2.

Question #	Question	Possible Answers			
1	What is your previous degree of comprehension about the EWA method?	None	Low	Intermediary	High
2	What is your previous degree of comprehension/involvemnt with Engineering Design projects?				
3	What is your previous degree of experience with gamified teaching activities?				

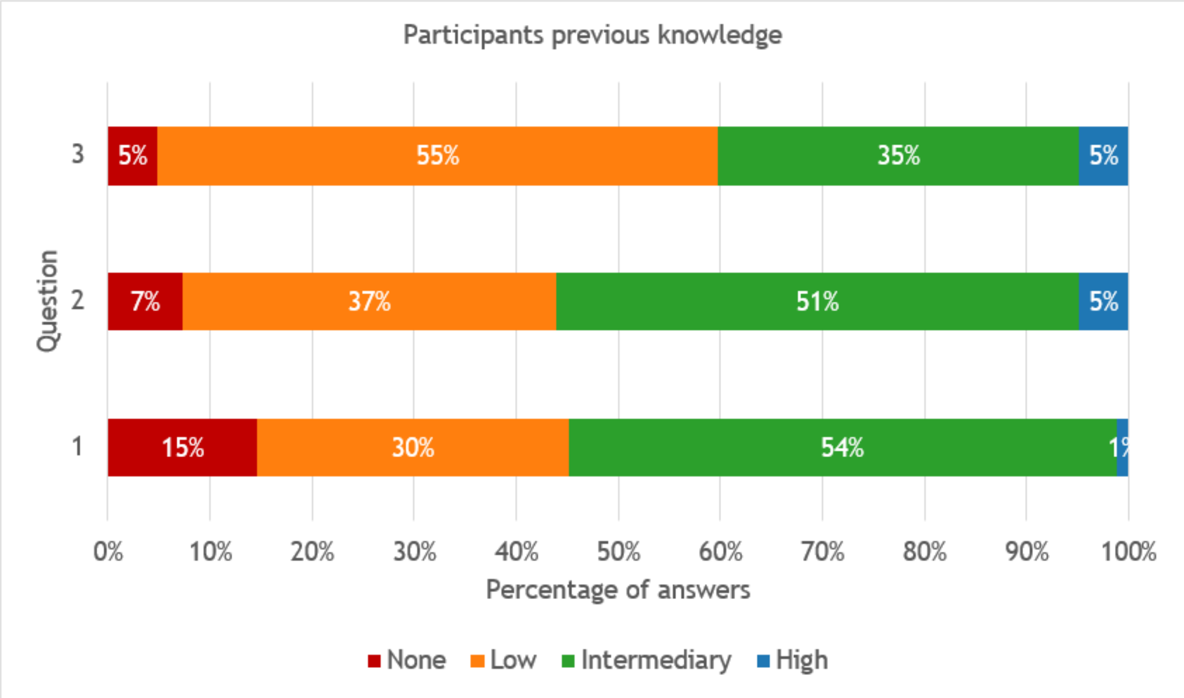

Figure 2. Questions on participants' previous knowledge of the themes

As expected, considering the activity was embedded in the ergonomics course which contemplated the theory of the EWA methodology and topics on engineering design, a substantial proportion of the participants answered they had some knowledge on the topics. However, the format of a game-like workshop was relatively new to most participants (55% had only a low degree of experience with such activities and 5% had never experienced one).

The second part of the feedback questionnaire inquired participants of their perception on the contribution of the activity to their understanding of the ergonomics concepts and how to apply them to a practical situation. Two questions specifically asked about the workshop structure and its competitive nature, to see if participants felt more motivated by it. The questions and the answers can be seen in Figure 3.

Question #	Question	Possible Answers				
4	The activity contributed to improve my understanding of concepts related to the EWA method.					
5	The activity contributed to improve my understanding of concepts related to workspace design.					
6	The activity helped me to understand how to apply the EWA method concepts to a conception project.					
7	The activity helped me to comprehend the difference between the concepts of prescribed work (task) and actual work (activity)	Strongly disagree	Disagree	Neither	Agree	Strongly Agree
8	The activity helped me to understand how to incorporate workers' activity in the design process.					
9	The competitive nature of the activity increased my involvment with the topics making me want to propose a better design.					
10	The practical nature of the activity made the theoretical concepts more interesting to learn.					

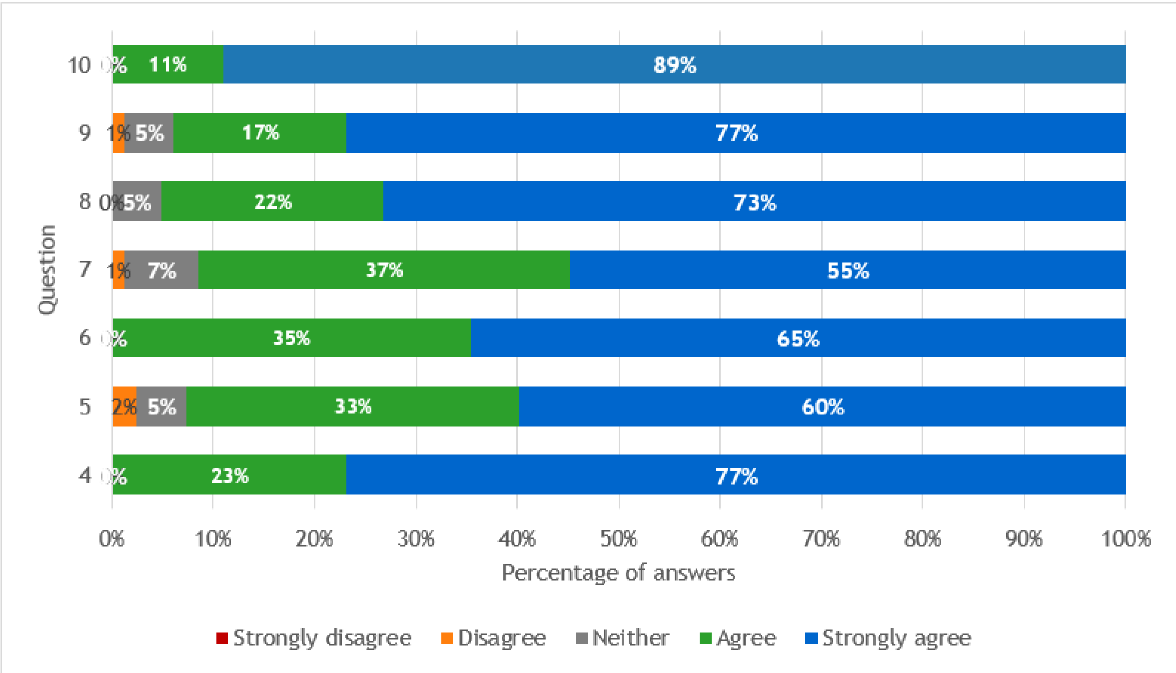

Figure 3. Feedback questions on concepts understanding and application

Participants' answers to these questions were mainly positive, especially questions 4, 6 and 10 which only received concordance answers. It's interesting to note that question 7 was the one with the lowest proportion of "strongly agree" answers. This question asked if participants understood the key concepts of task and activity better after the workshop. Overall, the feedback analysis highlights participants' perception that the workshop helped with the understanding of the main concepts approached and that the dynamic and practical nature of the activity was more engaging to learn.

Finally, the comment section of the questionnaire was open for the participants to share what they most liked or disliked about the activity. A total of 66% of the participants (n=54) commented. The comments were read and 74 relevant segments were identified and coded to three categories: "positive comment", "negative comment" and "suggestion". Most comments were positive 66% (n=49), 24% (n=18) were negative and the other 10% (n=7) suggestions. Figure 4 shows a subset of the comments and their categorization and Figure 5 synthesizes the overall distribution of comment types in a pie chart.

Participants' comment	Positive comment	Negative comment	Suggestion
The practical nature of the activity was interesting to me and I liked to participate in it. The competitive aspect of the activity was important because it made my group to be more committed to it.	▪		
I liked a lot the activity. I suggest adding some variation from one round to another, so the groups have to adjust to it.	▪		▪
The activity was very interesting, it made us think about the concepts, the design process and the role of ergonomics, and the competitive factor was a nice touch to the activity. Maybe we could have more time in the first round, once we have drafts to star from in the following rounds, but not in the first.	▪	▪	

Figure 4. Example of participants' comments and classification

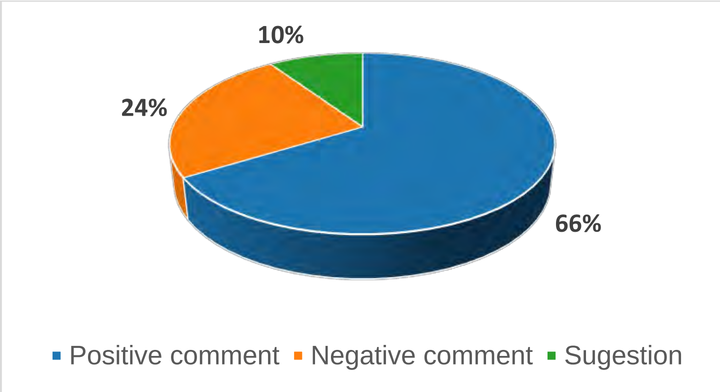

Figure 5. Comment types distribution

DISCUSSION

The workshop divided participants in groups that competed against each other to propose a "better" solution for the case presented. Competition in this sense, may be an engagement factor that motivates participants to better understand the concepts and case and thus propose better designs. Additionally, interaction within the "design groups" revealed many familiar aspects of ergonomics and design practice such as difficulties for communication, usage of intermediary objects, cooperation and so forth, giving participants a sense of how an ergonomic-guided design process may unfold.

The role of the facilitators varies during the workshop. At times, they must play the operators, giving participants details and insights about the analyzed situation. It's also up to the facilitators to keep track of time and to manage conflicts; depending on the degree of engagement of the participants, they may get too excited or lose track of time, which could lead to delays on the workshop schedule. However, as the workshop has the premise of simulating a real-world scenario, time is a constraint and participants must learn to manage it efficiently. The "design kit" helped the participants in simulating scenarios and estimating their budget expenditures. The gameboard was a physical artefact that congregated efforts and facilitated the discussion on current and future activities and implications derived from the proposed changes in the layout.

The evolution of the groups in the workshops' rounds point toward a better understanding of the issues present in the current situation presented and how they could solve them to better accommodate operators' needs and assure the reliable performance of the activities that take place in the LCR. The rounds configuration is essential to give participants' room for experimentation, trying different configuration and seeing the scores achieved. Once again, the facilitators can assist groups, pointing them towards the need to understand the problems and trying to solve them through the new proposal.

Participants' feedback was mostly positive. The practical nature of the task at hand gave participants a taste of what a real-life design project can feel like. The key concepts of the activity appeared to be passed on to participants with success. An instrument to evaluate participants' actual comprehension of the concepts could be developed and applied before and after the workshop to directly measure to which extent it helps participants on understanding and linking theory and practice.

Conflicts regarding the interpretation of scoring that each group constructed are significant in the sense that they tend to question what is the logic behind the scoring. However, the rounds system also helped with this when they see that proposing changes that positively impact operators' work has greater value, leading back to the understanding of the situation to transform it.

Challenges remain to incorporate other concepts and mechanics into the workshop to continuously improve its potential. The incorporation of virtual environments developed using game engines is a feasible path we are already pursuing, aiming to enable participants to explore the situation virtually, interacting with the workers and the environment itself. The use of 3D printed models of the furniture and equipment also helps participants to visualize their design proposals and could be employed in future applications. Replacing the budget spreadsheet for a web-based application that could run on smartphones as well as computers makes it easier and more flexible to have workshop sessions in different locations.

CONCLUSIONS

The current evolution in learning styles and attitudes of contemporary students and their close relationship with technology and digital tools are crucial drivers for searching for new tools and methods for teaching and learning practice across all knowledge domains. The ergonomics and human factors education can also benefit from such initiatives, especially considering the inherent design-driven characteristic of the field, which requires a practical focus without neglecting the underlying theoretical concepts.

The workshop presented had a beneficial impact on participants understanding of some core concepts of francophone ergonomics and in how to apply those concepts in a workspace design simulation setting. Further developments are needed however to continuously improve the efficacy of the workshop as a teaching tool and to make its experience meaningful to participants. The incorporation of 3D virtual environments, virtual reality applications, 3D printed models of the furniture and equipment are some of the developments that could help achieving improvements in participants' engagement and understanding in the workshop.

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ANALYSIS, VALIDATION AND DESIGN: USING GAME ENGINES TO SUPPORT ERGONOMICS INTERVENTION AND DESIGN PROCESS

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KEYWORDS
Game engines, design, simulation, intermediary objects

SUMMATIVE STATEMENT
Ergonomists currently use several tools and intermediary objects during the analysis, validation and design of work systems. The use of game engines (computer software commonly employed to design 3D games) can be a valuable tool to enhance the efficacy of ergonomics intervention.

Analyse, validation et conception : utilisation de moteurs de jeu afin d'appuyer les interventions ergonomiques et le processus de conception

MOTS-CLÉS
Moteurs de jeu, conception, simulation, objets intermédiaires

SOMMAIRE
Les ergonomes utilisent actuellement plusieurs outils et objets intermédiaires lors de l'analyse, de la validation et de la conception des systèmes de travail. L'utilisation de moteurs de jeux (des logiciels couramment utilisés pour concevoir des jeux 3D) peut s'avérer un outil précieux pour améliorer l'efficacité de l'intervention ergonomique.

PROBLEM STATEMENT

The engineering design process is regarded as a social process (Bucciarelli, 1988) in which participants from different areas of expertise, inhabiting their own “object-worlds” characterized by particular systems of symbols, constraints and instruments. It becomes fundamental for the success of the design process to effectively communicate across this boundaries as they are an ever-present obstacle due to organizations’ characteristics of knowledge specialization (Carlile, 2002). In this context, challenges arise in the ergonomics integration into engineering design (Hall-Andersen & Broberg, 2014).

The ergonomic work analysis methodology proposed by (Wisner, 1995) and expanded by (Güérin, Laville, Daniellou, Duraffourg, & Kerguelen, 2001) has a clear design-driven final outcome: the improvement and transformation of work analyzed. The concept of validation during the ergonomics intervention is crucial to restituting information back to those who gave it and also allowing for corrections and complementation of the ergonomists’ work (Güérin et al., 2001; Wisner, 2004). According to (Güérin et al., 2001), three moments are necessary for validation, the first when giving a feedback to workers the analysis performed, the second during the evaluation of the current situation diagnosis and solutions propositions and thirdly, in the evaluation of the ergonomics intervention as a whole, after the implementation of the proposed improvements. e to achieve it effectively, the engineering design process associated must integrate the ergonomics knowledge generated on the situation.

The role of knowledge objects, artefacts produced and circulated by team members, is crucial to the development of the design process itself. According to (Vinck, Jeantet, & Laureillard, 1996) intermediary objects can be considered “closed” (when the user is bound to a specific use or interpretation of the object, designed by the person who produced it) or “open” (when the object allows room for interpretation and maneuverability). When utilizing an artefact as means to represent, learn about, transform knowledge and resolving conflicts across functions, the artefact takes on the form of a boundary object (Carlile, 2002).

Knowledge objects shape relations behaviors and attitudes as well as fostering coordination, cooperation and understanding among team members (Carlile, 2002; Vinck et al., 1996). These objects can take several forms, from physical scale models, full scale mock-ups, prototypes, sketches and blueprints to computer simulations, 3D renderings and so on (Braatz, Lopes, Camarotto, & Menegon, 2011; Broberg, Andersen, & Seim, 2011; Conceição, Silva, Broberg, & Duarte, 2012; Hall-Andersen & Broberg, 2014).

The advances in hardware and software development of the last decades render computational technologies more accessible to ergonomics practitioners and researchers alike. It’s not a surprise that current Ergonomics and Human Factors (E/HF) research and practice increasingly relies in computational supports for modelling, analysis, visualization and simulation of the various aspects of work systems, with special focus on physical analysis using Digital Human Modelling (DHM) and postures, movements and biomechanical analysis (Chaffin, 1997; Feyen, Liu, Chaffin, Jimmerson, & Joseph, 2000; Santos et al., 2013; Wilson, 1999).

These digital resources when appropriated by ergonomists and integrated into the design process may act as knowledge objects. Researchers have long used DHM software as a tool in workplace design activities (Feyen et al., 2000; Paul & Wischniewski, 2012; Santos et al., 2013). Recent researches however, point to novel technologies such as virtual environments and virtual reality as possible tools for E/HF incorporation into design (Aromaa & Väänänen, 2016; Braatz, Toledo, Tonin, Costa, & Menegon, 2011; Gatto, Mól, Luquetti Dos Santos, Jorge, & Legey, 2013; Lawson, Herriotts, Malcolm, Gabrecht, & Hermawati, 2015; Lawson, Salanitri, & Waterfield, 2016).

Virtual reality and augmented reality environments can be created and deployed using commercially available software designed primarily with the intent to develop game applications. These software packages known as Game Engines (GE) provide a set of preprogrammed tools (e.g. complex interactions programming, advanced AI physics and rendering capabilities, high quality graphics and virtual reality environments development, etc.) for designers to build their own applications more easily. GEs have been used in several areas such as education (Hamari et al., 2016; Koops, Verheul, Tiesma, de Boer, & Koeweiden, 2016), personnel training and knowledge management (Allal-Chérif & Makhlouf, 2016; Aziz, Chang, Esche, & Chassapis, 2015; Kwon & Lee, 2016) and facilities simulation and design (Braatz, Toledo, et al., 2011; Gatto et al., 2013; Koutsabasis, Vosinakis, Malisova, & Paparounas, 2012).

Game engine-powered virtual environments (VE) have intrinsic affordances that can be appropriated and applied to the field of E/HF such as their integrated support for 3D visualization, simulation environments, real-time navigation and manipulation of objects and environments, user embodiment and feeling of presence (Koutsabasis et al., 2012).

RESEARCH OBJECTIVE

In this context, this paper aims to explore how game engines can be appropriated by ergonomists as a tool to support the analysis, validation and design stages of work systems' design process and ergonomics interventions.

METHODOLOGY

Two virtual environments were developed using game engine technology: one representing a real situation in a local control room in an oil refinery industry and the other a fictional industrial scenario. The development of the scenarios was guided through four major axes: "virtual environment", "digital human", "interaction" and "analysis" as shown in Figure 1.

The **virtual environment** dimension presents the most usual possibilities for creating a scenario in a GE. Designers may use existing 3D CAD (computer aided design) models they develop themselves or look for suitable models in comprehensive online libraries such as Sketchup's 3D Warehouse. The information intended to be communicated through the virtual environment must also be considered when selecting the 3D models and spatial distributions in the scenario. The **digital human** dimension highlights the needed considerations when creating and deploying the characters that will populate the virtual environment. Anthropometry and biomechanical aspects must be considered when modelling and animating the characters, which can be achieved through movement capture (MoCap) technologies, or other similar tools. The **interaction** dimension relates what are the possible actions the user can perform in the VE and their immediate results to the environment and other characters and components of the system. **Analysis** are enabled by previous three dimensions presented, being qualitative or quantitative in its nature, according to the specific objectives aimed at the VE design.

These dimensions are interdependent, and the relevant aspects of its relationships are presented in Figure 1 along the edges of the main diamond shape. Analysis focusing on the digital humans represented in the VE will pass through reach and access analysis, field of view and mannequins postures' and actions. On the other hand, analysis on the spatial environment built in the GE will focus on its physical layout, environmental conditions (lighting, noise, etc.) and relevant design variables. Similarly, interactions on the VE may focus on scenarios changes, objects, equipment movements and layout modification, as well as information gathering about the overall system depicted in the GE. Defining how users will navigate and experience the VE and the possible interactions with other players (multiplayer support), with non-player characters (NPCs) programmed to perform certain actions or even powered by sophisticated AI are also necessary steps for VE development.

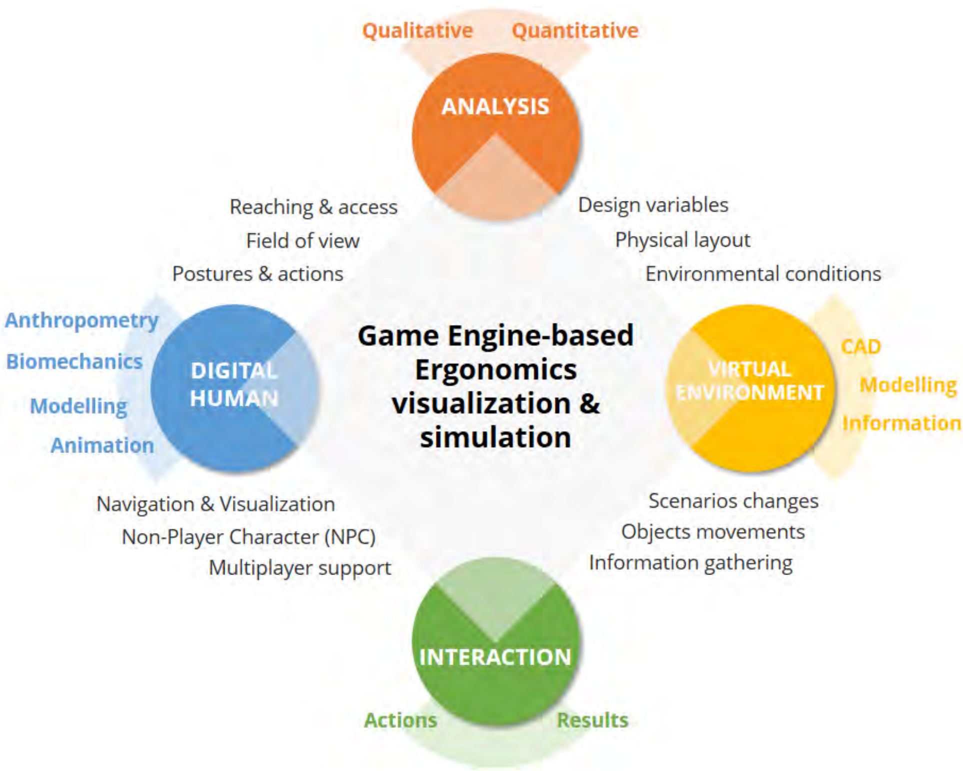

Figure 1. Conceptual framework for GE-based ergonomics visualization and simulation

The first step of the development of the scenarios was the selection of the GE. There are several commercially available GEs, the most well-known ones being Unity 3D and Unreal Engine, both being free to use for personal projects. In our case, we chose the latter due to the authors' familiarity with Unreal Engine and its better off-the-shelf graphics settings and visual programming solutions. The development of the 3D characters used Adobe's Fuse CC software, which allows for great customization of the characters and integration with animation databases (such as the Mixamo library also used for the animations) and GEs in general.

The authors designed the 3D models of the first scenario on traditional CAD software (Autodesk's AutoCAD), retrieving some specific pieces of furniture and equipment from the 3D Warehouse models' library and other free assets libraries. Assets downloaded from the 3D models' libraries mostly composed the second scenario.

Hardware requirements for GE utilization are robust. The computer used in the development of the scenarios had an Intel i7 4700HQ processor, a dedicated GTX 860M graphics card and 12 GB of RAM memory.

RESULTS

The first scenario developed aimed at representing a real work system in a VE. The goal of this VE was to enable users to explore the environment and through their interactions with NPCs (dialogues) and with objects and equipment, to achieve a better understanding of the issues existent in the represented workplace. Figure 2 shows two snapshots of the VE developed.

Figure 2. First scenario developed in the GE. Views from the local control room (left) and operational area (right).

Users could navigate the scenario in a first-person point of view, using either a computer keyboard and mouse or a standard Xbox 360 controller, with or without cable. Interacting with characters or objects was achieved by either pressing a preset keyboard key or joystick button, or by pointing the cursor over interaction points. Dialogues with employees' characters were designed based on real operators' verbalizations. Relevant information about organizational aspects (e.g. the information exchange among shifts using the white board was presented interest points.

The second scenario, aimed to represent a fictional industry setting providing users the freedom to explore the environment in a multiplayer setting, based on local area network. Users could also interact and change the layout of the production floor, from a process layout to a manufacturing cells layout. Figure 3 shows the second scenario developed with six players' characters in the VE.

Figure 3. Second scenario developed in the GE. View from the first player perspective.

DISCUSSION

Due to its intrinsic characteristics reported by (Koutsabasis et al., 2012) and verified in the VE presented, GEs have the potential to could be a powerful tool to ergonomists and designers. Drawing back from (Güérin et al., 2001; Wisner, 1995) we propose a schematic model of GE utilization in the ergonomics intervention process, shown in Figure 4.

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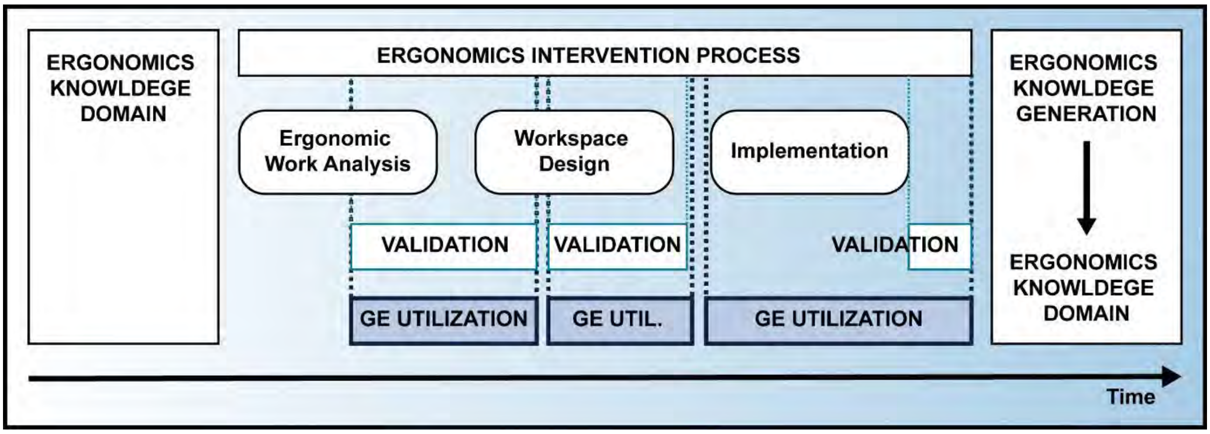

Figure 4. Schematic model of GE utilization in ergonomics intervention.

The conceptual model of the ergonomics intervention process depicted in Figure 4 chronologically positions the validation moments in the intervention. Validation of the analysis and diagnosis of the current situation, spans until the beginning of the design of the proposed solutions. At this point, validation focus changes towards the solutions being proposed and after the conclusion of these solutions, a final validation is required to assess the effectiveness of the ergonomics intervention process.

Similarly, the first moment GEs can be employed in the ergonomics intervention is in the analysis stage of the current work situation. By providing a visual platform where ergonomists input their insights from the current situation and at the same time validate these perceptions with the personnel from the area, we argue that GE's visual and graphical affordances make communication and interactions easier, thus presenting a boundary object nature. Furthermore, throughout the design phase of the intervention, ergonomists, designers, engineers and workers may use GE to simulate and discuss about different configurations and future scenarios, creating new concepts and alternatives. The role of GEs in this stage would be more in line with (Vinck et al., 1996) open intermediary object, due to its concept generation and iterations support. Finally, after a design solution definition and even before the implementation of the solution, the GE can be deployed as a tool for training personnel in the new work procedures proposed. The communication and "getting to know" the chosen future scenario span throughout its implementation takes GE's role towards a closed intermediary object (Vinck et al., 1996).

Nonetheless, it could be a challenge to develop a GE-powered virtual environment once it usually requires skills in 3D modelling, animation and programming and is a time-consuming endeavor. Multi-disciplinary teams would be necessary to fully realize GE potential for ergonomics.

The analysis GE-based VE allow are not to be compared to those performed in traditional DHM software, since the latter are specialized solutions for very specific issues, mainly in the analysis of current situations. However, if necessary, GEs could support more refined postural and biomechanical analysis through the implementation of algorithms and scripts to perform the required analysis. The differential of GEs lies mostly in its high-end graphical visualizations and interactivity which allows for the creation and simulation of complex scenarios and work systems, enabling it to be used both and analysis and design tool.

CONCLUSIONS

Acknowledging GEs as a knowledge object which can foster communication and collaboration during the analysis, validation and design stages of an ergonomic intervention is an expected step towards the continuous development of tools and techniques that empower ergonomists to achieve the ergonomics' dual outcome of assuring workers' well-being and performance.

Furthermore, it could be interesting to follow closely the development of GE technologies, once the gaming industry operates with a multi-billion-dollar budget and there's always new features being released (e.g. virtual reality/augmented reality support). Limitations of the technology such as the absence of native, high fidelity, digital human modelling tools which consider anthropometric and bio-mechanical can restrict the range of analysis conducted with GEs. For strengthening the integration of ergonomics into the design processes we suggest further research on how practitioners and researchers may use novel technologies in the ergonomics intervention process.

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HUMAN CAPABILITY DEMANDS REQUIRED FROM THE ELDERLY AND DISABLED PARTICIPANTS IN THE USER CENTERED DESIGN NEEDS ELICITATION METHODS- A SURVEY STUDY

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KEYWORDS:
User Centered Design, Human factors, Needs elicitation methods, Ergonomics, Design for disabled

SUMMATIVE STATEMENT:
This paper presents results from the expert survey data on the cognitive, physical and perceptual abilities needed by older adults and people with disability to participate in 18 user centered needs elicitation methods (UCNEM) and the principles for the first iteration of a decision support matrix to support determination of appropriate needs elicitation methods for designers, researchers and developers of technologies for older adults and people with disabilities.

Une enquête sur les capacités requises de participants âgés ou ayant un handicap dans les méthodes d’interprétation des besoins centrés sur l’utilisateur

MOTS-CLÉS
Conception centrée sur l'utilisateur, facteurs humains, méthodes d'interprétation des besoins, ergonomie, conception pour les personnes ayant un handicap

SOMMAIRE
Cette communication présente les résultats d’une enquête menée auprès d'experts sur les capacités cognitives, physiques et perceptuelles requises par les personnes âgées et les personnes ayant un handicap pour participer à 18 méthodes d'interprétation centrée sur les besoins des utilisateurs (UCNEM). Elle aborde aussi les principes de la première version d'une matrice d’aide à la prise de décision pour favoriser le choix des méthodes d'interprétation des besoins appropriées par les concepteurs, les chercheurs et les concepteurs de technologies pour les personnes âgées et les personnes ayant un handicap.

PROBLEM STATEMENT:
Devices developed without understanding user needs runs the risk of disengaging the user and a resulting in product failure. According to the Government of Canada (2015a), in 2011, 14.8% of the Canadian population was above 65 years of age and over 33.2% of that population is considered disabled. Within this population 81.3% of people have reported using aids or assistive devices (Government of Canada, 2015b). Despite the increasing population of older adults, there is less effort in design projects accounting for this population’s user needs. Mann et al. (2002) suggests that the major reasons for the non-use of technology is because the users thought that the products did not serve their purpose, found it unnecessary or too complicated to use. These results suggest that there is an important gap in the designer’s ability to collect older adult’s needs and design for those needs.

Typically, UCNEMs are human centered, however, only a few of them take into account the capabilities and limitations of older adults and disabled population, particularly in terms of expectations for physical, cognitive and perceptual abilities (Eisma et al., 2004). They also suggest that experiential gaps and being unaware of various technologies present barriers to using conventional UCNEMs with older adults and people with disabilities (Sujan Samuel Roy, Neumann, & Fels, 2016). Also, a UCNEM could be effective with one type of participant but may be incomplete or inappropriate with others. Thus, one of the main challenges in needs elicitation study is deciding which technique to use with participants that have different abilities. According to Ayalew (2006) "Most analysts, especially novice ones have problems on what factors to consider when deciding on which technique to use for a specific situation"(p.93). Different studies conducted by Hickey & Davis (2003) and Vredenburg, Mao, Smith, & Carey (2002) shows the consideration of factors such as ease of execution, speed, quality of results and problem domain in planning a needs elicitation study. But there were no studies found which focuses on the consideration of a person's ability to participate a needs elicitation study. These findings suggest that there is an important gap in the designers' or researchers' ability to collect data from older adults and the lack of consideration of human capability demands in designing a needs elicitation process.

RESEARCH OBJECTIVE:
The goal of this research is to collect survey data on the different level of cognition, physical abilities needed and the level of difficulty faced by the participants with different visual and auditory ability to participate in the UCNEMs. This data will then be used to create a decision support tool for novice designers and researchers to determine compatible UCNEMs based on the participant's capability.

METHODOLOGY
Researchers, designers or developers either having experience with accessible technology design or using UCNEMs with older adults were recruited from the Age-Well National Centre of Excellence for the survey study.

38 candidates participated in this study which included 7 professional researchers/ designers, 1 clinical psychologist, 2 research psychologists, 7 novice designers, 12 participants from other professions such as occupational therapist, human computer interaction (HCI) researcher, user experience professional and 9 other participants who did not mention their profession. The data on the different human capability demands required of older adults to participate in a set of 18 UCNEMs was captured by asking the participants to provide an assessment of following for each UCNEM:

1) The cognitive demand was captured in terms of three different levels of impairment "Cognitively intact", "Moderate cognitive impairment", "Severe cognitive impairment" (Morris et al., 2016).
2) The motor demands were assessed as ability to use:
    i) A computer input device to select options (e.g. keyboard, mouse)
    ii) A mobile/ tablet touchscreen to select options (e.g., tapping, swiping)
    iii) Gesture (e.g., Sign language, orient a mobile device)
    iv) A computer input devices for text input (e.g. keyboard, touchscreen)
    v) An alternative device for text input (e.g., switch devices, joystick, voice recognition)
    vi) Speech
    vii) Eye movement (e.g., look at different areas)
    viii) Manually write

3) The auditory demand was determined by capturing the level of difficulty (not difficult, moderate difficulty, very difficult) faced by older adults with different levels of hearing ability "Normal hearing", "Moderate hearing impairment" and "Deaf" (Clark, 1981).
4) The visual demand was determined by capturing the level of difficulty (not difficult, moderate difficulty, very difficult) faced by older adults with different levels of visual ability "Sighted", "low vision" and "Blindness" (International Council of Ophthalmology, 1988).

A chi-square analysis was then used to assess whether the questionnaire responses were significantly different from chance. For the categories, which were significantly different from chance, a frequency distribution was performed. The mode value from the frequency distribution corresponding to human factor component in a UCNEM was used to determine the options or level of difficulty. These responses were then used to populate the values into a decision matrix that aids designers or researchers in selecting an appropriate method for their target users.

RESULTS:

Although the responses for many cognitive and physical abilities components were significantly different from chance ($p<0.05$), most of the statistically insignificant results occurred for methods that were frequently marked by survey participants as unknown or not used such as cultural probes and card sorting as there were too few responses. For significant results, the highest occurring response for the acceptable level of cognition and the level of difficulty to participate due to different visual and hearing disabilities is seen in Table 1. Table 2 shows the different physical tasks necessary to participate in the different UC needs elicitation. The data in Table 1 have been classified based on the statistical significance where the fields which are not highlighted are statistically significant, yellow highlighted cells represent responses that did not have a significant chi-square result but which had a larger number of responses, cells containing no entries were not statistically significant and had fewer than five responses in most categories. If a needs elicitation method had a statistically insignificant response for any field, the method was not considered for the first iteration of the decision support matrix tool but was earmarked for further assessment by experts.

DISCUSSION:

As expected, methods such as surveys and focus groups seemed easy for survey respondents to select human capability demands as these are commonly used methods in many different disciplines (Vredenburg et al., 2002). This may be because of the increased accessibility of survey platforms or because of the flexibility of the method to be inclusive of a wide variety of capabilities. Also this may be because of the fewer and lower level of difficulty faced while conducting focus groups with older adults due to the availability of detailed guidelines. (Krueger & Casey, 2014; Morgan, 1997a, 1997b).

To translate these results into a decision support tool to assist researchers and designers in determining needs elicitation techniques that fits their target user abilities, a decision matrix was developed. The responses in the categories of methods which had statistically significant results were assigned numerical weights. The decision matrix algorithm maps the demands required of the UCNEMs as indicated in my survey with the user's specification of their participant's abilities. The numerical weights of the methods which matched the user's specification will be summed and the final score will be ranked. Tool users are then provided with a list of apt UCNEMs which can be used in their needs elicitation study.

Six methods including variances of cultural probes and card sorting with no cell entries in Table 1 seem to be less well known or used even by experts; more than 60% of respondents did not know that these methods existed or had never used them although these methods may be appropriate for needs elicitation. This may be due to the increased effort to prepare the needs elicitation process (Thoring, Luippold, & Mueller, 2013), challenges faced by participants due to limited physical abilities (Wherton et al., 2012) or the lack of knowledge of these methods among researchers or designers (Magnúsdóttir, 2011).

To include these lesser known methods in the decision matrix, further research is required. A focus group will be carried out with experts who have conducted needs elicitation study with older adults and disabled participants. Consensus for the various capabilities required for these methods will be used. The focus group data will also be used to create instructions and guidelines for the decision support tool with specific emphasis on using needs elicitation methods with older adults and persons with disabilities. As new methods are discovered and developed, it will be consequently added to the UCNEM determination tool.

Table 11:Acceptable level of cognition and the level of difficulty to participate in UC needs elicitation methods due to varied visual and hearing abilities. Yellow/ shaded cells indicate non-significant results but more than five responses, blank cells were non-significant and had fewer than five responses.

UC needs elicitation methods	Acceptable cognitive impairment	Difficulty for different hearing abilities			Difficulty for different vision abilities		
		Hearing	Moderate hearing	Deaf	Sighted	Low vision	Blind
Face to Face interviews	Moderate impairment*	Not difficult*	Moderate difficulty *	Difficult*	Not difficult*	Not difficult	Not difficult
Telephonic interview	Cognitively intact*	Not difficult*	Moderate difficulty	Difficult	Not difficult	Not difficult	Not difficult
Open ended survey (Online survey)	Moderate impairment	Not difficult	Not difficult	Not difficult	Not difficult*	Moderate difficulty	Difficult
Open ended survey (Paper type)	Moderate impairment*	Not difficult*	Not difficult*	Not difficult*	Not difficult*	Moderate difficulty	Difficult*
Structured questionnaire (online survey)	Moderate impairment*	Not difficult*	Not difficult*	Not difficult*	Not difficult	Moderate difficulty	Difficult
Structured questionnaire (paper type)	Moderate impairment*	Not difficult*	Not difficult	Not difficult	Not difficult*	Moderate difficulty	Difficult
Paper prototyping	Moderate impairment	Not difficult	Not difficult	Not difficult	Not difficult	Moderate difficulty	Difficult
Focus groups	Moderate impairment*	Not difficult*	Moderate difficulty *	Difficult*	Not difficult	Not difficult	Not difficult
Open Card sorting	Moderate impairment*						
Closed Card sorting	Moderate impairment*						
Reverse card sorting	Moderate impairment*						
Cultural probe (Camera)		Not difficult*	Not difficult*	Not difficult*	Not difficult*	Moderate difficulty*	Difficult*
Cultural probe (Diary recording)	Moderate impairment*	Not difficult*	Not difficult*	Not difficult*	Not difficult*	Not difficult*	Difficult*
Cultural probe (Voice recorder)		Not difficult*	Not difficult*		Not difficult*	Not difficult*	Not difficult*
Think aloud protocol	Moderate impairment	Not difficult*	Not difficult	Not difficult	Not difficult	Not difficult	Difficult
Think aloud protocol (sign language)	Moderate impairment*	Difficult*	Moderate difficulty *	Not difficult*	Not difficult	Not difficult	Difficult*
Retrospective Think Aloud protocol	Moderate impairment*	Not difficult*	Not difficult	Not difficult	Not difficult	Not difficult	Difficult
Mediated workshop	Moderate impairment*	Not difficult*	Not difficult*	Not difficult*	Not difficult	Not difficult*	Not difficult*

**Significantly different from chance (p<0.05)*

Table 12: Physical capabilities necessary to participate in the different UC needs elicitation methods (Y – Yes (Capability required), N – No (Capability not required))

Physical ability / UC methods	Use a computer input device to select options	Use a mobile/ tablet touchscreen to select options	Gesture/ use sign language	Use standard computer to input text/type	Use alternative input for text input (switch devices)	Speak	Move eyes around	Manually write
Face to Face interviews	N	N	N	N	N	Y	N	N
Telephonic interview	N	N	N	N	N	Y	N	N
Open ended survey (Online survey)	N	N	N	Y	Y	N	N	N
Open ended survey (Paper type)	N	N	N	N	N	N	Y	Y
Structured questionnaire (Online survey)	Y	Y	N	N	N	N	N	N
Structured questionnaire (Paper type)	N	N	N	N	N	N	N	Y
Paper prototyping	N	N	N	N	N	N	N	N
Focus groups	N	N	N	N	N	Y	N	N
Open Card sorting	N	N	N	N	N	N	N	N
Closed Card sorting	N	N	N	N	N	N	N	N
Reverse card sorting	N	N	N	N	N	N	N	N
Cultural probe (Camera)	N	N	N	N	N	N	N	N
Cultural probe (Diary recording)	N	N	N	N	N	N	N	N
Cultural probe (Voice recorder)	N	N	N	N	N	N	N	N
Think aloud protocol	Y	Y	N	Y	Y	Y	Y	N
Think aloud protocol (Sign language)	Y	Y	Y	Y	Y	Y	Y	N
Retrospective Think Aloud protocol	Y	Y	N	Y	Y	Y	Y	N
Mediated workshop	N	N	N	N	N	Y	Y	N

CONCLUSION:

The survey data on the different human capability demands needed by older adults and people with disability has been captured for more commonly used methods such as surveys, interviews and focus groups. For six methods including variances of cultural probes and card sorting even the survey participants were not able to provide statistically significant responses on the different human capabilities needed by older adults and people with disability to participate in different UCNEMs. This leaves a gap where further research is required to capture this missing data. This data will be captured through a focus group session with expert panel as part of the future work. The statistically significant data captured so far in the expert survey has been transformed into a decision matrix upon which the tool to determine the list of apt UC needs elicitation methods is being developed.

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INTEGRATING EXPERIENCES FROM OPERATIONS INTO ENGINEERING DESIGN: MODELLING KNOWLEDGE TRANSFER IN THE OFFSHORE OIL INDUSTRY

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KEYWORDS
Knowledge transfer, operations knowledge, engineering design projects

SUMMATIVE STATEMENT
Integrating human factors and users' experiences in design projects is a well-known challenge. This study focus on the specific challenges for transferring these experiences and how using a knowledge transfer model can help this integration on the design of high-risk productive work systems, such as offshore oil rigs.

Intégrer les expériences relatives aux opérations dans la conception technique : modélisation du transfert de connaissances dans l'industrie pétrolière extracôtière

MOTS-CLÉS
Transfert de connaissances, connaissance des opérations, projets de conception technique

SOMMAIRE
Parvenir à intégrer les facteurs humains et les expériences utilisateurs dans les projets de conception est un défi bien connu. La présente étude met l'accent sur les défis particuliers liés au transfert de ces expériences et explique comment un modèle de transfert de connaissances peut faciliter cette intégration lors de la conception de systèmes de travail productifs à haut risque sur les plateformes pétrolières en mer.

PROBLEM STATEMENT

Poorly designed workspaces result in adverse effects on occupational health and safety, as well as reduced efficiency and productivity. In large-scale engineering projects and, in special the offshore oil sector that has to face geographical and workwise distance between operations and engineering design teams, integrating human factors and transferring knowledge are key aspects when designing for better performance systems.

It is acknowledged that offshore operations are a potential knowledge source to be exploited when attempting to optimize new and existing units in terms of cost, safety and production effectiveness (Conceição et al., 2012; Johnsen, 2014), knowledge transfer being the main source of practical information during the projects development (Pagenhart et al., 1998). However, many times knowledge captured from the rigs in the form of documentation and pushed into knowledge systems is not necessarily reused on the engineering design side (Vianello and Ahmed, 2012). There is the need to translate and structure knowledge in a way that addresses the needs of the engineering designers in order for such knowledge to be successfully shared and applied (Ahmed-Kristensen and Vianello, 2015).

RESEARCH OBJECTIVE/QUESTION

Based on an in-depth empirical investigation in an offshore oil company, this study aims to provide a framework for the knowledge transfer process from operations into engineering design that helps identifying and facing the challenges for such a transfer process.

METHODOLOGY

The research was carried out as a case study in an offshore oil company. We used the empirical data collected through interviews and surveys to identify the main challenges for the knowledge transfer process based on a pragmatic 4-step framework (Figure 1).

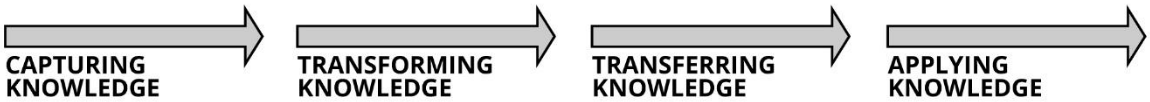

Figure 1 – 4-step knowledge transfer framework

At a later stage, we developed a set of requirements to improve the knowledge transfer from operations into design.

RESULTS

Knowledge transfer implies the knowledge to be 1) *captured* on the operating units, 2) *transformed* into an engineering design context, 3) *transferred* to the appropriate project team members, and finally 4) *applied* throughout the design process of new installations. It is a four-step process involving challenges going from not having specific performance indicators encouraging rig workers to focus on capturing knowledge targeted to design to not having this knowledge available to be applied at the right time in the projects, making it at times impossible to implement in terms of design specifications. Challenges also pass through dealing with the large amount of knowledge registered in the systems without standards to categorise and store this knowledge, to being difficult to access and retrieve the knowledge in the systems.

DISCUSSION

Transferring knowledge and experiences from users brings human factors into play and modelling the knowledge transfer process provides a better idea of what is involved. Overall, the requirements developed based on the identified challenges point to the need to have clear procedures and standards to capture the operational knowledge, as well as an alignment of the key performance indicators related to the knowledge transfer process, since it will allow for better collaboration and communication between the two divisions. Furthermore, clear methods and resources to systematise and transform the knowledge, together with appropriate methods to make it available to the project teams are paramount.

The entire process requires a continuous flow in order to develop a permanent repository that is continuously updated and is used to optimise the design towards better system performance. The framework was developed pragmatically based on the literature and tested using a single case company in the offshore oil sector; more studies are needed to consolidate it. Furthermore, the challenges identified and the system requirements proposed should also be tested at other companies in the sector to verify their generalizability.

CONCLUSIONS

Using a framework helps to identify challenges is of importance for both practitioners and researchers, since it 1) helps developing practical requirements for improving knowledge transfer and 2) supports framing the knowledge transfer process in a systematic way, allowing for comparison within different cases towards generalising the findings.

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Technical Session 15: Transportation & Mining

Séance technique 15: Transport et secteur minier

Conditions favorables pour intégrer les nouveaux travailleurs du secteur minier – un outil d'autodiagnostic

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MOTS-CLÉS
Outil d'autodiagnostic, intégration, nouveaux travailleurs, mines, SST.

SOMMAIRE
Un outil d'autodiagnostic, élaboré à la suite d'une recherche effectuée dans cinq mines québécoises, permet aux entreprises minières de faire le bilan de conditions favorables pour intégrer les nouveaux travailleurs, dans une perspective d'amélioration continue.

FAVORABLE CONDITIONS TO INTEGRATE NEW MINING SECTOR WORKERS – A TOOL FOR SELF-DIAGNOSIS

KEYWORDS
Self-diagnosis tool, integration, new workers, mines, OHS

SUMMATIVE STATEMENT
A self-diagnosis tool, developed as a result of research conducted in five Quebec mines, allows mining companies to review the favorable conditions for integrating new workers from the standpoint of continuous improvement.

ÉNONCÉ DU PROBLÈME

Selon des estimations réalisées en 2015 par le Comité sectoriel de la main-d'œuvre de l'industrie des mines (CSMO mines, 2015) le nombre d'emplois dans le secteur minier québécois devrait passer de 13 554 en 2015 à près de 20 000 en 2025. Durant cette même période, un total de 17 150 emplois miniers devront être pourvus dont 59 % pour combler les postes laissés vacants suite à des départs à la retraite ou vers d'autres secteurs d'activité. Les besoins de formation et d'intégration des nouveaux travailleurs dans ce secteur sont importants, d'autant que les travailleurs qui y occupent un emploi manuel font partie des groupes ayant les plus hauts taux de fréquence-gravité de lésions professionnelles indemnisées (Duguay et coll., 2017).

Une recherche d'envergure réalisée dans cinq mines québécoises s'est penchée sur les conditions pouvant favoriser l'intégration des nouveaux travailleurs (Ledoux et coll., 2015). Cent quinze cadres et travailleurs ont été rencontrés en entretiens et des observations ont été réalisées à des postes d'entrée et des postes spécialisés. L'étude a montré que des conditions de différents niveaux influencent l'intégration: cadre réglementaire (ex. code criminel et le souci de faire preuve de diligence raisonnable), caractéristiques du secteur (ex. cycles de croissance et de ralentissement), organisation du site minier (ex. mode de rémunération, structure du dispositif d'intégration), organisation du département mine (ex. planification de la production, disponibilité des véhicules), équipe de travail (rôle des travailleurs expérimentés, suivi dans la durée). Pour réussir l'intégration, définir le contenu technique des formations ne peut donc pas suffire. À l'issue de la recherche, et à partir des expériences recensées dans les entreprises à l'étude, des pistes d'intervention pour soutenir l'intégration des nouveaux travailleurs ont été proposées.

OBJECTIF

Pour rendre ces résultats de recherche utiles aux entreprises minières, une activité de transfert des connaissances a été réalisée. L'objectif était de développer un outil qui permettrait aux entreprises minières de faire le bilan des conditions qu'elles ont mises en place pour intégrer les nouveaux travailleurs et de choisir des priorités d'action pour apporter des améliorations à leur processus d'intégration.

MÉTHODOLOGIE

En collaboration avec l'Association paritaire pour la santé et la sécurité du travail du secteur minier (APSM), les faits saillants de l'étude (Ledoux et coll. 2015) ont été extraits et formulés sous forme de questions afin de constituer un outil d'autodiagnostic. La première version de l'outil a été soumise à du personnel œuvrant dans des minières afin d'en vérifier la pertinence et d'ajuster le contenu. Cette consultation a pris la forme de webinaires réunissant des représentants des travailleurs, des cadres, de même qu'un consultant qui œuvre en formation. Une deuxième version de l'outil a été validée par l'APSM et par le Comité sectoriel de main-d'œuvre de l'industrie des mines (CSMO) avant d'être finalisée.

RÉSULTATS

Un outil d'autodiagnostic

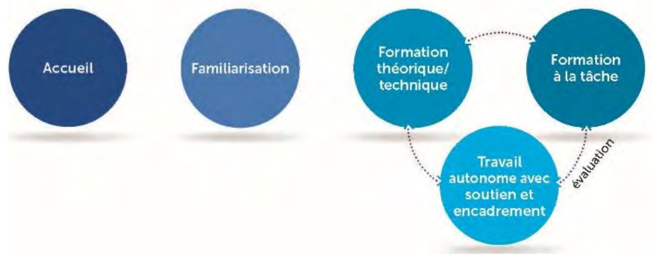
L'outil d'autodiagnostic propose aux entreprises une démarche en cinq points (fig. 1) :
1) constituer un comité « intégration », 2) déterminer les objectifs du processus d'intégration,
3) collecter l'information afin de répondre aux questions des fiches d'autodiagnostic,
4) dresser le bilan et cibler les pistes d'amélioration, 5) élaborer un plan d'action.

Figure 38. La démarche suggérée pour réaliser l'autodiagnostic.

Ainsi, il est suggéré aux entreprises intéressées à utiliser l'outil de former un comité réunissant des représentants d'expertises variées : santé et en sécurité du travail (SST), ressources humaines, opérations minières, formation et travailleurs. Ce comité doit d'abord déterminer sur quel secteur de la mine ou sur quel poste portera l'autodiagnostic. Il doit aussi déterminer les objectifs de l'intégration par exemple quels travailleurs sont intégrés (ex. après une absence prolongée ?) et quelles sont les attentes à la fin de l'intégration. Le cœur de la démarche (fig. 1, point 03) consiste ensuite à remplir les onze fiches d'autodiagnostic qui abordent, d'une part, les cinq étapes du processus d'intégration et, d'autre part, les principaux acteurs de l'intégration (fig. 2).

Étapes du processus d'intégration – 5 fiches

- Accueil
- Familiarisation
- Formation théorique/ technique
- Formation à la tâche
- Évaluation - Travail autonome avec soutien et encadrement



Acteurs principaux – 6 fiches

- Formateur
- Compagnon
- Superviseur
- Équipe de travail
- Équipe SST
- Représentant des travailleurs

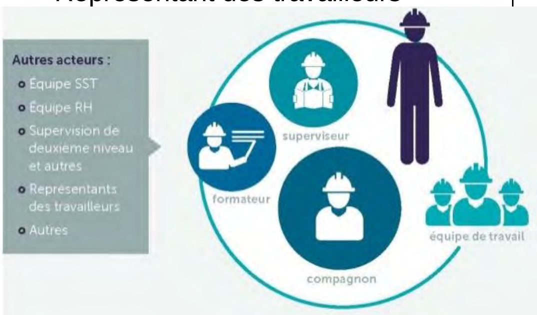
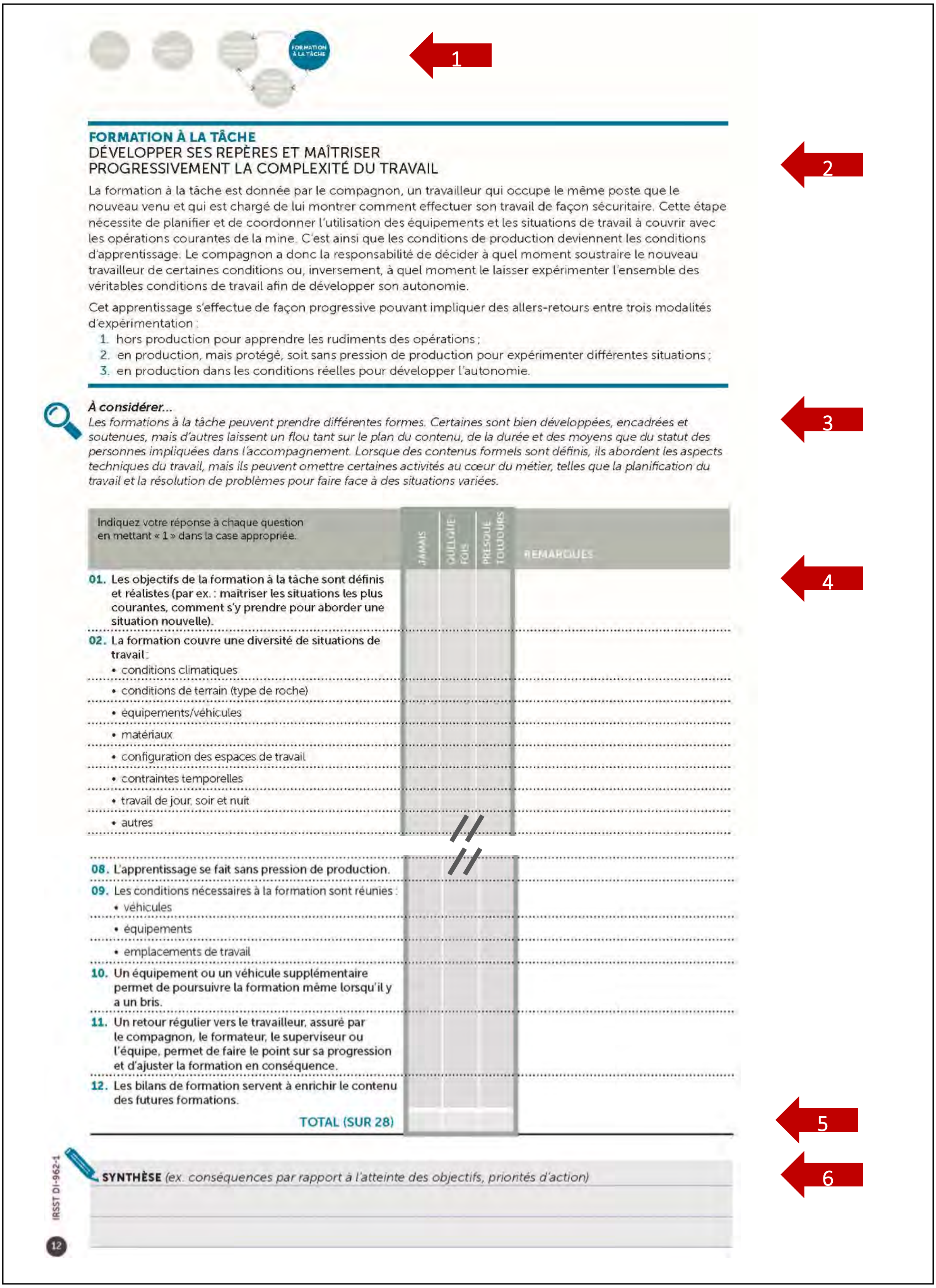


Figure 39. Sujets des onze fiches d'autodiagnostic

Toutes les fiches sont construites sur le même modèle tel que le montre l'exemple de la figure 3. Le schéma permet à l'utilisateur de repérer rapidement le sujet traité dans la fiche (fig.3, flèche-1). Un court texte (fig. 3, fl.-2) décrit l'étape du processus d'intégration ou le rôle de l'acteur, selon le cas. Le symbole de loupe (fig. 3, fl.-3) apporte matière à réflexion sur des bénéfices ou difficultés particulières à prendre en considération. La grille contient des conditions favorables à l'intégration (fig. 3, fl.-4) en lien par exemple avec : la variété des situations de travail à couvrir, le déroulement temporel des étapes, les moyens techniques mis à la disposition pour former, la place de la formation dans les opérations quotidiennes, la reconnaissance du rôle des compagnons, le soutien offert au nouveau travailleur après sa formation et aux acteurs chargés d'intégrer les nouveaux. Le comité doit estimer dans quelle mesure ces conditions font partie des pratiques lors de l'intégration au poste étudié et cocher la case appropriée : «jamais », « quelquefois » ou « presque toujours ». Les réponses sont ensuite compilées au bas de chaque fiche (fig. 3, fl.-5) et le comité peut inscrire la synthèse de son analyse (fig. 3, fl.-6) en regard notamment des objectifs qu'il a définis précédemment.

Après avoir rempli les onze fiches, la section bilan de l'outil permet la compilation de toutes les réponses; l'utilisation de l'outil en format PDF interactif permet la compilation automatique. Cet état de la situation, conjugué à des questions générales portant sur l'atteinte des objectifs (ex. ce qui est prévu dans le dispositif d'intégration correspond-il à ce qui se fait réellement ? Les pratiques sont-elles en phase avec les valeurs de l'entreprise ? Dans quelle mesure les moyens mis en place permettent-ils d'atteindre vos objectifs d'intégration ?), amènent le comité à se fixer des priorités d'amélioration. La dernière section de l'outil est une grille permettant au comité d'inscrire son plan d'action.



FORMATION À LA TÂCHE
DÉVELOPPER SES REPÈRES ET MAÎTRISER PROGRESSIVEMENT LA COMPLEXITÉ DU TRAVAIL

La formation à la tâche est donnée par le compagnon, un travailleur qui occupe le même poste que le nouveau venu et qui est chargé de lui montrer comment effectuer son travail de façon sécuritaire. Cette étape nécessite de planifier et de coordonner l'utilisation des équipements et les situations de travail à couvrir avec les opérations courantes de la mine. C'est ainsi que les conditions de production deviennent les conditions d'apprentissage. Le compagnon a donc la responsabilité de décider à quel moment soustraire le nouveau travailleur de certaines conditions ou, inversement, à quel moment le laisser expérimenter l'ensemble des véritables conditions de travail afin de développer son autonomie.

Cet apprentissage s'effectue de façon progressive pouvant impliquer des allers-retours entre trois modalités d'expérimentation :

1. hors production pour apprendre les rudiments des opérations ;
2. en production, mais protégé, soit sans pression de production pour expérimenter différentes situations ;
3. en production dans les conditions réelles pour développer l'autonomie.

À considérer...
Les formations à la tâche peuvent prendre différentes formes. Certaines sont bien développées, encadrées et soutenues, mais d'autres laissent un flou tant sur le plan du contenu, de la durée et des moyens que du statut des personnes impliquées dans l'accompagnement. Lorsque des contenus formels sont définis, ils abordent les aspects techniques du travail, mais ils peuvent omettre certaines activités au cœur du métier, telles que la planification du travail et la résolution de problèmes pour faire face à des situations variées.

Indiquez votre réponse à chaque question en mettant « 1 » dans la case appropriée.	JAMAIS	QUELQUE FOIS	PRESQUE TOUJOURS	REMARQUES
01. Les objectifs de la formation à la tâche sont définis et réalistes (par ex. : maîtriser les situations les plus courantes, comment s'y prendre pour aborder une situation nouvelle).				
02. La formation couvre une diversité de situations de travail : • conditions climatiques				
• conditions de terrain (type de roche)				
• équipements/véhicules				
• matériaux				
• configuration des espaces de travail				
• contraintes temporelles				
• travail de jour, soir et nuit				
• autres				
08. L'apprentissage se fait sans pression de production.				
09. Les conditions nécessaires à la formation sont réunies : • véhicules				
• équipements				
• emplacements de travail				
10. Un équipement ou un véhicule supplémentaire permet de poursuivre la formation même lorsqu'il y a un bris.				
11. Un retour régulier vers le travailleur, assuré par le compagnon, le formateur, le superviseur ou l'équipe, permet de faire le point sur sa progression et d'ajuster la formation en conséquence.				
12. Les bilans de formation servent à enrichir le contenu des futures formations.				
TOTAL (SUR 28)				

SYNTHÈSE *(ex. conséquences par rapport à l'atteinte des objectifs, priorités d'action)*

Figure 40. Exemple de fiche d'autodiagnostic (extraits de la fiche portant sur l'étape de formation à la tâche).

Une illustration d'un processus d'intégration
Un deuxième document intitulé « L'intégration d'Antoine au poste d'opérateur de camion à benne surdimensionné », illustre l'ensemble des étapes d'intégration d'un nouveau travailleur. Cet exemple, construit sur la base de plusieurs observations de recherche, vise à contextualiser ce qui est présenté dans le guide d'autodiagnostic. Il pourrait aider le personnel des entreprises minières à mieux s'approprier le contenu de l'outil d'autodiagnostic et à initier des discussions autour du processus d'intégration mis en place dans la mine.

DISCUSSION ET CONCLUSION

Le roulement de personnel, les cycles de ralentissement et de relance amènent les entreprises minières à déployer beaucoup de ressources pour accueillir de nouveaux travailleurs ou former ceux qui changent de postes. Une fois leur intégration terminée, on s'attend généralement à ce que les travailleurs soient capables de fonctionner au sein d'une équipe, de résoudre des problèmes, d'atteindre des objectifs de production et de qualité en assurant leur propre sécurité et celle des autres et à ce qu'ils contribuent à la culture de SST. Les informations recueillies dans cinq mines québécoises ont permis de mettre au jour des pratiques qui paraissent avantageuses en matière d'intégration et d'autres, moins favorables pour satisfaire ces attentes. L'outil d'autodiagnostic met maintenant les résultats à la disposition des entreprises minières et pourrait leur permettre de faire le point sur des exigences parfois sous-estimées pour mener au succès d'une intégration sécuritaire, soit : 1) une organisation du dispositif d'intégration qui permet de soutenir l'apprentissage ; 2) une planification de la production qui tient compte de l'intégration et de la formation ; 3) une affectation des ressources humaines et des ressources matérielles adéquates; 4) une prise en considération de la complexité des tâches et de la variabilité des situations de travail. L'utilisation de cet outil d'autodiagnostic pourrait donc contribuer à bonifier les pratiques des minières dans une perspective d'amélioration continue.

L'outil a été lancé au printemps 2017 dans le cadre de l'assemblée générale annuelle de l'APSM et des représentants en SST de chaque mine membre en ont obtenu copie. Quelques personnes ont signifié leur intention de s'en servir dans un avenir prochain, notamment en prévision de vagues d'embauches. Il est prévu de faire un suivi de ces expériences d'utilisation.

L'outil et l'illustration d'un processus d'intégration sont disponibles gratuitement sur le site Web de l'IRSST en versions française et anglaise https://www.irsst.qc.ca/integration-travailleurs-mines (Ledoux et Beaugrand, 2017a, b, c, d).

REMERCIEMENTS

Un grand merci à tout le personnel des entreprises minières qui a contribué au projet de recherche et à la bonification de l'outil d'autodiagnostic. Nous remercions également l'IRSST, l'Association paritaire pour la santé et la sécurité du travail du secteur minier (APSM) et le Comité sectoriel de main-d'œuvre de l'industrie des mines (CSMO), pour leur soutien financier.

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MANAGEMENT OF THE OPERATION OF AN AIR TRANSPORT COMPANY: A SCHEDULING ACTIVITY ARTICULATING HEALTH, SKILLS AND PERFORMANCE ISSUES

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KEYWORDS
Scheduling, performance, management, regulation, health

SUMMATIVE STATEMENT

The paper's aim is to show that scheduling is much more than a management tool. Indeed, it is intended to demonstrate that this activity can handle both health and skill regulations of one specific airline's employees, while reaching production goals, which could contribute to the system's overall performance.

Gérer l'exploitation d'une compagnie aérienne : une planification des activités qui s'articule autour de la santé et des enjeux liés à la competence et au rendement

SOMMAIRE

Le « silence organisationnel » – c'est-à-dire la tendance à ne pas signaler les facteurs qui ont une incidence néfaste sur le rendement – est un phénomène très répandu. Cette communication présente une méthodologie axée sur les « espaces de discussion sur le travail » (EDT) qui a été expérimentée dans le but de briser le silence organisationnel.

PROBLEM STATEMENT

This action-research project is part of a broader research program named "FragiTrav" supported by the French Research Agency (Delgoulet & al, 2015). It is conducted within an airline company, which can be characterized by increasing health problems, an aging workforce and frequent organizational changes. The paper's aim is to study the informal regulation of health problems through the prism of the regulators' activity. The latter schedule in real and deferred times the tasks of agents (services to clients and baggage handlers).

RESEARCH OBJECTIVE/QUESTION

The objective is to understand the construction and degradation of health according to the scientific guidelines that health is linked with performance; indeed, "activity of work" can be both productive and constructive (Delgoulet & Vidal-Gomel, 2015). Health can be considered as "not only the ability to survive in a workplace by enduring its constraints and without declared illness, but also the ability to create a milieu in which to live and be the subject of *'A mediating activity during which the power to act progresses*[2]*'*" (Clot, 2016). Thus, by health

[2] Our translation

problem we mean all the attacks relating to the psychic, physical and/or social spheres formalized and not formalized.

Our main hypothesis is that regulators contribute to the sustainability of agents' work situations (Volkoff & Gaudart, 2015) in favor of the overall performance of the system (Delgoulet & Vidal-Gomel, 2015), the latter acting as health care provider. These elements of primary prevention do not only appear in a corrective approach; they are also situated in a developmental and constructive approach of health. Thus, the concept of "capacity to act" is used in order to highlight the subjective commitment of the worker concerned while considering the role of the means available for the development of this capacity. This commitment goes beyond the purpose of the task. Actually our main assumption is that this activity not only pursues objectives of prevention of the regulators' health but also of that of others, on the medium and long terms. According to this point of view, the scheduling activity is then considered as a chain of opening of possibilities to what is desirable for the regulators (objectives of performance and preservation of their health), for the agents and for the customers. The real-time scheduling choices, in a short-term span, would thus be of major importance to contribute in the long term to the overall performance of the system and orientation of career paths.

From a systemic perspective that takes into account both the organizational and technical dimensions (Berglund & Karltun, 2007), the first step is to uncover the different modes of regulation deployed by regulators in a complex and dynamic environment (Cegarra, 2008; Cellier, De Keyser & Valot, 1996), in particular those revealing the trade-offs and compromises between health, skills and production. Studies have explored the scheduling activity in terms of the reasoning processes and the strategies used. While relying on these results, we intend to emphasize this activity as belonging to the management of others, taking into account the agents' health issues (infra-pathological disorders and disorders leading to skills limitations), skills, relationships between individuals / teams and clients who are the final beneficiaries.

METHODOLOGY

The function of regulation as the nodal point of the airline:

As an action-research, the methodological guidelines are discussed and chosen in consultation with the company's stakeholders (ergonomists, occupational physician, occupational health and safety specialists, human resources managers, etc.).

Thus, the first methodological choice was made on two sites differing in sizing, type of activity (destinations of flights), geographic and economic basin as well as socio-demographic characteristics of workers. Two specific services were chosen too: operations agents (services to clients and baggage handlers). The latter are in the front line to meet the company's performance objectives, including service relationship, punctuality, airport security and luggage management.

The second methodological choice was to focus on the activity of the regulators, who are scheduling in real time the different activities of the exploitation (for example, making the embarkations, the arrivals and the passenger check-in or the loading and unloading of aircraft luggage). Indeed, the prism of the regulator's activity allows a multi-level analysis of the regulation of health, skills and performance issues: their specific position in the organization chart leads them to do a more or less discretionary management at an individual level (creating individual planning) but also at a collective one (organizing all schedules, make-up binomials and flight teams according to organizational justice). This management takes into account different forms of health issues (infra-pathological disorders or medical restrictions), skills (non-formalized qualifications or formal skills) all the while attempting to achieve performance objectives (customer satisfaction, punctuality, etc.). It is therefore a relevant point of view to understand how the health and skills issues are mixed with those of performance.

21 sessions of systematic observations of regulatory activity were carried out, in the two sites and services, at 3 times of the day: the first session starting at 5 am; the peak of the second session (between 10:30 am and 1:30 pm) and the last session beginning at 4:00 pm.
This set of parameters (site, population, time of the session) could enrich the analysis by revealing the diversity of the construction / degradation of health while grasping common mechanisms.
Systematic observations were equipped with video and audio materials as well as an observation grid (Guérin *et al*., 2007). The regulators work in teams of 2 or 3 on a software (RTC: real time control) that represents a hundred schedules. It was decided to include in the grid: communications and their support (telephone, walkie-talkie, microphone), software actions (assigning or decommissioning a task, refining a schedule, etc.), work timespan, and events leading regulators to revise their schedule.

Event as unit of the analysis:
The final objective is firstly to reveal the complexity and the dynamism in which they operate, which are illustrated by the number of elements to be managed simultaneously in a tight temporal span. The main idea of this type of treatment is that the conditions of their activity have an influence on the activity of the agents whom they manage and on the achievement of performance goals. We aim to consider regulators as health operators through the links between health and performance by mediating the work activity of regulators, while taking into account the collective and co-built aspect of the schedules.
In order to understand how health and skill stakes are encased in production issues, we have chosen to focus the analysis on the identification of events, which are defined as anything that lead regulators to revise their initial scheduling. An event can be determined by its duration, its results on the schedule and agents, the configuration of its occurrence, the meaning that regulators give to it and its degree of urgency. Above all, an event is categorized according to its origin, that is production or health. For example, “Production” events include changes of boarding gate, the detection of a task overlap on the software, or the need for agent reinforcement in the recording area. As for “Health” events, they contain all alerts or requests on the agents’ schedule (related to their state of health or skill,, requests for time, absences or delay, etc.).

On the other hand, we would uncover the regulatory strategies regulators induce during self-confrontation interviews to the traces of their activity (film sequences collected during systematic observations) (Mollo & Falzon, 2004; Clot & al., 2000). Our study will also bring to light the models of health, skills and performance, built throughout the career path, and being active in the choices of assignment of tasks.

RESULTS

As an example, here is the analysis of a “Production” event:
At an observation session, the regulator posted a change of boarding gate at 8:53 am, directly from the software, from "classic" to "self-boarding". Gateway changes are common events due to the variability of flights and aircraft rotations. During the observation period, the transformation of the "classic" boarding gates into self-boarding doors was in full deployment phase and the agents were being trained. The boarding of this flight is at 9 am and is initially taken care of by an interim agent. This presupposes that the regulator can find an authorized agent at the last minute. The regulator therefore searches for an available agent, according to specific criteria (state of health, qualification, availability or if unavailable, easiness to relocate the task already assigned to him). His first choice stops on an agent with a medical restriction,

which has fewer tasks than the others. She then calls this agent to the regulation via a microphone announcement. The two other regulators remind him that this agent has a medical restriction and that he has been made a tailor-made schedule ("He is useful where he is"). The regulator cancels her announcement by microphone and looks for another agent likely to be able to take this flight at the last minute. The regulator will summon the acting staff member to ensure that she is not qualified as self-boarding. While explaining the situation to the interim agent, she sails on the board and finds an adequate schedule: she will be able to make a switch between a traditional boarding of agent x and the self-boarding of the temporary employee. Simultaneously to the operation, agent x presents himself at the counter with a precise request. The regulator explains what she is doing. It is now 8:56 and the agent must be at the embarkation at 9:00.

In this way, this event reveals that the choices of assignment are based on a compromise between health, production and skill criteria. It can be noted that this event is processed by reaction and becomes a priority since it is the main object of communications between regulators. The communications and the actions on the software indicate the elaboration of a compromise between different criteria in order to find the "relevant" agent: in terms of availability, priority and importance of the task, state of health and qualification (trained for "self-boarding"). The treatment of this event, due to its urgency, lasted 4 minutes. Here, the frequency of changes in gateways, the urgency, the scarcity of certain skills and the unavailability of the occupied workers for equally important tasks, reduce the anticipation strategies, impoverish the possibilities of choice, make it difficult to reconcile all the criteria.

The analysis of a global shift (5:30) also shows that the duration of events can be very much variable, and that the regulator can manage several events simultaneously, while continuing to pursue the initial objective, which is to assign tasks to agents. Also, this analysis allowed the recording of 64 events (32 events "health" and 32 events "production"), making it a typology and estimating treatment duration. An event would begin when there is a clear intention to modify (or trigger an agent, find reinforcement, etc.) and would end when it is no longer the subject of action, nor of exchange between regulators. This duration can range from one minute to 3:35. For precision, duration does not represent the processing time of an event (hence its complexity), but rather shows how long the regulator can have an event and its consequences in mind (snowball effect). The complexity would then be more represented by the number of elements managed in parallel (other events, alerts, information requests, daily tasks, etc…). Those other elements and tasks have been identified. This treatment allows us to understand the complexity of the regulators' activity by referring to the work done on the cognitive load (number of elements to be managed simultaneously in a tight temporal span).

A qualitative analysis of the restitution of the actions and the communications is scheduled for the end of May 2017 and will focus on two events: one whose initial source relates to questions of "health" (a schedule anomaly detected by the regulator) and the other whose initial source is linked to "production" (change of gate).

DISCUSSION

Re-scheduling in a complex and dynamic environment

These first results echo the issues raised in the literature. The dynamism of the situation is reflected in a change in the situation, independent from the operator's actions on the software (Samurçay & Hoc, 1989, reprinted by Cellier, 1996) and results from re-scheduling induced by external events and chain effects of their appearances on the scheduling structure (for example, changing at least twice). This dynamism, combined with the different levels of assignment selection criteria (characteristics of agents, tasks and schedules), increases the complexity of their activity. Dynamism and complexity lead regulators to constantly update their representation of the situation and to synchronize a diversified set of temporalities (Cellier, De Keyser and Valot, 1996; Hoc, 1996).

Thus, interactions between regulators and agents or between regulators in the same shift show "organizational work" (Terssac, 2012), where interactions crystallize around schedules, and then contribute to the production of rules. In this example, the regulators argue about the tasks to be assigned depending on the restriction of an agent.

Arrangements favorable to primary prevention of health and skills development

This co-production of schedules leads us to think of this scheduling activity as a prevention tool, both primary and "opportunistic". Indeed, this prevention is not the subject of a prescription in its own right and found to be conditioned by the resources available and the principles of justice momentarily shared by the regulators in office. Consideration of health issues, beyond the application of formalized restrictions, can thus be part of the objectives specific to the regulators in operation and can be strategic in order to keep the performance stakes. These first analyses will be extended to the 21 sessions observed. They also invite to deepen our analysis of the management of health issues by identifying the resources and organizational constraints that allow the regulator to develop his or her ability to act, and, by the same token, the sustainability of the agents' work.

We consider the regulator to be a health care provider, especially since his functions partly cover those of the proximity supervisor (work of articulation of the ascending and descending elements, planning of the work of others). Thus, by questioning the stakes underlying a posture oscillating between autonomy and discretion, which characterizes this "primary-opportunistic" prevention, we focus on grasping the different constraints that weigh on their activity and which, if managed in their activity, can shift over that of agents (Detchessahar, 2010; Zara-Meylan, Gotteland & Pueyo, forthcoming). This daily prevention could then contribute to the orientation of the pathways in a medium and long term.

CONCLUSIONS

Focusing on the activities of regulators reveals invisible regulations of different levels (individual, collective and organizational) contributing to the overall performance of the company, through individualized and collective management of health and skills. However, this primary prevention could be undermined by the reduction in leeway in the possibilities of assignment, as a result of demographic aging and organizational transformations.

These first results offer prospects for transformations in order to support the work of regulators, at the technical (software) and organizational (work space, organization with teams) levels, as well as in terms of career paths.

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RESULTS OF A MACROERGONOMIC ANAYLSIS INTEGRATING SAFETY CLIMATE IN THE LONG-HAUL TRUCKING INDUSTRY

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KEYWORDS
Macroergonomics; Safety Climate; Trucking

SUMMATIVE STATEMENT
The purpose of this study was to develop a methodology that extends safety climate beyond just an overall score. The MacroErgonomic Analysis and Design (MEAD) method (Kleiner, 2004, 2006) was used to help determine if specific factors found in the system clarify the meaning of safety climate in an organization. Key informants in the trucking industry identified 19 themes that affect safety, ranging from balancing work and family/personal time, the company's policy vs. practice, and respecting the job of the driver, and such information can be used to design interventions to change the safety climate of an organization.

Les résultats d'une analyse macroergonomique intégrant un climat de sécurité dans l'industrie du camionnage de longue distance

MOTS-CLÉS
Macroergonomie, climat de sécurité, camionnage

SOMMAIRE
La présente étude avait pour but d'élaborer une méthodologie afin que le climat de sécurité s'étende bien au-delà d'une note globale. La méthode d'analyse et de conception macroergonomique (MEAM) (Kleiner, 2004, 2006) a été utilisée pour déterminer si des facteurs particuliers décelés dans le système clarifient la signification du climat de sécurité dans une organisation. Des informateurs clés de l'industrie du camionnage ont identifié 19 thèmes qui influent sur la sécurité – allant de la conciliation travail-famille, des politiques de l'entreprise par rapport aux pratiques jusqu'au respect du travail du conducteur – et dont les informations peuvent servir à concevoir des interventions pour modifier le climat de sécurité dans une organisation.

PROBLEM STATEMENT

A specific advantage of human factors and ergonomics (HFE) is its consideration of the broader context of an individual within the work environment (Dul et al., 2012). Additionally, assessments performed by HFE specialists lead to recommendations and actions for designing or redesigning the work system (Dul et al., 2012). Safety climate research focuses on the social interactions between employees and supervisors, and safety climate interventions address changing those interactions to emphasize safety as a priority through improved communication. Research is needed to show if safety climate improves when factors within a work system, other than communication, are modified.

RESEARCH OBJECTIVE / QUESTION

The goal of this study was to integrate safety climate theory and the HFE subdiscipline of macroergonomics to find different aspects of the work system in two similar trucking companies that could be modified through the design of future interventions.

METHODOLOGY

Two companies were targeted for recruitment based on high and low safety climate scores from Huang et al. (2013)'s safety climate study. Figure 1 illustrates the study procedure. A total of 27 one-hour long, semi-structured interviews were conducted during the initial data collection with a total of 28 participants. See Table 1 for details. Affinity mapping is a procedure that synthesizes qualitative information into conceptual groupings and was used to analyze the interview data. It was an inductive process in that codes were created from key phrases in the interviews without having predetermined categories. A bottom-up approach was used in which codes were grouped into themes based on their content.

RESULTS

For this study, two coders identified 1,838 codes in the 27 interview transcripts. Using an affinity mapping procedure, those codes were distributed to two researchers and one research assistant who grouped the codes into initial themes they identified individually. Then they worked together to combine their individual themes into 42 larger themes. Combining the themes further led to 19 overall themes. It was the 19 themes that were taken to key informants for validation. After the validation process with subject matter experts, further categorizing was done using Murphy, Robertson, and Carayon (2014)'s model (See Table 2).

DISCUSSION

Many of the issues raised had to do with the over-arching themes created using the Murphy et al. (2014) model. Given that research has shown employees' safety climate perceptions impact their safety behavior (Christian, Bradley, Wallace, & Burke, 2009; Neal & Griffin, 2006), future research can be done to determine which themes from this study most greatly influence employees' perceptions to then be able to create a safer work environment.

CONCLUSIONS

This study used a methodology to expand the number of components which might influence safety perceptions. Safety climate has traditionally focused on communication issues between supervisors and employees, but this study showed using a macroergonomic analysis that safety is affected by multiple sources, including technical and environmental factors. Future research can further examine the overarching themes found in this study to determine which themes should be addressed in interventions to change the safety climate perceptions of long-haul truck drivers.

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Table 1. Study participants

Participants	Initial Data Collection		Validation	
	Company 1	Company 2	Company 1	Company 2
Senior executives	2	-	-	1
Safety personnel	2	2	2	1
Operations personnel	3	1	-	-
Direct supervisors	2	2	3	3
Drivers	6	4	2	2
Driver trainers	-	4	1	2
Maintenance/Road service personnel	-	-	1	1

Table 2. Themes

1. Worker Activity
• **Multiple skills of a driver:** *Technical skills need to be mastered while utilizing softer people skills and planning coordination.* • **Varied range of skills required of driver trainer:** *Mentoring, patience, quality of training, conflict of duties (two jobs in one).* • **Driver autonomy and assertiveness:** *Speaking up in an industry culture of "keep going."* • **Pros and cons of experience:** *Understanding the job but risk being "too comfortable."* • **Health and wellness of drivers:** *Often difficult for drivers to achieve well-being (adequate sleep, healthy diet/exercise, personal security) while on the job.*
2. Technical Subsystem
• **Onboard technology can be helpful, lacking, or even hazardous:** *Can detect unsafe technical maneuvers but not driver behavior, frequent alarms can be distracting.* • **Maintenance as a department and as a role (fixing equipment):** *Relationship between mechanics and drivers, reliable/functioning equipment, timeliness of repairs.*
3. Personnel Subsystem
• **Supervisor and driver relationship:** *Supervisor needs to build personal rapport/trust so drivers feel supported and so supervisors understand what drivers experience on the job.* • **Insufficient training for drivers:** *Lack of time (in classroom or on road), individual attention, integration of safety, training evaluation.*
4. Organizational Design
• **Supervisor/driver ratio disproportionate:** *Overstaffed supervisors compromise communication and morale.* • **Policy vs. practice:** *Safety is part of the company's value system, on-time delivery vs. safety.* • **Communication:** *Misinformation/lack of information creates mistakes, channels of communication restricted, methods of communication misaligned.* • **Active listening and meaningful feedback:** *Asking for input from all drivers, eliciting valuable input, following up on feedback.*
5. Physical Environment
• **No specific themes are categorized under "Physical Environment"**
6. Internal Environment
• **Sense of belonging in the company:** *Feeling like part of a family/team as opposed to a number in an organization, not being physically separated.* • **Balancing work and family/personal time:** *Drivers need to ensure a healthy balance for themselves, company needs to honor time at home.* • **Driver as company representative:** *Trusting the driver to be professional enough to function as liaison between the customer and company.* • **Respecting the job of the driver:** *Drivers take pride in their job but often lack respect by their company, industry, and society.*
7. External Environment
• **Supply (of qualified drivers) vs. demand (from industry):** *Not enough drivers affects recruitment/hiring and retention/turnover.* • **External factors:** *Impact of industry and ever-changing government standards on companies.*

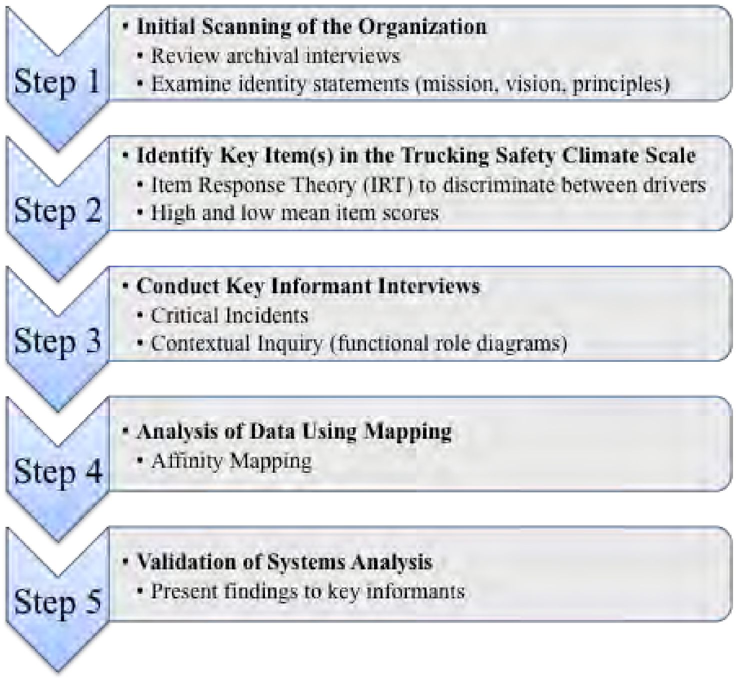

Figure 1. Systems analysis procedure based on macroergonomic principles.

COORDINATION BETWEEN STAKEHOLDERS TO IMPROVE THE RISK PREVENTION IN MSES: CASE STUDIES IN TRANSPORT AND CONSTRUCTION PROGRAMS.

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SUMMATIVE STATEMENT: The dynamics of micro and small enterprises (MSEs) in risk prevention depends on the coordination of stakeholders in the network to create program with various actions related to the specific needs of each sector. The stake in risk prevention in MSEs is to support some initiatives by branch to improve successful strategies.

Le rôle de la coordination entre les intervenants pour améliorer la prévention des risques dans les PME : des études de cas de programmes dans le transport et la construction

SOMMAIRE : La dynamique des micro et petites entreprises (MPE)) sur le plan de la prévention des risques dépend de la coordination des intervenants dans le réseau afin de concevoir un programme comportant diverses mesures en fonction des besoins particuliers de chaque secteur. L'enjeu de la prévention des risques dans les MPE est de soutenir certaines initiatives par secteur afin d'améliorer les stratégies efficaces.

PROBLEM STATEMENT: The problematic is how the motivation of owner-managers in MSEs can be developed to have an integrated OSH management in real activity with their requirements of subcontractors or customers.

RESEARCH OBJECTIVE / QUESTION: The aim is to describe the coordination between OSH advisors and professional organisations to develop good practices in risk prevention in MSEs, which they are often not demanding. The business market is a higher priority. The problematic is how the motivation of owner-managers can be developed to have an integrated OSH management in real activity. We will explore a determining factor: the role of the coordination of stakeholders in the network to create program.

METHODOLOGY: This study in French context is part of the work package 3 (WP3) of the Sesame study, financed by the EU-OSHA. We compare two networks with different OSH intermediaries that developed risk prevention actions in MSEs adapted to both sectors (road transport and construction). We made collective interviews (2) with the leader of each program, completed by individual interviews (4), the redaction of a case study (2). We did also discussion groups during the dialogue workshop (1).

RESULTS: The program of the Social security and its OSH strategy in France defined the target group to reach. The program is to creating tools related to the needs of MSEs. In the road transport program, the network is issued from the coordination of public OSH institutions, a regional prevention service and several partners. OSH advisors have difficulties to directly contact owner-manager. The kind of support offered by the network is the training of counselors, information about an online risk assessment tool, financial subventions about material's equipments, e-learning for training tutors of young apprentices. The construction sector program is directly composed by a research and professional association. It was initiated by representative of both professional associations. The collaboration between different partners offer various support to help MSEs: advices for safer equipment, tools to make the risk assessment, an online training about safety. Globally, the motivation of owner-manager to develop an OSH approach is: the perception of risks, the personal motivation, the experience of OSH, the regulation with written document, the financial subventions.

DISCUSSION: In both cases, the promotion of advices is given by professional partners. Their contribution is a key factor to develop OSH practices in companies.

CONCLUSIONS: The cooperation between professional organisations and OSH advisors is necessary to develop a proactive approach. Furthermore, the required written risk assessment document determines the dynamics of MSEs in risk prevention.

INVESTIGATING ORGANIZATIONAL SAFETY CONTROL STRUCTURES WITHIN A COMMUTER RAIL OPERATION SETTING

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KEYWORDS
Sociotechnical systems, rail operations, safety, STAMP, organizational safety

MAIN MESSAGE
Analyses of hazards and accidents in complex work settings frequently focus solely on either the worker or the immediate interface between the worker and technical system. However, as Jens Rasmussen argued, important causal influences may exist well beyond the point of contact between operator and system, including organizational decision-making and communication processes, macro-economic and regulatory constraints, and many others. In this paper, we describe the application of the System Theoretic Accident and Modeling Processes (STAMP; Leveson, 2012) approach to the analysis of an organizational safety control structure in a commuter rail setting, to identify organizational influences on worker safety.

Une enquête sur les structures de contrôle de sécurité dans une organisation de trains de banlieue

MOTS-CLÉS
Systèmes sociotechniques, exploitation ferroviaire, sécurité, STAMP, sécurité organisationnelle

MESSAGE PRINCIPAL
L'analyse des dangers et des accidents dans les milieux de travail complexes est souvent exclusivement centrée sur le travailleur ou l'interface immédiate entre le travailleur et le système technique. Cependant, comme le fait valoir Jens Rasmussen, des influences causales importantes peuvent exister bien au-delà du point de contact entre l'opérateur et le système, à savoir les processus de prise de décisions et de communication de l'organisation, les contraintes macroéconomiques et réglementaires et bien d'autres. Dans la présente communication, nous décrivons l'application du modèle STAMP (Leveson, 2012) dans l'analyse d'une structure de contrôle de sécurité organisationnelle dans un milieu de

trains de banlieue afin de déterminer les influences organisationnelles sur la sécurité des travailleurs.

PROBLEM

Historically, rail operations have been one of the most hazardous of all workplace settings. Despite significant improvements over the many decades of this industry' existence, an unacceptably high rate of serious injuries remains. Using STAMP, we set out to examine the utility of a systems theoretic perspective for identifying organizational influences on worker safety in this setting.

ACTIONS

Using STAMP, we generated an organizational safety control structure (SCS). The SCS modeled control and feedback relationships between organizational and technical sub-systems insofar as they specifically related to the management of safety. The model was developed by means of a combination of interviews and focus groups with front-line employees, supervisors and upper management, document review and work observations. The model was subsequently validated by means of follow up interviews and focus groups.

OUTCOMES

Findings demonstrated the presence of several different classes of control and feedback limitations within the system, including missing and or otherwise dysfunctional (e.g., "noisy', time-delayed, infrequent, etc.) control and/or feedback links. Additionally, fluctuations in the perceived competition between productivity (e.g., on-time performance) and worker safety further impacted the nature of control actions (in particular) through a bias toward productivity. Additionally, cultural factors such as fear of retribution, lack of trust, etc. exerted an occasionally powerful, negative influence on feedback links.

DISCUSSION

Like other complex work environments, commuter rail operations are managed by means of a hierarchical organization. Our findings illustrate a number of ways in which the characteristics of control and feedback relationships between components of such a system contribute to the creation, enhancement or mitigation of hazards to worker safety.

CONCLUSION

The field of safety studies is becomingly increasingly comfortable with the notion that systemic, organizational factors significantly influence safety – for better or worse – in complex work settings. However, the development of systematic approaches specifically designed to identify hazards and influences arising from control and feedback relations within complex sociotechnical systems has only recently begun to mature The current work demonstrates that methods derived from the STAMP perspective are effective in identifying causal influences on worker safety that extend well beyond the worker-machine interface.

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Panel Sessions / Round Tables - Abstracts

Tables rondes – Les Résumés

CHALLENGES AND EMERGING ISSUES OF PARTICIPATORY, INTEGRATED PROGRAMS FOR WORKER SAFETY, HEALTH AND WELL-BEING

Les défis et les nouveaux enjeux des programmes participatifs et intégrés touchant la sécurité, la santé et le bien-être des travailleurs

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KEYWORDS
Participatory ergonomics, macroergonomics, Total Worker Health

ABSTRACT
The organization of work and the working environment are important factors in the social determinants of health. The World Health Organization and leading public health agencies from Canada, the United States, and other countries support the concept that a “healthy workplace” is comprised of physical and psychosocial aspects of the work environment that directly and indirectly impact health. Integrated program models such as the CDC Total Worker Health® (TWH) program, offer specific strategies to make work organization more conducive to safety, health, and well-being. Participatory engagement of workers in the design of interventions is one core strategy that offers a mechanism for designing integrated interventions using a macroergonomic approach. However, participatory, integrated program approaches have not been widely adopted, particularly in some countries. This session will provide an opportunity to discuss specific challenges and emerging issues related to dissemination and implementation of participatory integrated workplace programs. Five

panelists will briefly introduce specific topics and a panel Chair will moderate a dialogue with the panelists and the audience.

DESIGNING HEALTH INFORMATION TECHNOLOGY FROM A HUMAN FACTORS PERSPECTIVE

Concevoir des technologies de l'information en matière de santé du point de vue de l'ergonomie

Panel

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KEYWORDS
Keywords: Healthcare, health information technology, design requirements

SUMMATIVE STATEMENT
This is a panel presentation on design of health information technology (HIT) from a human factors perspective. HIT has the potential to solve many of the problems in healthcare. However, in many cases, health IT implementation has proven to be difficult. In this panel we discus some of the design and implementation issues as well as some of the solutions.

CONCEVOIR DES TECHNOLOGIES DE L'INFORMATION EN MATIÈRE DE SANTÉ DU POINT DE VUE DE L'ERGONOMIE

MOTS-CLÉS
Soins de santé, technologies de l'information en santé, exigences de conception

SOMMAIRE
La présente table ronde est axée sur la conception de technologies de l'information en santé (TIS) du point de vue de l'ergonomie. Bien que la TIS ait la possibilité de résoudre de nombreux problèmes dans le secteur de la santé, la mise en œuvre s'est révélée difficile dans bien des cas. Cette table ronde permettra d'échanger sur certains enjeux de conception et de mise en œuvre de la TIS et de présenter des solutions.

PROBLEM STATEMENT
How can we design and implement health information technology that fulfills the information needs of the end-users (clinicians or patients), does not interrupt workflow or add to workload, but results in satisfaction and engagement?

INTRODUCTION

Health care is one of the industries that has shown tremendous growth in past decades, and the odds are that, due to population aging and technological advancements, it will continue to grow. This tremendous growth causes several problems. First, resources are limited. For example, costs of health care have grown from 5% of GDP in 1960 to nearly 20% in 2016. Second, health care has become more complex. One of the reasons that people live longer is that specialized care has improved significantly. One possible solution to make healthcare processes more efficient is implementation of health information technology (IT). In the past two decades, health IT has been implemented on a large scale in both hospitals and clinics. However, in many cases, health IT implementation has proven to be difficult. In this panel, we examine health IT implementation from a human factors perspective. Several experts will share their experiences with health IT implementation, followed by a general discussion of human factors' contribution to health IT.

Ann Schoofs Hundt, PhD will present the results from her recent study on clinical decision support for venous thromboembolism (VTE). As electronic health records (EHRs) were introduced to healthcare organizations, many believed that clinical decision support (CDS), integrated in the various EHR functionalities, would have significant impact on improving safety and quality. Although benefits have been observed and guidelines in their development exist (Bates et al., 2003), we are still far from achieving the intended goal of CDS. In hindsight, organizational decisions and the manner in which EHR CDS is implemented seem to account for at least some of the shortfall. In our study on clinical decision support for VTE diagnosis and prevention, we better understand physician perspectives on the organizational decisions made and, in some instances, lack of user input in the CDS design and implementation process. VTE is a potentially life-threatening condition in which, untreated or undiagnosed, can lead to pulmonary embolism and death. VTE can be prevented with small dose anticoagulants and, if diagnosed, is treated with therapeutic doses of anticoagulants.

Onur Asan, PhD, will discuss health IT research on improving family engagement in a pediatric ICU. This study focuses on a novel health IT application that has the potential to become a next generation system; but to our knowledge no previous IT research has been published (Asan et al., 2016; Richard J. Holden, Asan, Wozniak, Flynn, & Scanlon, 2016). This is a Large Customizable Interactive Monitor (LCIM), a 42" inch (diagonal) flat panel touch screen monitor that displays validated patient information including vital signs, laboratory results, medications and interventions recorded in the EHR. The LCIM is located in each patient room. In contrast to traditional health IT that requires a secure login by providers, the LCIM can be used by providers as well as patients and their families without repeated login.

Data were collected from all potential users including providers, nurses and family members. This study revealed that this next generation health IT appears to have great potential for family-centered rounds, team education during rounds, and family education/ engagement in their child's health in the patient room. Continuous access to the data makes families feel more empowered while better understanding their kid's health status and progress. This study also highlights the effect of training and orientation on the adoption patterns of new technology. Finally, the findings also have implications for research, design and implementation for patient/family centered informatics.

Peter Hoonakker, PhD will present some results on the implementation of a patient portal for parents of hospitalized children. Difficulties arise when implementing information

technology (IT) in complex healthcare settings, with in some cases healthcare organizations reverting to the paper chart system. Several explanations have been offered, such as lack of end user involvement in design and implementation and not adapting health IT to the existing clinical workflows. As a result, health IT is often added to the tasks that clinicians already perform, and thus increases their workload (Hoonakker, Carayon, & Cartmill, 2017). In this study, we examined the implementation of health IT that benefits patients: acute care or inpatient portals. Inpatient portals are provided to hospitalized patients and their caregivers to engage them in care. Tethered to the hospital electronic health record (EHR), these portals present a summary of a patient's health information (i.e., hospital problem list, vitals, medications, test results, schedule) and allows the patient to communicate with their healthcare providers. In general, patients and caregivers have been enthusiastic about the use of inpatient portals (Kelly, Hoonakker, & Dean, 2017; O'Leary et al., 2016). Studies among healthcare providers have shown that clinicians – after initial reluctance pre-implementation – were moderately satisfied with inpatient portal implementation (Kelly, Coller, & Hoonakker, 2017; Pell, Mancuso, Limon, Oman, & Lin, 2015).
In this study, we report on results of a series of interviews with parents of hospitalized children who received an inpatient portal to use during their child's hospital stay. We examined what parts of the portal they like best and why. Results show that the patient portal provides parents with a sense of control using functionalities such as the schedule and medication list. Parents can use this information to check if their child has indeed received their medication, etc.: "*You know, I could come back and be like, okay, yep, she got it. Versus coming back and going, hey, you know, did Kara get her medicine… it's great. I love it"*. Overall, most parents were very satisfied with the inpatient portal and recommend that the hospital continue its use.

Rupa Valdez, PhD will present results of her studies that are aimed at adapting health IT to a specific group of end users, patients with disabilities. Recent trends have emphasized patient engagement through health IT as a means of improving self-management experiences and health outcomes (Dentzer, 2013; Valdez, Holden, Novak, & Veinot, 2015). However, an unintended consequence of this movement may be the increased marginalization of populations, such as individuals with disabilities, who face barriers to more active participation in their health and health care in addition to barriers to IT use (Goldberg et al., 2011; R. J. Holden, Valdez, Schubert, Thompson, & Hundt, 2016). Consequently, it is imperative that consumer health IT is designed in ways that are responsive to the needs and preferences of these populations. This study focuses on assessing the needs and preferences of individuals with physical, cognitive, and sensory disabilities. The goal of the study is to develop consumer health IT design guidance for individuals with disabilities in the context of one form (i.e., mobile health applications) and one functional domain (i.e., health information communication with social network members).

A patient work approach (R. J. Holden et al., 2016; Valdez et al., 2015) is being used to assess the consumer health IT needs and preferences of individuals with disabilities. Specifically, we are seeking to characterize each aspect of participants' existing work systems and how these impact participants' experiences with existing consumer health IT solutions (i.e., Microsoft HealthVault, Epic MyChart, and CaringBridge) through interviews, task analyses and journaling exercises. Our initial interview findings demonstrate how multiple work systems factors interact to shape with whom, how and why health information is communicated in daily life. During the task analyses, several participants demonstrated difficulties interacting with the application, in part because the applications were not designed to effectively interface with standard OS accessibility features. Blind participants in particular had great difficulty using voice over functionality without assistance from another individual. We have enrolled 33 participants to date and will report on a larger cohort.

Yushi Yang, PhD, & A. Joy Rivera, PhD., will discuss interruptions mediated by mobile technology. Mobile devices are ubiquitous in healthcare work systems. Examples are wireless pagers, hands-free communication devices (Richardson & Ash, 2010), and mobile digital assistants (Ammenwerth, Buchauer, Bludau, & Haux, 2000). They connect nurses with team members who are geographically dispersed and improve workflow and communication (Breslin, Greskovich, & Turisco, 2004). They complement and often replace the method of face-to-face communication (Parker & Coiera, 2000). However, they also introduce complications into the work system; because communication can be initiated virtually at any time, it tends to be unexpected and becomes new sources of interruptions (Yang & Rivera, 2015). Research needs to be done to determine how the dynamics of interruption mediated by technologies differ from the existing knowledge of nursing face-to-face interruptions (Rivera, 2014). In this presentation, we will discuss a specific type of mobile technology, the hands-free communication devices, in the context of nursing work. We conducted observations in two different healthcare settings. Both settings have implemented the same hands-free communication products; nurses wear a device around their neck, and can use a voice command to initiate outgoing calls or manage incoming calls. In the first setting, we conducted 30 hours of observations, shadowing nurses and recorded 22 interruptions mediated by the device. In the second setting, we conducted 15 hours of observations with nurses and recorded 14 interruptions mediated by the device.

Findings highlight the uniqueness and complexity of interruptions mediated by the hands-free communication device. We found that receiving nurse might experience interruptions upon interruptions. For example, patient care is interrupted by patient's questions inside the patient room, which is further interrupted by an incoming call. Stacking up interruptions makes it even more difficult for nurses to resume to their primary task, because of the cost of short-term memory (Wiberg & Whittaker, 2005). In addition, we identified "grounding" or a negotiation process between the caller and receiver immediately after the call connects. Nurses may proceed with the conversation or terminate the call depending on each other's availability and urgency. That said, nurses may not achieve an effective communication even when their workflow is already disrupted. As described, the complexity of interruptions mediated by mobile technology can negatively impact nursing work from a human factors perspective, but we can address them proactively using a systems design approach.

CONCLUSIONS

Health IT implementation has proven to be difficult. Lack of end-user involvement in design, and failing to incorporate the IT into existing clinical workflow have contributed to the problems with health IT. However, in recent years, some progress has been made. As the presentations in this panel show, there are some areas where progress has been made. Clinical decision support (CDS) has become better in recent years, but still needs improvement, especially CDS that supports teams, as opposed to individuals (Hundt). The other area that has proven to be successful is health IT aimed at involving patients and their caregivers (Asan, Hoonakker, Valdez). However, "patient facing" IT also needs to be adapted to the specific needs of end users (Valdez). Finally, despite the fact that recently there is more involvement of end-users in the design of health IT, the impact that health IT has on clinical workflow still needs to be tackled (Yang & Rivera). In the panel discussion, we will focus on the contribution of human factors to the design, implementation and evaluation of health IT.

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DESIGNING AND MANAGING HEALTHCARE TRANSITIONS

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KEYWORDS
Healthcare, transitions of care, work system design

Concevoir et gérer les transitions en soins de santé

MOTS-CLÉS
Soins de santé, transitions des soins, conception des systèmes de travail

INTRODUCTION

As health care has become more complex, care has been organized into specialty groups. However, due to this specialization, care transitions (e.g., between in-and outpatient care, between services in a hospital, etc.) have become more common. These transitions represent the transfer of information, authority and responsibility between clinicians, and are areas of risk as well as opportunities to prevent error (Abraham, Kannampallil, & Patel, 2014). In this panel, we will examine care transitions from different perspectives, and discuss how these transitions can be better designed and managed.

ABIGAIL R. WOOLDRIDGE, MS will discuss research on care transitions in the pediatric trauma care process. Trauma is the leading cause of death and disability in children and young adults (Stewart et al., 2003). In the emergency department (ED), the trauma team must stabilize the critically injured child while initiating diagnosis and care. Treatment beyond the ED can include inpatient care in a variety of physical locations, or units (Shook et al., 2016). Therefore, caring for pediatric trauma patients inherently requires coordination and transitions between several clinician teams (e.g., pediatric emergency medicine, pediatric trauma surgery, pediatric critical care, pediatric hospitalist team), which may or may not be collocated. These transitions include communication and coordination activities.

As part of a larger, multisite study investigating teamwork and transitions in pediatric trauma care, we focused on three frequent transitions in the pediatric trauma care process: ED to surgery, ED to pediatric intensive care unit (PICU) and surgery to PICU (Wooldridge et al., 2017). We conducted interviews with three physicians from four services (ED, surgery, anesthesia, PICU) over 14.5 hours. Based on these interviews, we identified the roles involved, tasks included and information exchanged in these transitions. These data are used to describe these three transitions and the context in which they occur, i.e. the work system, using the SEIPS model (Carayon et al., 2006). The work system was then linked to communication and coordination activities. Two contextual factors were identified as impacting these activities: physical presence of the receiving providers in the first department and role- versus team-based organization of transitions.

AYSE P. GURSES, PhD, MPH will discuss how human factors engineering can be used to study teamwork and care transitions for pediatric trauma. Trauma is the leading cause of death and permanent paralysis among the pediatric population (Heron, 2013). Ineffective care transitions can pose significant risks to patient safety and result in poor clinical and financial outcomes. This is especially true for transitions of pediatric trauma patients from the trauma bay to the pediatric intensive care unit (PICU) that are often completed under high-stress, high-paced conditions, with uncertain and incomplete information. Integrated care, especially for complex trauma patients (e.g., spinal cord or traumatic brain injuries), require effective teamwork and coordination from a large number of specialties including pediatric surgeons, pediatric trauma surgeons, pediatric specialists in emergency medicine, orthopedics, neurosurgery, anesthesia, critical care, physical medicine and rehabilitation, anesthesia, nursing, respiratory therapy, pharmacy, and social work as well as family members (Wesson, 2012). Each of these services needs to be “weaved” together so that the patient receives coordinated, effective care without safety problems or delays.

A few studies have examined communication breakdowns in some of these transitions (Ligtenberg et al., 2005; Ong & Coiera, 2011; Yamamoto, Wiebe, Maiava, & Merry, 1991), but little is known about the actual work of the team (e.g., problem solving, decision-making, strategies used) during these transitions, which is critical for developing effective interventions. In this presentation, we will describe findings from a study aimed at gaining an in-depth understanding of the pediatric trauma care transitions process from emergency department to PICU, discovering barriers and facilitators to teamwork, and determining implications of study findings for next-generation health IT design. Specifically, we have conducted 12 semi-structured interviews with front-line clinicians and 8 interview sessions with experts (i.e., those who have expertise on pediatric trauma care and who are also on the study team). Qualitative analysis has shown that the nature of trauma makes it difficult to get necessary information because it arrives piecemeal, that there is often a lack of familiarity with caring for pediatric patients, and that time pressure results in a tendency to want to touch the patient rather than listen to care transition information.
Dr. Gurses will present findings related to teamwork, information needs, current health IT design and process facilitators. Results show that health IT does not support a shared mental model and situation awareness among team members; further, a better representation of the problem list (”the story”) of the patient over time is needed. Implications for health IT design include the presentation of patient information to see the entire “story” of the patient over time, role/team specific information displays, and IT design to support a standardized care transition process.

EVA-MARIA CARMAN, MS and **PATRICK WATERSON**, PhD, will discuss human factors and ergonomics research on the handover of care during the discharge process between hospital and community staff. Continuity of care is a vital aspect as the patient transfers from acute to community-based care. As such patient handover during the discharge process has been identified as an area of risk (World Health Organization, 2007). In addition to the safety aspect, the discharge process has also been identified as a potential area for cost containment (Gonçalves-Bradley, Lannin, Clemson, Cameron, & Shepperd, 2016). By ensuring the process is as quick and safe as possible, inpatient costs can be reduced and, in certain cases, by ensuring adequate post-discharge support is in place, unplanned readmissions can be reduced (Phillips et al., 2004). Despite numerous studies investigating interventions aimed at improving discharge planning, it is still uncertain whether these have an effect (Gonçalves-Bradley et al., 2016). As the handover from acute care to community-based care during the discharge process spans several different subsystems within the healthcare context, a holistic approach that includes the different subsystems is required when investigating this process and designing interventions.

The authors will present the method and results from an explorative study investigating not only traditional safety aspects and influencing factors but also factors that aid in task success from various perspectives of staff members involved in the discharge process. Individual focus groups were conducted with both community-based staff and hospital-based staff. Elements explored included aspects of a good discharge, errors, influencing factors, weak signals, learning opportunities, and system elements that assisted in achieving a successful task outcome. Key findings included identifying person-, task-, and organization-related examples that promote a good discharge. Weak signals and elements aiding success will be presented in relation to the SEIPS 2.0 model (Holden et al., 2013). Additionally, the differences and similarities identified by hospital-based and community-based staff will be highlighted. The development plan for an intervention based on participatory ergonomics and including both staff from the community and acute care will be presented.

MARY SESTO, PhD will discuss some of her findings on care transitions of cancer patients. There are more than 13.7 million cancer survivors in the United States (Siegel et al., 2012). This number will double by 2050 due to increasing cancer incidence in an aging population as well as improved screening and treatment. A major consequence of surviving cancer is that treatment-related symptoms can persist and result in work limitations and/or work disability. Nearly 30% of previously employed survivors do not return to work following treatment (de Boer, Taskila, Ojajärvi, van Dijk, & Verbeek, 2009; Mols, Thong, Vreugdenhil, & van de Poll-Franse, 2009; Spelten, Sprangers, & Verbeek, 2002; Steiner, Cavender, Main, & Bradley, 2004) and up to 50% of working survivors report decreased physical and mental work ability (Gudbergsson, Fosså, Borgeraas, & Dahl, 2006; Hansen, Feuerstein, Calvio, & Olsen, 2008; Johnsson et al., 2009; Short, Vasey, & Tunceli, 2005; Steiner et al., 2008; Taskila & Lindbohm, 2007). These limitations can contribute to the “financial toxicity” of cancer treatment. The growing number of survivors – many with multiple comorbidities – creates tremendous challenges in a fragmented health care system. While employment is a critical component of quality of life, it is often not addressed by the health care team leaving many survivors to navigate employment challenges on their own.

An innovative, interdisciplinary approach to improve work ability and employment outcomes was used to develop a web-based, information support system for breast cancer survivors. Strategies from human factors engineering (HFE), decision support, and oncology symptom management were used to develop the WISE (Work ability Improvement through Symptom management and Ergonomic education), a survivor-centered intervention. The conceptual framework for the WISE is based on a macroergonomics work systems model that evaluates aspects of the work system and its interaction with the individual. Our research team investigated the feasibility and short-term effectiveness of the WISE to address employment challenges and improve work ability in breast cancer survivors.

Breast cancer patients undergoing treatment with curative intent and working at time of diagnosis were randomized to the WISE intervention (n=22) or standard of care (n=22) groups. The intervention group was provided access to the WISE that contains occupational and symptom management strategies to address employment and work challenges occurring during and following cancer treatment. Results support that a web-based intervention, easily implemented in the clinical setting, showed improved work ability and decreased work limitations earlier in the intervention group than the control group. Future research will investigate integrating the WISE intervention in the electronic health record so it can be used by patients as a source of patient-centered information to help address the work challenges that may occur during and following cancer treatment.

CONCLUSIONS

Transitions are an inherent, crucial part of the healthcare system, and can be between providers, units, services or facilities. They are complex activities (Abraham, Nguyen, Almoosa, Patel, & Patel, 2011), both an area of risk as well as an opportunity to detect errors and reduce costs. Following the panelists' presentation, we will discuss how human factors can contribute to better design of care transitions to address these complexities.

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ERGONOMICS BUSINESS METRICS: EXPLORING INDUSTRY VALUE BEYOND MUSCULOSKELETAL DISORDERS

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KEYWORDS
Ergonomics Programs, Metrics, Work-related Musculoskeletal Disorders, Participatory Ergonomics, Leading Indicators, Macroergonomics

MAIN MESSAGE
In many companies, the business value of ergonomics is measured through the reduction of work-related musculoskeletal disorders (WMSD) injury rates and associated costs as required by a country's health and safety regulations. The additional benefits of ergonomics to improve quality, delivery, efficiency, employee satisfaction, and profitability are intermingled with other initiatives such as Six Sigma, Total Quality Management, Lean Manufacturing, Sustainability, Safety, and general good business practices. This roundtable discussion will explore strategies industry may apply to realize the value of ergonomics beyond the reduction of WMSDs.

Les paramètres d’affaires liés à l’ergonomie : explorer la valeur de l’industrie au-delà des tms

MOTS-CLÉS
Programmes d'ergonomie, paramètres, troubles musculosquelettiques, ergonomie participative, indicateurs avancés, macroergonomie

MESSAGE PRINCIPAL
Dans de nombreuses entreprises, la valeur commerciale de l'ergonomie se mesure par la réduction des taux de blessures liées aux troubles musculosquelettiques et des coûts connexes exigés par la législation en matière de santé et de sécurité d'un pays. Les avantages supplémentaires de l'ergonomie pour améliorer la qualité, la prestation des services, l'efficacité, la satisfaction des employés et la rentabilité sont interreliés à d'autres initiatives telles que Six Sigma, la gestion de la qualité totale, la fabrication sans gaspillage, la durabilité, la sécurité et les bonnes pratiques commerciales générales. Cette table ronde explorera des stratégies que l'industrie pourrait appliquer pour comprendre l’importance de l'ergonomie au-delà de la réduction des TMS.

PROBLEM

An abundance of formal research, industry case studies and epidemiology results, have demonstrated the positive impact upon the health and wellbeing of hundreds of millions, if not billions, of workers around the world by the application of ergonomics to the design of workstations and jobs. Albert Einstein has been credited with saying “Not everything that counts can be counted, and not everything that can be counted counts.” The value of integrating ergonomics into business processes is less well researched and documented, in part due to the difficulty of identifying, measuring, and understanding complex business-related metrics.

ACTIONS

ROUND TABLE DISCUSSION OUTCOMES

Participants will gain a broader understanding of ergonomic-related business metrics and how they may be applied in industry. Those attending should leave with a new or renewed appreciation for the importance of ergonomics in all types of industries, as well as an appreciation for driving ergonomics through whatever avenue is available for them within their organizations. There will be sufficient time given to audience contribution to the discussion. Participants are encouraged to come to share metrics they have used, why it was chosen and the value it derived to the business.

INTEGRATING HUMAN FACTORS INTO LARGE SCALE ENGINEERING DESIGN PROJECTS

In this symposium, speakers from different countries will illustrate how human factors became integrated into large-scale engineering design projects with a goal to improve both human and system performance. Speakers are from the following sectors: design of light rail transit systems (Canada); knowledge transfer in oil rigs design (Denmark); design for manufacturability in aerospace (US), and design of oil refineries (Brazil). Speakers will share their experiences of integrating human factors into design, including what has worked and not worked. The goal is to share lessons learned for other sectors and organizations, and discuss how our profession can help improve engineering design processes.

1. **Integrating Human Factors into the Systems Lifecycle (ISO 15288) of a Large Light Rail Project**
   Judy Village, Human Factors Consultant

2. **Designing for Production System Safety in Aircraft Development Processes**
   Richard Gardner, Boeing Research & Technology

3. **Integrating experiences from operations into engineering design: modelling knowledge transfer in the offshore oil industry**
   Carolina S. Conceição, Researcher, Technical University of Denmark

4. **Requirements for incorporating human factors/ergonomics into the design process through simulation: oil refinery experience**
   Brasil

Biosketch of Organizer:

Dr. Judy Village is a human factors consultant. She has been involved in large infrastructure design projects of light rail systems in Canada and elsewhere, including train interfaces, control room design, human machine interface design, train signaling systems, station design and wayfinding. Her PhD in industrial engineering at Ryerson University investigated how human factors can be integrated into the manufacturing design process at BlackBerry Ltd.

THE CHALLENGES AND BENEFITS OF CALCULATING THE CUMULATIVE ERGONOMICS RISK ASSOCIATED WITH MULTIPLE SUBTASKS

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KEYWORDS
muscle fatigue, recovery, complex tasks

MAIN MESSAGE
This roundtable session will present a method to determine the recommended cumulative recovery duration required when combining any number of occupational different tasks. The panelists will describe the development of the computational methods used, present their experiences with these methods and outline future challenges to incorporating this approach into their ergonomics practice.

Les difficultés et les avantages de calculer les risques cumulatifs liés à l'ergonomie avec les multiples sous-tâches

MOTS-CLÉS
Fatigue musculaire, récupération, tâches complexes

MESSAGE PRINCIPAL
La table ronde permettra de présenter une méthode visant à déterminer la durée de récupération cumulée recommandée lorsque plusieurs tâches de travail variées sont combinées. Les experts décriront comment les méthodes de calcul ont été développées. Ils présenteront ensuite leurs expériences avec l'utilisation de ces méthodes et donneront un aperçu des défis à relever pour intégrer cette approche dans leur pratique de l'ergonomie.

INTRODUCTION
Most ergonomics tools evaluate individual tasks for injury risk and/or acceptability for a target population (eg. 25th percentile female). While there is usually one subtask that poses the highest risk, most jobs have multiple subtasks that contribute to the overall risk. Until recently, there have been few methods to assess the combined effects of all subtasks. Potvin (2012) presented a meta-analysis of a wide variety of psychophysical studies of upper extremity, and determined that the maximum acceptable effort (MAE), as a percentage of maximum strength, could be characterized with a simple equation requiring only the input of duty cycle (DC - the percentage of a cycle that the task's efforts where exerted). More recently, the ACGIH proposed a new threshold limit value (TLV) for the localized fatigue of the upper limbs with an equation based on the data in Potvin (2012).

Potvin subsequently developed a method to determine a weighted average of the effort levels (taken to the fourth power) across multiple subtasks. The root mean quartic (RMQ) effort could be compared to the MAE from the total duty cycle across all subtasks. Several the panelists have used that method to successfully characterize multiple subtasks, and even optimize subtask allocation in the field. More recently, panelist Murray Gibson made some substitutions in the MAE equation to determine the rest allowance required, for any given subtasks, if its required effort, frequency and effort durations were known. Gibson and Potvin teamed up to develop a tool to calculate the total rest allowance required (termed the 'recommended cumulative recovery allowance' or RCRA) across multiple subtasks, so it can be compared to the total rest provided in each cycle. This method now provides a means to take information, that was already used to perform individual subtasks analyses, and combine it for a total job risk score. The RCRA method shows great promise to optimize subtask allocation and to identify total jobs that have unacceptable risk, even if each subtask was deemed to be acceptable in isolation.

Each panelist has experience using the RMQ and/or RCRA in the field. They will provide their perspective on this issue and speak of the technical challenges when using these methods, their successes with companies in a variety of fields, the current limitations of the methods and future research needs for such tools. We will also solicit ideas, experiences, cautions and suggestions from the audience.

METHODS

The recommended cumulative recovery allowance (RCRA) method, developed and published by Gibson and Potvin (2015) provides a powerful tool for exploring potential improvements to jobs. It is sensitive to small changes in posture, exposure, force, and therefore allows the user to experiment with various ideas. Among its limitations, the most significant is that it is very time-consuming, and leans heavily on the expertise and skill of the user and the validity of the strength analysis software or method. These limitations will surely be overcome with technological advances over the next few years.

A work cycle, for the purpose of this paper, is defined as the interval of time during which each task on a job or within a job rotation, is performed at least once. To use the RCRA, the user must quantify the force, frequency, and duration for each task within a work cycle. (Where several jobs within a rotation are included, each task on each job in the rotation must be captured.) S/he also needs to obtain sufficient information about the postural demands, typically captured with photos and measurements of hand height, forward, and lateral reach. Demands for each task are entered into a biomechanical model in order to estimate the task demands for each joint as a percentage of maximum voluntary exertion (%MVE). These values are entered into a spreadsheet, which is used to calculate the RCRA, and a risk index for each body part.

Where the risk index is high, the user may explore various options. For example:

1) Changing the job rotation may be explored by eliminating tasks and reducing the cycle time (i.e. fewer tasks performed more often), or adding different tasks and increasing the cycle time (i.e. more tasks performed over a longer rotation).
2) Similarly, limiting a worker's exposure to a task may be explored by increasing the cycle time. For example, exposure to a 5 minute cycle for one half of the shift could be approximated by assessing the 5 minutes' task, using a 10 minute cycle. This would assume that the other half of the day is spent in rest.
3) A potential reach reduction would be evaluated by repeating the biomechanical analyses with the hands closer to the body. The new %MVE values are entered to the spreadsheet and a new risk index can be calculated. Other potential postural improvements (height changes, reduction in obstructions, alternate hand positions) can be similarly explored by repeating the biomechanical analysis. Note that

significant reach reductions would likely also reduce the duration required to complete the task; these time components can be mocked up or estimated using industrial engineering methods (time study research, such as MOST).

CASE STUDIES

This method has been applied in three different work environments: automotive foam manufacturing, sausage making, and stand—up forklift driving. They will be discussed during this panel discussion.

1) Automotive foam: In this project, a 3.8 cm reach reduction was shown to reduce the shoulder risk index to more acceptable levels. Various other potential solutions were also explored, including changes to the job rotation schedule.
2) Sausage making: In this project, changes to working height (providing a platform) and to the work method (eliminating the need to rotate a cart half way through the cycle by extending the platform into the cart) were shown to reduce the shoulder risk to acceptable levels. Analysis was also completed to confirm that the platform would not increase the risk of back injury for taller workers.
3) Forklift driving: In this project, changes to the job rotation schedule were shown to moderate the demands on the back and shoulder to acceptable levels, by limiting exposure to backwards driving.

CONCLUSIONS

The methods presented are easy to implement, if individual task analyses have been performed. While future challenges exist, and developments of the method are needed, these types of methods finally allow ergonomics assessments to evolve from single task evaluations of acceptability, to more comprehensive evaluations of a whole job.

REFERENCES

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