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TASK AND ERROR ANALYSES OF INTERCOSTAL CHEST DRAIN INSERTION

S. Kuan[1] and A. O'Dea[2]

[1]Emergency Department, Midlands Regional Hospital Mullingar

[2]Royal College of Surgeons in Ireland, 123 St Stephens Green, Dublin 2, Ireland

Abstract

Background

Intercostal chest drains (ICD) insertion or tube thoracostomy is a common surgical procedure performed in the Emergency Department. Despite training, performance competencies vary and errors in task execution have resulted in adverse events and fatalities (Lamont et al., 2009). We have applied three task analysis tools in order to identify tasks, potential errors and error criticality for the ICD procedure.

Methods

Hierarchical Task Analysis (HTA) is a structured and objective approach to identify and describe the tasks and subtasks that users need to perform in order to achieve a goal. In this incidence, HTA was used to devise a framework of goals, tasks and subtasks required for successful ICD insertion. Credible errors were classified, and rated for probability, criticality and detectability using the Systematic Human Error Reduction and Prediction Approach (SHERPA). The Failure Modes, Effects and Criticality Analysis (FMECA) technique was used to calculate a criticality Index (CI) for each error (O'Sullivan et al., 2011). This method allows all potential errors associated with the procedure to be rated in order of criticality. All of the task analysis methodologies were conducted using expert consensus. This involved expert reviews of the literature and educational materials describing ICD; Semi-structured interviews to define goals, tasks and sub-tasks; focus groups to classify errors; and questionnaires to rate and score errors. Five experts were involved in the expert consensus.

Results

The HTA identified 13 tasks and 61 subtasks associated with the performance of an ICD. Eighty-six potential errors were analysed using SHERPA. Using FMECA, the most critical errors all relate to Task 2 "Mark site of entry" and corresponded to the following errors: incorrect identification

of the 2nd intercostal space (ICS) landmark, marking a site not at the 4th or 5th ICS, marking a site lower than the 5th ICS and failure to check position in safe triangle. The next two most critical errors were failure to anaesthetise the pleura and failure to identify and remedy a persistent air leak.

Conclusion

This study presents an analysis of the tasks and sub task associated with successful performance of an ICD insertion. The study also identifies the most critical errors that can occur during the procedure. Potential application of these data include the development of evidence based guidelines on ICD insertion, procedures to support novices until proficiency is attained, and the development of structured training strategies to teach ICD insertion.

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DO GAPS IN METACOGNITION OF MEDICATION ERRORS INHIBIT REPORTING AND OPEN DISCLOSURE?

C. Duffy[1], G. Bass[2], and A. O'Dea[3]

[1] *Department of Anaesthesiology & Intensive Care Medicine, St. James's Hospital, Dublin 8, Ireland*

[2] *Department of Surgery, Tallaght University Hospital, Dublin 24, Ireland*

[3] *Royal College of Surgeons in Ireland, 123 St Stephens Green, Dublin 2, Ireland*

Abstract

Background

Peri-operative medication errors (ME) resulting from process failures and human physiological and cognitive limitations are a major source of in-hospital patient morbidity (DeVires et al., 2008). The true incidence of peri-operative ME is unclear, with wide variance between self-reported and observational studies (Nanji et al., 2016). A recent unpublished survey of Irish anaesthesiologists found a metacognitive deficit (lack of self-awareness) into error-prone activity in personal practice. The aim of this study was to explore anaesthesia practitioners' awareness of medication error and their willingness to report and disclose them.

Methods

Ten clinical vignettes involving a ME or a near-miss, were developed using e-Delphi consensus. An online survey instrument presented these vignettes to three groups of anaesthesiology practitioners along with a series of questions assessing (i) error awareness (ii) potential harm severity (iii) likelihood of reporting and (iv) likelihood of open disclosure to the patient. Comparison to expert ratings, inter-group differences, and effect of prior training in medication safety were explored.

Results

The survey was completed by 104 respondents from 14 hospitals across Ireland (14% anaesthesia nurses, 46% anaesthesiology trainees and 39% consultant anaesthesiologists). Just 35.6% of anaesthesia practitioners reported having had previous medication safety training; this training was significantly-more common among nurses than physicians ($p<0.001$). ME awareness was variable as was assessment of potential harm severity. Error awareness was

positively-correlated with assessment of potential harm severity. The likelihood of incident reporting was low and independent of harm severity assessment; respondents were even less likely to disclose MEs or near-misses to patients.

Conclusions

This study demonstrates that ME metacognition is lacking amongst anaesthesiology practitioners. This is unsurprising as the majority have never undergone formal medication safety training. Consequently, reporting and disclosure of MEs was poor. Improvements will depend on the introduction of formal education and training to support anaesthesia practitioners' awareness of personal as well as process susceptibility to error, as well as culture change to embed a proactive culture of reporting and disclosure.

Acknowledgements

The authors would like to thank Dr Niamh Hayes (Consultant anaesthesiologist) Dr Eileen Relihan (Medication Safety Officer) for participating in the eDelphi consensus expert group that assessed the vignettes presented in this manuscript.

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OPTIMISING THE SCANNING OF BARCODED PATIENT IDENTIFICATION BANDS FOR IN-PATIENT BLOOD SAMPLING IN A STAND–ALONE MATERNITY HOSPITAL

S. Enright

Rotunda Hospital,

Parnell Square,

Dublin 1

Introduction

The Maternal and Neonatal Clinical Management System (an electronic healthcare record system) and specimen labelling system were implemented simultaneously in November 2017. The rationale for this study was the laboratory reported an increase in blood specimen labelling errors since implementation of the new system. The aim of the study was to increase compliance with scanning of the patient ID (identification) band for in-patients and reduce the patient resampling rate by 50% over a six-month period.

Background

Staff were not fully utilising the patient ID band scanning system. The system for scanning the patient ID band at the time of blood sample collection can be by-passed. This led to specific process failures with the system, resulting in an increase in the number of patient who required repeat sampling due to labelling errors (See Figure 1). Clinical areas required additional equipment to facilitate bedside scanning of patient ID bands. Clinical staff were challenged adapting simultaneously to a new electronic clinical and laboratory system.

Methods

The implementation of targeted blood specimen collection education sessions for end users and promotion of scanning the patient ID band when collecting blood samples from the patient. Clinical areas were assessed individually to determine if they had the necessary equipment to facilitate scanning of patient ID bands.

Results

Auditing of blood sample errors rates performed through the laboratory (specifically from blood transfusion laboratory) over a six-month period has shown a 60% reduction in the number of blood sample errors (see Figure 1) and a 50% increase in the use of the barcoded scanning system (see Figure 2). Measurement of samples rejected and compliance with scanning the ID band was performed through the laboratory.

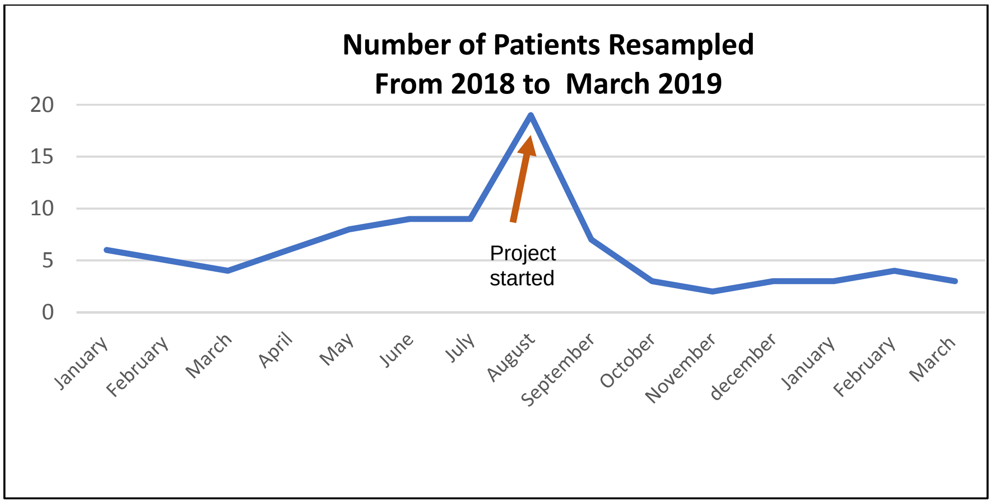

Figure 1. Number of Patients who required resampling * (*Transfusion Laboratory)

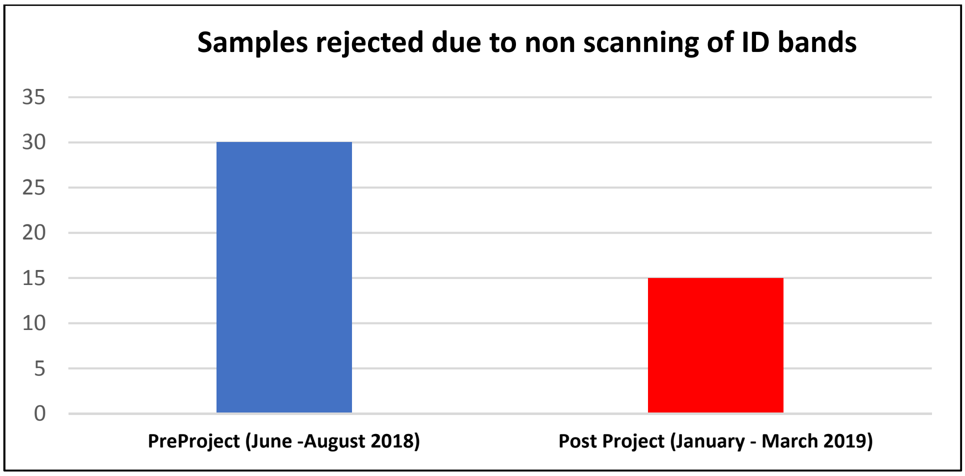

Figure 2. Samples rejected due to non-scanning of ID band* (*Transfusion Laboratory)

Discussion

Technology, combined with Human Factor science are very important for error reduction and patient safety. Equipment manufacturers and organisations do not incorporate the strategies to reduce error and the responsibility for this lies with those directly delivering care to patients. The results exceeded expectations and there has been a change in culture. The project has had a positive impact by improving patient safety and efficiency of the electronic specimen labelling system.

THE HSE PATIENT SAFETY STRATEGY 2019-2024

Mr. Patrick Lynch, Dr. Sean Denyer, Dr. Samantha Hughes.

Quality Assurance and Verification, Office of the Chief Clinical Officer, Health Service Executive.

Introduction

National and international evidence shows us that as many as 1 in 8 patients suffer harm while using healthcare services, with up to 70% of this harm preventable (Rafter et al., 2016). It is for this reason that the development and implementation of the first overarching HSE Patient Safety Strategy 2019 – 2024 is a priority for the newly established Board of the HSE. Our vision is that all patients using our health and social care services will consistently receive the safest care possible.

Methods

A co-design approach was adopted for the development of the strategy. Wide ranging consultation on the draft strategy was undertaken with both internal and external stakeholders.

Results

The HSE Patient Safety Strategy describes 6 key commitments to patient safety and outlines actions required to address these commitments. We commit to:

- **Empower and Engage Patients to Improve Patient Safety**
- **Empower and Engage Staff to Improve Patient Safety**
- **Anticipate and Respond to risks to Patient Safety**
- **Reduce Common Causes of Harm**
- **Use Information to Improve Patient Safety**
- **Provide effective Leadership and Governance to Improve Patient Safety**

Discussion

Nurturing a culture of patient safety which places emphasis on a culture of transparency and organisational learning, including a focus on building resilience and learning from when things go right, as well as where they go wrong, is critical. This must be supported by meaningful involvement of patients and staff, effective governance and leadership and a commitment to enhancing our safety capability.

A National Patient Safety Programme has been established, led by the Chief Clinical Officer to oversee, monitor and report on the implementation of the strategy.

References

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SIMULATION & SYSTEMS:

IMPROVING THE DOOR TO NEEDLE (DTN) TIME FOR THE STROKE PATIENT

F.Connaughton, D.Khalil, D.Carolan

Acute Stroke Service,

Our Lady of Lourdes Hospital,

Drogheda

Introduction

Intra Venous tissue Plasminogen Activator (IV tPA) remains the standard treatment for Ischaemic Stroke (IS) presenting to the emergency department within four and a half hours of last being well. The benefits of IV tPA are time-dependent and treatment for eligible patients should be initiated as quickly as possible (Jaunch et al., 2013). Early 2018, we initiated a study to explore alternative ways to reduce our Door To Needle (DTN) times to less than 60 minutes.

Method

Based on change management theories and models we changed our system using a range of methods. To determine which model of change to use, we looked at our organisation type and decided on the model for improvement (Institute for Healthcare Improvement, 2003). Human Factors /Ergonomics (HFE) strategies were applied throughout all stages of the system re-design (Xie and Carayon, 2015). The measurement for improvement (Donabedian, 2005) was used to evaluate the impact of the interventions proposed in the change project. In-situ Stroke Simulation (SS) was used to test change during Plan Do Study Act (PDSA) cycles. Kirkpatrick's evaluation model was used to assess the learning in the organisation during these cycles .This model was then used to evaluate if learning had led to behavioural changes, resulting in improvement in the overall aims of the project.

Results

The DTN times in our hospital have been reduced from a Median of 82.5 minutes to 59 minutes. Quantitative, qualitative and observational data was collected. An observational checklist was completed during the SS, highlighting potential /actual risks. A feedback form with a likert scale was completed after each SS. To date 22% (23/106) of participants agreed and 78% (83/106) strongly agreed that they had more confidence to deal with a stroke scenario after the SS.

Conclusion

The combination of simulation based education and changes implemented within the system have led to sustainable improvements in our DTN times.

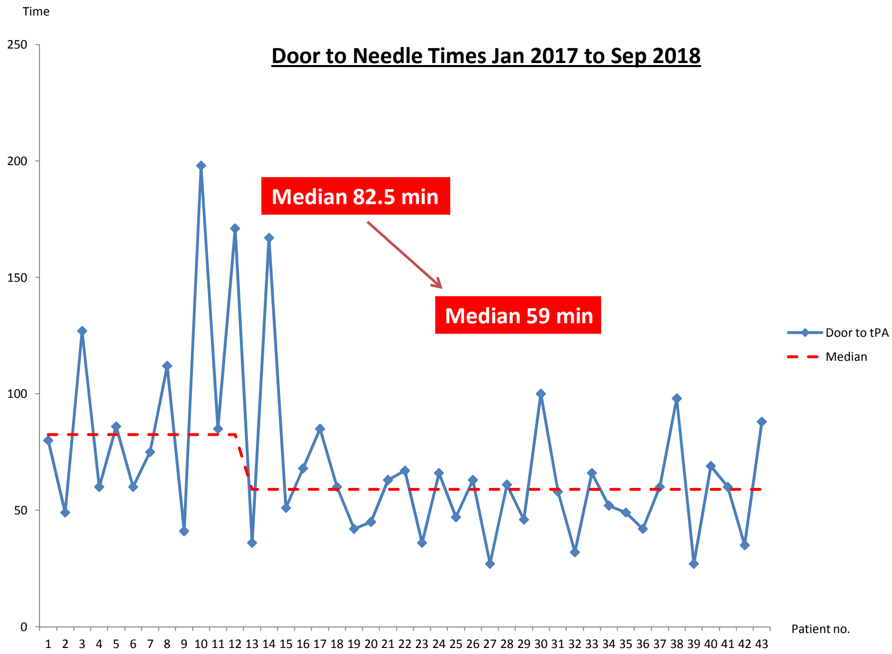

Figure 1. Door To Needle (DTN) times

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REDUCING THE RISK OF RETAINED FOREIGN OBJECTS

Corrigan, S., O'Byrne, K., Kay, A., Galen, D., and Cromie, S.

Centre for Innovative Human Systems, School of Psychology,

Trinity College Dublin

Introduction/background

'Never events', like Retained Foreign Objects (RFOs) are typically rare but can lead to serious outcomes in healthcare.

Methods

This research aims to explore this problem by applying a multi-stage qualitative study that not only focuses at the level of the 'human error' but also at the system level in order to develop, implement and evaluate effective interventions.

Results

The three key themes emerging from the data to date include:

(ii) Personnel resources: limited staffing levels appear to create challenges for counting procedures and policy revision. Challenges were reported in managing staff changeovers in theatre, especially in relation to counts e.g. interplay of different nursing roles (anaesthetic nurse performing circulatory role).

(ii) Education and Training: a lack of formalized education and training for the prevention of RFOs surfaced. Another important aspect was the sharing of experiences as informal learning from incidents or near-misses. However this is dependent on the personnel and due to its informal nature is not always guaranteed.

(iv) Communication: Good teamwork and communication is evident and facilitates tacit knowledge sharing however there was no formal training in place to capture this learning to assist in the prevention of foreign object retention. Staff also reported that both nurses / midwives and junior doctors would benefit from training in how to assertively challenge superiors in a non-aggressive manner.

Discussion

One of the interesting findings to emerge from this study is to further explore if there is a role for a practical solution to increase reporting of near-misses and formalise the potential learning from both incidents and near-miss trends? Would the learning from near miss reports provide a better understanding of the current challenges as they arise? What role does culture play in how important the count is perceived by some and why does this permeate to the perception of near misses as non-events?

Acknowledgements

The authors gratefully acknowledge the Health Research Board of Ireland who provided the Grant for this research (Grant reference: RCQPS-2016-2) and all participants.

THE VALUE OF SOCIO-TECHNICAL SYSTEMS ANALYSIS IN UNDERSTANDING CHANGE IN HEALTHCARE: LEARNING FROM THE APPLICATION OF RFID-ENABLED TECHNOLOGY TO THE TRANSPORT OF PRECIOUS LABORATORY SAMPLES

Una M. Geary

Quality and Safety Improvement, St James's Hospital, James's Street Dublin 8, Ireland; Honorary Clinical Lecturer, School of Medicine, Trinity College Dublin.

Introduction

The purpose of this study was to capture systems learning from the re-design, delivery and management of an innovative RFID-enabled specimen transport system, to better understand of complex systems change in an acute hospital setting and identify areas for systems improvement.

Methods

The value of systems analysis, using a socio-technical systems analysis (STSA) framework, the "Cube" (McDonald, 2018 a, b; Corrigan et al., 2018), was explored in an acute hospital setting through an action research case-study, with qualitative and quantitative data collected using mixed methodologies of interviews, site visits, document review, data analysis, a focus group and a workshop. An action research (AR) approach was deployed to progress successive core cycles of the project. Meta-cycles of reflection were conducted by the researcher and with study participants to identify and evaluate actionable knowledge.

Results

The Cube STSA provided a useful framework for the extraction and organisation of information about the system and identified areas for improvement. The analysis and AR approach created new social interactions and reflective learning among the system's teams. It also enabled the value of RFID implementation to be described.

Conclusions

The study demonstrated that the Cube framework, combined with AR, offers a pragmatic approach to systems analysis in a healthcare setting and adds value through

the co-creation of new knowledge and enhanced social interactions. Specific implementable improvements were identified, including the need for a real-time monitoring and audit system and a shared commitment to the further strategic development of the system that emerged from the project facilitated its expansion and further business planning has since been progressed.

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INVESTIGATING THE PREDICTORS OF HAND HYGIENE IN THE ICU SETTING: A CROSS-SECTIONAL OBSERVATIONAL STUDY

E. O'Dowd, S. Lydon, C. Madden, C. Walsh, S. Fox, K. Lambe, O. Tujjar, C. Greally,

J. Bates, M. Power, P. O'Connor

Irish Centre for Applied Patient Safety and Simulation, School of Medicine

NUI Galway

Galway, Ireland

Abstract

Background

Critically ill and immuno-compromised patients in Intensive Care Units (ICUs) are particularly vulnerable to Healthcare Associated Infections (Tajeddin et al., 2016). Despite the recognition of appropriate hand hygiene practices as the most effective preventative strategy for infection, adherence continues to be suboptimal in ICU settings (Lambe et al., 2018). The aim of the current study was therefore to examine hand hygiene compliance in Irish ICU settings, and to consider variables (professional role, shift pattern, and type of opportunity) which may impact compliance levels.

Methods

A cross-sectional observational study was conducted in four ICU units across three teaching hospitals in Ireland. The standardised WHO method 'Five moments for hand hygiene' (WHO, 2009), was applied to assess compliance. At each bed space, a trained observer openly observed all healthcare workers (HCWs) who came into contact with patients or the patient zone during a period of 20 minutes. Observers recorded the professional category of the HCW, total number of 'opportunities' for HH (i.e., the occurrence of any of the five WHO indications during the observed care sequences), and whether compliance was achieved (either by hand washing with soap and water or hand rubbing with alcohol-based hand rub).

Results

A total of 712 opportunities were recorded, with an overall compliance rate of 56.9%. Logistic regression analysis revealed that HCWs were up to four times more likely to engage in hand

hygiene compliance after bodily fluid exposure and after contact with patient surroundings, than before an aseptic task. Physicians were less likely than nurses to engage in hand hygiene compliance. HCWs were twice as likely to comply during night shifts compared to morning shifts.

Discussion

The compliance rate is similar to those of previously conducted studies (Lambe et al., 2018). Findings suggest there is a need for research that aims to understand why differences exist across professional roles, shift patterns, and between specific opportunities, before novel and practical improvement strategies can be implemented.

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Acknowledgements

The "A Moment for Hand Hygiene in the Intensive Care Unit: How Can Compliance Be Improved?" project is funded by the Health Research Board.

INTERNATIONAL HAND HYGIENE COMPLIANCE FALLS SHORT OF TARGETS IN INTENSIVE CARE UNITS

K.A. Lambe[1], S. Lydon[1], C. Madden[1], A. Vellinga[2], A. Hehir[2], M. Walsh[2] and P. O'Connor[1]

[1] *Irish Centre for Applied Patient Safety and Simulation, School of Medicine*
NUI Galway
Galway, Ireland

[2] *School of Medicine*
NUI Galway
Galway, Ireland

Abstract

Background
Hand hygiene is regarded as the most effective means to prevent infection and is of particular concern in the Intensive Care Unit (ICU) (Pittet et al, 2006). However, compliance in the ICU is reported to be low (Lydon et al, 2017). The objective of this systematic review was to synthesise the literature describing compliance with WHO hand hygiene guidelines in ICUs, to evaluate the quality of extant research, and to examine differences in compliance rates levels across geographical regions, ICU types, and healthcare worker groups, observation methods, and Moments (indications) of hand hygiene.

Methods
Electronic searches were conducted using Medline, CINAHL, PsycInfo, Embase, and Web of Science. Study characteristics and compliance were extracted by two authors, and mean compliance, effect size and heterogeneity were calculated.

Results
Out of more than 5,480 papers screened, 61 studies met inclusion criteria. Most were conducted in high-income countries (60.7%) and in adult ICUs (85.2%). The median number of opportunities observed per study was 903 (mean = 3,026). Weighted mean compliance was 59.6% (n=184,597 opportunities). Compliance levels varied by geographic region (high-income countries 64.5%, low-income countries 9.1%) and type of healthcare worker (nursing staff 43.4%, physicians 32.6%, other staff 53.8%).

Discussion
Mean compliance appears notably lower than international targets, which are often set at >80%. The data collated provides context for Irish compliance and may offer useful benchmarks indicators for those evaluating, and seeking to improve, hand hygiene

compliance in ICUs internationally. Further research is required to establish the reasons for variations in performance, which will inform targeted interventions based on human factors and behaviour change principles.

Table 1. Levels of compliance with hand hygiene in ICU

	Weighted mean % compliance	Weighted SD	No. studies	Total no. opportunities
WHO Moments				
All observed Moments	59.6	15.88	61	184597
Moment 1	36.0	17.85	16	6521
Moment 2	31.5	15.81	15	2633
Moment 3	49.1	24.76	14	2447
Moment 4	54.4	19.68	13	4478
Moment 5	45.6	17.60	11	4175
No Moment-specific data presented			43	
Observation method				
Covert	57.9	14.63	12	14378
Not covert	58.3	17.20	36	115266
Observation method not reported			16	
Study location income				
High income	64.7	14.13	37	124016
Upper middle income	43.0	18.01	12	14062
Lower middle / low income	41.7	20.48	10	11290
No location-specific data presented			2	
Participants				
Nurses and nursing staff	43.4	13.64	21	20786
Physicians	32.6	10.84	16	5760
Other staff	53.8	23.47	5	1178
No HCW-specific data presented			40	
ICU type				
Adult	58.2	16.04	49	145912
Paediatric / neonatal	58.2	21.50	16	8304
No ICU-specific data presented			4	

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Acknowledgements

The "A Moment for Hand Hygiene in the Intensive Care Unit: How Can Compliance Be Improved?" project is funded by the Health Research Board.

THE INFLUENCE OF HUMAN FACTORS EDUCATION ON THE IRISH REGISTERED PRE-HOSPITAL PRACTITIONER WITHIN THE NATIONAL AMBULANCE SERVICE

Desmond Wade and Alfredo Ormazabal

National Ambulance Service College,

3rd Floor, The Rivers Building,

Tallaght, Dublin 24

Abstract

Background
The range of tasks and competencies of a paramedic in Ireland continues to expand, and so does the complexity of contents included in the education of such practitioners. Current recognised institutions include Human Factors Education (HFE) for paramedic training; however the extent of it rarely goes beyond the '6 rights' principles of Medication Safety (1).
This study focuses on the areas of Stress, Workload and Decision Making, to gain knowledge of the current state of the art in HFE among National Ambulance Service practitioners.

Methods
A mixed methods approach was used, with a 45-item online questionnaire and semi-structured individual interviews. All participants were pre-hospital practitioners, registered with the Pre-Hospital Emergency Care Council, and currently employed by the National Ambulance Service.

Results
208 questionnaires were returned with a completion rate of more than 95% and 6 interviews took place. The results of the questionnaire indicate that there is uneven understanding of the concept of Human Factors, with a significant lack of recognition of the importance of HF in mitigating risk areas such as Stress, Workload and Decision Making.

Conclusions
The evidence presented leads to the conclusion that in the National Ambulance Service there is a considerable lack of education of Human Factors and the levels in understanding of how to manage Human Factors in practice vary across its spectrum.

There is a strong case for the development of a Human Factors Education Module in current paramedic training.

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TRUST IN GOVERNANCE

Nick McDonald

Centre for Innovative Human Systems,

Trinity College Dublin,

Ireland

Abstract

The logical conditions for a transition from compliance-focussed regulation to a productive, performance-based regulation are explored. Three criteria for governance are suggested: comprehension of complexity; efficacy of response; and scalability of the solution to all relevant parts of the system. The general principle that self-reference enables the system to change underlies an escalating virtuous cycle of systemic knowledge creation about operations and change, leading to evidence-based governance. Governance as a process should explicitly manage 'self-organisation' by creating appropriate enabling conditions – motivation to act and clear management channels for action. Through this one can build accountability based on a realistic appraisal of both positive and negative outcomes (rather than blame for failure) and foster trust in system governance.

Introduction

When something goes wrong we expect the following from the institutions we trust:

- Understanding of what happened despite all the complexity of the circumstances;
- Do something effective about it - a proportionate response to the problem;
- Prevent it from happening again – wherever such an event may potentially occur.

These suggest three criteria for governance: comprehension of complexity; efficacy of response, both in principle and in practice; and scalability of the solution to all relevant parts of the system. These criteria are even more pertinent in the anticipation and prevention of operational hazards before they can contribute to an adverse event.

New versions of safety regulation increasingly call for understanding and management of risk inherent in performance, implementation and verification of outcomes of improvement, a common understanding and culture that values safety, within a policy that goes beyond compliance to being proactive, predictive and preventive (for example ICAO, 2018, Draft Patient Safety Strategy, 2019).

There is a massive disproportionality between the cost of failure and the cost of prevention. In Ireland in 2009, the cost of adverse events related to adult in-patients was €194m – 4% of public hospital expenditure (Rafter et al. 2016). The cost of prevention is a small fraction of the cost of harm; for some conditions (e.g. VTE) it can be as little as 0.13% of the overall cost of the harm. Yet the literature consistently shows little visible improvement in these rates over the last 10-15 years (Slawomirski et al., 2017).

When we talk to those responsible for safety in leading institutions, they often report that they are overwhelmed with reports and data that demand a response. Thus, they do not have time to be reflective, preventive and to focus on the implementation of solutions. What is the fundamental problem underlying this apparent stasis? What steps are necessary to build confidence that the system can be changed in line with policy aspirations?

Methodology

This is a conceptual paper that seeks to explore the logical conditions which would enable a transition from a largely compliance-focussed regulation to a productive, performance-based regulation. The methodology is based on the Socio-Technical Analysis Cube (McDonald, 2018 a, b; Corrigan et al., 2017) which provides a framework for analysing complex socio-technical problems, identifying core mechanisms that are critical for the quality of outcomes, and tracking an implementation programme. There are four main functional dimensions to the analysis, each representing a basic organisational principle: purposive systems have goals; there is a minimal sequence of activity necessary to achieve those goals; people work with others and report to others; information and knowledge make this possible, with flow, transformation and feedback determining the quality and validity of that knowledge. These dimensions of activity can be represented as a functional system; as measured or recorded activity; as made sense of by participants and as it is reflected in the cultural values, norms, sub-cultures and beliefs of the community. This paper considers the functional point of view of the system, looking for plausible logical or causal relationships within the system that could explain how it could function. Some theoretical considerations that seek to account for the functional system 'as-it-is' are then put forward. Alternative theoretical propositions are proposed which could show how to transform the current 'as-is' into a productive governance 'to-be'. Based on this, the elements of a Productive Governance model are put forward.

This is the first stage of a system design process – exploring an operational concept for a future governance system as a functional model. This is part of the requirements gathering process for the design and building of a platform to support evidence-based governance against criteria of complexity, efficacy and scalability. It links also to requirements for the development of training to support full implementation of SMS in a variety of industries – aviation, health, and emergency services. It draws on a series of EU framework projects (most particularly, but not exclusively, HILAS, MASCA, PROSPERO, ACROSS, FutureSkySafety). It builds on work on implementing improvement (Ward et al., 2010), change processes (McDonald, 2015; Ulfvengren and Corrigan, 2015), data analytics (Baranzini, 2017), governance (McDonald et al., 2019; Callari et al., 2019; McDonald and Ulfvengren, 2019), analysing incident investigations (McCaughan et al., 2017).

Results

The results are summarised in the following three tables.

Table 1. Knowledge

Current state of art	Current theoretical propositions	Resolution of dilemma	Productive Governance model
1. Even results of serious investigations are context bound and difficult to generalise 2. Operational data, when used, tends to be used reactively, focusing on deviations 3. There are many competing recommendations that tend to be local and limited by context; thus, it is uncertain what to change in the system. 4. Strategic oversight is of trends only, rather than underlying problems. 5. Providing assurance against a stable standard predominates (ALARP)	Hollnagel (2014) suggests that complex S-T systems are intractable; emergent characteristics are situation specific and not generalisable. Only those at the 'sharp end' really understand the operation. Vincent and Amalberti (2016) propose fewer systems investigations, concentrating on fewer more extended investigations. Dekker (2006) provides examples of great depth of analysis from point of view of protagonists – but provides little prospect of generalisation. The problem of the representativeness of an event with respect to the general variance of the system is not discussed.	Single events are not representative of variance in a complex system. Understanding complexity requires a multiplicity of normal and non-normal data. Change processes are more complex than routine operations but can be better understood through multiple case studies with common methodology. Integrated data analysis and model-based reasoning can identify new emergent system characteristics, which point to leverage to change the system. Different types of risk are in part commensurable; i.e. the cost of operational failure is calculable; as is the operational risk associated with a financially motivated decision.	1. Big data - quantitative operational data can identify predictive risk patterns. 2. Qualitative analysis of many events, change projects, emergency response can identify common factors and emergent characteristics. 3. Systemic tracking of implementation of change, in multiple projects & business units, can link quality of activity with outcome 4. Aggregation of operational risk in these ways enables integrated risk-based strategic decision-making 5. Governance can be built on a solid evidence base.

Table 2. Process

Current state of art	Current theoretical propositions	Resolution of dilemma	Productive Governance model
1. Data remains in silos 2. Assumption of simple linear process – risk, mitigation, action, sign-off 3. Lack of process linking solution to implementation to verification. Weak implementation of complex solutions 4. Lean / PDSA initiatives have local impact 5. Risk registers give vertical oversight, but lack implementation force	Change is emergent and cannot be managed (Dawson) 'Spontaneous' complex adaptive system tendencies can be facilitated (Braithwaite et al., 2018)	Being well informed about the importance of a problem, the efficacy of a solution, and the availability of the next steps, together create a 'compelling obligation to act' to hand the problem over to the next implementation stage. This motivational framework within routine management processes can improve reliability of achieving outcomes. Outcomes motivate intervention	1. Integration of all relevant sets of data for systems analysis. 2. Explicit management processes link risk assessment, implementation of mitigation, and verification of outcome. 3. Integrated management of operational, technical and strategic risks. 4. Integrated risk management drives planning, resource allocation and performance management

Table 3. Social Relations

Current state of art	Current theoretical propositions	Resolution of dilemma	Productive Governance model
Social relations: Accountability 1. Credibility of 'just culture' policy requires alternative ways of establishing cause and ensuring mitigation. 2. Risk professionals report little proactive influence over strategic decision makers 3. Liability and blame are key drivers of accountability	Model of supervision of operations deal will many organisational issues – culture, coordination, etc. – but not the management of risk (Raaijmakers, undated)	Trust is based on establishing common goals, open communication, time and opportunity to review and adjust (Ward, 2005)	1. Accountability can be built on understanding link between action and outcome (both positive and negative). 2. Transparent and effective governance builds trust. 3. Trust enables productive relations across an extended enterprise (where formal accountability is weak).

Discussion

The diagnosis of the problems faced by the current state of the art largely come from the the point of view of Resilience Engineering and provide powerful reasons why the current regulatory system cannot work effectively. However this diagnosis has not offered practical solutions, beyond an argument for a change in mindset, though this is important. A rethinking of the fundamental problem is necessary. There are three aspects to the crisis of governance that suggest a pathway to a solution:

1. Knowledge – knowing what to do and how to do it, understanding problems and implementing solutions.
2. Process – joined up governance of organisations to ensure robust management processes that are capable of managing from problem identification to solution to implementation to verification of effective outcome.
3. Accountability for outcomes, based on understanding of systemic causes and effects, rather than liability and blame in the case of failure.

In relation to the knowledge dimension, there is a general principle that self-reference enables the system to change; this can be an escalating virtuous cycle in the following way:

1. Operational system acting in the world at large

Single events cannot be representative of complex dynamic systems. Therefore one cannot draw firm and generalisable conclusions from their analysis alone. We need to analyse multiple events to deduce common properties that are generalisable across the system. The detection of common patterns across different events enables the identification of emergent system properties. It commonly requires deep system knowledge and experience to pose new system properties using model-based reasoning. Once this is done it provides the basis for a new activity based on this knowledge: e.g. initiating an improvement or change project.

2. Governance acting on the system:

Likewise it takes many projects to understand how the system itself can be changed – both parallel projects on similar topics, and contrasting topics, across different business units. This will enable detection of emergent properties of system change across a complex organisation. Model-based reasoning should take into account both the role of governance and self-organising capabilities within and between organisations.

3. Evidence-based governance

The system is now building evidence about both governance processes and system operation. This feeds back into both of those levels consolidating a new knowledge-based operation and its governance. This evidence base is sharable across and between organisations and industries.

Governance as a process should explicitly manage ‘self-organisation’ by creating appropriate enabling conditions – motivation to act and clear management channels for action. A compelling obligation to act can result from knowing the importance of the problem, the efficacy of the solution, and having a clear and accountable channel of action. Satisfying these criteria can enable a virtuous cycle of organisational activity at three levels: gathering diverse sources of information requires an explicit set of processes; the circulation of tailored risk information generates an operational focus on risk priorities; building a case for system change and understanding how to increase the reliability of outcomes builds a tactical capability of organisational responsiveness; actively managing the interaction of multiple projects across business units enables an integrated risk management linking strategic, technical and operational risks to support decision and action at system level. This should enable coherent and accountable planning, resource and performance management.

The rules of the game have now changed, with a new set of social relations. While previously there appeared to be irreconcilable contradictions between top-down (compliance driven) processes and bottom up self-organising, the new governance, while it does not eliminate conflicts of interest, provides evidence about context, cause and consequence that enables these conflicts of interest to be addressed at a new level, in a new way. It builds accountability based on a realistic appraisal of both positive and negative outcomes (rather than blame for failure). It builds trust based on a real appraisal of shared interests (as well as differences) and provides the opportunity to openly address how to maximise shared value.

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ARE STRESS AND MUSCULOSKELETAL DISORDERS STILL A PROBLEM FOR BUS DRIVERS AND FARE COLLECTORS?

Penpatra Sripaiboonkij[1], Ronnapoom Samakkeekarom[2], Arroon Ketsakorn[2, *]

[1]*School of Public Health, Physiotherapy and Sports Science, University College Dublin, Ireland*
[2]*Faculty of Public Health, Thammasat University, Thailand*

[*] *Corresponding author*

Abstract

Introduction: Sitting in a restricted area for a long time is not good for health in any task including bus driving. Several studies have shown that professional bus drivers are a vulnerable occupational group. There are several risks to bus drivers including coronary heart disease (Wang and Lin, 2001), cardiovascular disease (Chen et al., 2010) and stress as they have limited autonomy (Useche et al., 2018). Bus drivers sometimes have to follow shift schedules and might have to drive long hours depending on the company policy.

Methods: A cross-sectional study design was used. Bus drivers and fare collectors completed a self-administered questionnaire named Suanprung Stress Test-20 (SPST-20), and Abnormal Index (AI) for assessing stress and fatigue respectively. The researchers conducted ergonomic risk assessments in bus drivers and fare collectors using RULA and REBA. Descriptive data analysis was presented in the study.

Results: Of the participants (n=421), the majority (87.9%) were ≥ 45 years of age, had secondary level education (61.0%), married (61.8%) and had worked for more than 10 years (73.2%). The majority of bus drivers and bus fare collectors (75.8%) reported a low to medium level of fatigue. Sixty percent of bus drivers had a low risk level of musculoskeletal disorders and 61% of bus fare collectors had a medium risk level of musculoskeletal disorders. Bus drivers and fare collectors reported that they were stressed at work at medium to high levels (85.8%), See Table 1.

Discussion and conclusions: Risk of stress and musculoskeletal disorders are still a problem in bus drivers and fare collectors. Musculoskeletal disorders could influence stress and vice versa. It might be difficult to improve the workplace as the size and layout of buses are standardised so that to protect employees from stress and MSDs from work the primary prevention level e.g. dietary, exercise might have to be considered.

Table 1 Health risk in bus drivers and bus fare collectors

Health risk	Results	n	%
Fatigue (in bus drivers and bus fare collectors)	No issue	13	3.1
	Little, manageable	188	44.7
	Medium, concern	131	31.1
	Need help	70	16.6
	Need help immediately	19	4.5
Total (N = 421)			
Stress (in bus drivers and bus fare collectors)	Low	14	3.3
	Medium	205	48.7
	High	156	37.1
	Very high	46	10.9
Total (N=421)			
Risk of MSDs (in bus drivers)	Low risk	92	60.1
	Medium risk	61	39.9
Total (N=153)			
Risk of MSDs (in bus fare collectors)	Low risk	20	8.5
	Medium risk	143	60.9
	High risk	72	30.6
Total (N= 235)			

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GENDER DIFFERENCES OF WORK RELATED UPPER LIMB DISORDERS IN MANUAL THERAPISTS: ERGONOMICS OR BEHAVIOUR?

BA. Greiner[1,] and DAM. Hogan[1,2]

[1] *University College Cork, School of Public Health, Cork, Ireland*

[2] *South/South West Hospital Group, Programme Management Office, Office of the CEO, Cork*

Introduction

Female workers commonly show higher prevalence of work-related upper limb disorders (WRULD) than males. Research on explanatory factors is inconclusive (Coté, 2012). Objectives were to (1) determine gender-specific WRULD prevalence in Irish manual therapists, (2) systematically test explanations for gender WRULD disparities, such as differences in physical and psychosocial work exposures, exertion, good-practice work styles, and (3) compare whether women were more vulnerable to physical and psychosocial exposures.

Methods

Health In Hand - Intensive Tasks and Safety (HITS) study included 114 male and 233 female (n=347) hospital-employed and self-employed Irish Chartered Physiotherapists and Physical and Athletic Therapists (cluster and random sampling). They completed the Nordic Questionnaire (neck, shoulder, elbow, wrist, finger, thumb), the Copenhagen Psychosocial Questionnaire (demands, tempo, influence, predictability, social support), physical exposures questionnaire (repetitive movements, postures, Borg exertion scale), and questions on good-practice behaviour (Greiner et al., 2012). Logistic regression with adjusted prevalence odds ratios (POR), gender-stratified PORs was performed.

Results

Women reported a significantly higher prevalence for shoulder (56% vs. 35%) (POR=1.7, 1.2-2.7) and neck symptoms (58% vs. 44%) (POR=2.3; 1.4-3.7). Good work practices, physical exposures and exertion did not differ by gender, except for higher duration and frequency of neck twisting/bending in women. Women reported significantly higher tempo and emotional demands. The magnitude of associations between psychosocial and physical exposures and WRULDs were similar in gender-stratified analyses. Exertion due to repetitive arm and neck movements was more strongly associated with neck/shoulder symptoms in women than in men.

Discussion

Work-related explanations for gender disparities in neck/shoulder symptoms include higher exposure of females to certain psychosocial risks and higher vulnerability to physical exertion due to repetitive arm and neck movements. Gender-sensitive risk assessment for the prevention of WRULDS is warranted. Given the high WRULD prevalence in both genders, prevention in healthcare workers with hand-intensive occupations is necessary

Acknowledgement

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DOUBLING DOWN ON STAIR USAGE: THE EFFECT OF POINT OF DECISION PROMPTS ON STAIR USAGE IN A UNIVERISTY BUILDING

S. Griffin[1], S. White[1], K. Flanagan[1], S. Ryan[1], F. Maguire[2], M. Mullin[3], M. Tanner[4] and E. Barrett[1]

Discipline of Physiotherapy[1], School of Medicine[2], Healthy Trinity[3], Trinity Sport[4]

Trinity College Dublin, the University of Dublin,

Dublin

Abstract

Background: Stair use is a simple and cost-effective method of increasing daily incidental physical activity. Initiatives encouraging stair use through the installation of point of decision prompts have been found to be widely effective. The aim of this study was to evaluate the effect of such an intervention on stair use within a health sciences building in Trinity College Dublin.

Methods: This was a time-series observational study during which stair and elevator use within the building were made pre-, mid- and post-intervention.

Results: A total of 2506 observations were recorded. Overall no significant change in stair usage was found, however, a significant decrease in the number of users exiting the elevator on the second floor was recorded ($p<0.05$).

Discussion: Study results are discussed with reference to the feasibility and implementation of point of decisions prompts within a university environment.

Introduction

Physical inactivity and increased sedentary behaviour are major public health concerns that make a substantial contribution to the burden of chronic diseases (Lee et al., 2012a). Many public health initiatives have focused on the promotion of stair use in a variety of settings as a means of incorporating physical activity into daily life (Reynolds et al., 2014, Jirathananuwat and Pongpirul, 2017). Point of decision prompts (PODPs) include signage in the form of posters and stair-riser banners placed at the point of choice between stairs and elevators to encourage stair use. There is evidence to support these inexpensive, environmental interventions in a number of different settings such as office buildings, public transport stations and university campuses (Reynolds et al., 2014, Jirathananuwat and Pongpirul, 2017). Tailoring the messages to the target population has also been noted to enhance their effect (Eckhardt et al., 2015).

The Healthy Trinity Campus group was established in Trinity College Dublin in 2015 with an overarching goal to embed health into all aspects of campus culture. The present study falls under the remit of this committee's physical activity subgroup who, together with the health promotion officer, wished to evaluate the effect of point of decision prompts on stair use in a health sciences building; the Trinity Biomedical Science Institute (TBSI). A secondary objective was to investigate the feasibility of implementing these point of decisions signs on a more wide scale basis across the university.

Methodology

Study Design and Setting

This was a time-series observational study conducted over eight weeks from February to March 2019. The TBSI building consists of seven upper floors and includes facilities such as lecture theatres and laboratories. A total of four elevators are available in the building as well as a hidden stairwell, which are accessed from the main foyer by a set of double doors into a central area. The elevators are seen first upon entering this area along with a further door opening into a hidden stairwell.

Intervention and Design of the Signs

Point of decision prompts in the form of signage were installed within the TBSI to promote stair use. Initially, the Estates and Facilities Department TCD, were consulted and permission to install the signs, with restrictions, was received. A large sign was placed in the entrance foyer above the double doors into the central area, which was visible to all building users entering the facility. Within the central area on the ground floor smaller signs were installed on each elevator door. These were kept in place for a period of four weeks.

Initially, a consultation phase was carried out to inform the messages used on the signage. Previous studies had incorporated environmental, academic, goal-related, mental and physical health motivations for taking the stairs (Ford and Torok, 2008, Pillay et al., 2009, Lewis and Eves, 2012a). A survey was conducted in another health sciences building within the university to ensure the integrity of the intervention within the TBSI. Staff and students entering the building on a particular day were asked to choose one of eight messages which would motivate them most to take the stairs. The top five were chosen for use on the signage. The signage was then professionally produced by a graphic designer in compliance with the university’s visual identity policy (See Figure 1 for example).

Participants and Data Collection

The sample of this study included all staff, students and visitors to the TBSI. People were excluded from the count if they were carrying an excessive load, using an aid to mobilise or carrying laboratory equipment with which it was prohibited to take the stairs.

Data were collected at five observation points during the study; one pre-intervention, two mid-intervention and two post-intervention. Collection was carried out on the same days and at the same times for each observation point. Only one observation session was carried out during the pre-intervention period due to the signs being installed by the graphic designer prior to the agreed date. Following an exploratory observation period, the first and second floors were identified as the most heavily used within the building. Two researchers recorded ascending stair and elevator use from the ground floor. One researcher was assigned to the first and one to the second floor to observe elevator users arriving onto those floors from levels below. The users’ gender was also recorded.

Ethical approval for this study was obtained from the Trinity College Dublin School of Medicine Research Ethics Committee.

Data Analysis

Statistical analysis was completed using the Statistical Package for Social Sciences (SPSS) Version 24. All data were entered into SPSS and cleaned twice. The data were analysed using descriptive statistics and the Chi-square test was used to test for significant associations between categorical variables. A p-value of ≤ 0.05 was considered significant.

Figure 1. Banner style point of decision prompt

Results

Table 1 presents the results of the top five messages chosen in the survey used to inform the motivational messages for the PODPs. A total of 239 participants were consulted, overall 74.9% (n=179) of respondents were female and 25.1% (n=60) were male.

Table 1. Survey results to inform motivational messages

Motivational Message	Theme of message	Female		Male		Total
		Staff	Student	Staff	Student	% (n)
1. A healthier heart is the heart that takes the stairs	Physical Health	13	19	7	12	21.3 (51)
2. No time to exercise today? Your opportunity is now! If you're able take the stairs!	Physical activity	15	19	2	4	16.7 (40)
3. Boost your mood If you're able take the stairs!	Mental Health	8	13	3	10	14.3 (34)
4. Burn calories not electricity If you're able take the stairs!	Environment	4	25	3	2	14.3 (34)
5. Step up to a healthier lifestyle If you're able, take the stairs!	Physical activity	7	15	4	7	13.8 (33)
6. Other messages		13	28	2	4	19.6 (47)
Total % (n)		25.1 (60)	49.8 (119)	8.7 (21)	16.3 (39)	100 (239)

A total of 2506 observations were made over the five-week data collection period with 38.4% (n= 960) of these being male and 61.6% (n= 1546) female. Figure 2 presents the elevator and stair usage of all participants across the three study phases. Overall, there was no significant change in stair or elevator use across the study period. When gender was examined separately there was a trend towards a decrease in stairs usage amongst males and a trend towards an increase in stair usage amongst females but neither reached significant levels.

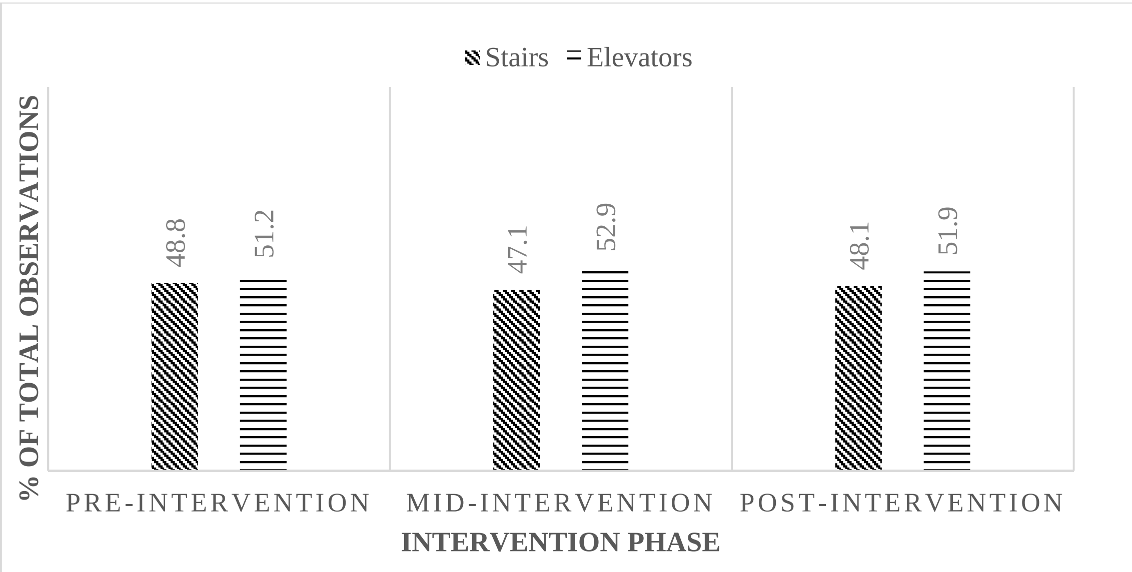

Figure 2. Stair and elevator use across the study phases

Table 2 presents the percentage prevalence of users exiting the elevator at the different floor levels across the study phases. This showed a statistically significant change. Of note was the reduction of users exiting the elevator at the second floor during the intervention phase.

Table 2. Exit floor of elevator users across the study phases

	P1 % (n)	P2 % (n)	P3 % (n)	Total % (n)	df	Chi Square	p-value
Exit Floor 1	3.2 (9)	3.4 (18)	4.3 (21)	3.7 (48)			
Exit Floor 2	22.5 (64)	10.4 (56)	15.4 (75)	14.9 (195)	4	22.211	p<0.001
Exit Floors 3-7	74.3 (212)	86.2 (461)	80.3 (391)	81.4 (1064)			
Total	285	535	487	1307			

P1=Pre-Intervention, P2=Intervention, P3=Post-Intervention, df= Degree of Freedom

Discussion

The main aim of this study was to assess the effect of point of decision prompts on stair use in the TBSI. Unlike previous studies, no increase in total stair use was found (Lee et al., 2012b, Lewis and Eves, 2012a, Eckhardt et al., 2015). Of note, a significant decrease in users exiting the elevator on the second floor as well as a non-significant trend of increased stair use for females was found during the intervention. There are a number of possible explanations for these outcomes. The baseline level of stair use in this study was high at 48.8% when compared to other non-university (Kwak et al., 2007, Bennett et al., 2018) and university studies (Lee et al., 2012b) in which rates were between 16.6 and 32.6%. The setting of this study within an academic health sciences building may have contributed to this increased baseline. The participants observed in this study were likely to be a well-educated, predominantly student population, factors associated with higher rates of participation in physical activity (Murphy et al., 2015). This particular sample consisted mainly of health science students who may have increased engagement in physical activity when compared to other student populations. This sample may not have considered an increase in incidental activity useful, due to already engaging in sufficient levels of physical activity.

The point of decisions prompts designed in this study were required to adhere to strict university regulations for sizing and colour. The signs on the elevators in this study were small (A3), however it is known that larger signs A1, A2 and banner style are more effective as they are more likely to be seen (Kerr et al., 2001). Additionally, the message content of these interventions have been noted to contribute to their effectiveness, particularly when tailored to the target population (Eckhardt et al., 2015). An effort was made to allow for this through a consultation process, however a more in-depth process may be warranted to reflect the complex nature of effective health promotion messages (Lewis and Eves, 2012b). Finally, the colours and graphics of the signs, in adherence with the university's visual policy, may also have lessened their impact as most other studies used brightly coloured signs with dramatic graphics (Bennett et al., 2018).

The environmental characteristics of the TBSI, including the building's height and the layout of its stairs and elevators, should also be considered. In general, increasing building height is negatively associated with stair use (Zacharias and Ling, 2015). Our study would support the difficulty of promoting stair use in a taller building. This may be further explained by individuals having a stair distance threshold, which represents the number of flights of stairs they are willing to climb, often noted as between two and four floors (Kwak et al., 2007). As the TBSI consists of seven upper floors, there are multiple floors past this potential threshold to which people are unlikely to travel to by stairs. This was also observed with the elevator exit floor results which showed a low baseline level of elevator transport to the first and second floors at 3.2 and 22.5% respectively. This also reduced significantly for the second floor during the intervention to 10.5% of total users. Additionally, this building was well serviced by elevators and the stairwell was hidden, both of which are negatively associated with stair usage (Olander and Eves, 2011).

Limitations and Future Implications

This study had a number of limitations. Firstly, due to only four researchers being involved in this study a limited amount of data could be recorded. Potentially useful data such as stair exit level, elevator exit level above the second floor and descending stair use could not be recorded. Also, this study was a time-series observational study with a restricted number of data collection days. A greater number of collection days would have provided a more robust observation period and may have altered the results. Due to the layout of the building, it was not possible to conceal those taking the observations and this may, therefore, have inadvertently influenced people's behaviour and added to the high baseline of stair use. Also, similar to other studies, a suitable control setting with matching characteristics was not available.

Following on from the findings of this study, future design of PODPs within the university would need to address the size and aesthetics of the signage in order to increase the potential impact of the same. A consultation process between all necessary college departments to design the signage based on best available evidence would be required. It is also advised that future implementation should be directed towards another university building with a more general or non-health related student population. A building associated with the School of Business, for example, in which students may not have the same level of engagement with physical activity as the population of a health sciences building may yield a different outcome. Combining this intervention with a wider campaign to increase stair use on campus, for example through social media, may be a more effective approach.

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A HUMAN FACTORS APPROACH TO IMPROVE VISUAL INSPECTION PERFORMANCE DURING AIRCRAFT MAINTENANCE TASKS

V. Hrymak, P. Codd , M. C. Leva,

School of Food Science & Environmental Health, TU Dublin

Abstract

Background

Visual inspection is the most frequently used aircraft inspection technique involving some 80% of all aircraft maintenance inspection tasks. However visual inspection remains a flawed process with aircraft maintenance engineers routinely missing observable defects during visual inspection tasks (Drury and Watson, 2002; See, 2012). This research presents evidence for an improved visual inspection method, named systematic visual search that was found to increase the observation of defects by aircraft maintenance engineers. Systematic visual search consists of using a set eye scanning strategy, designed to ensure all areas of an object under analysis is exhaustively searched using foveal vision. A randomised control trial was conducted with N= 22 experienced aircraft engineers and a pre-inspected aircraft with a known number of observable defects. In the control condition; N= 11 participants were randomly allocated to inspect this aircraft using their normal and customary visual inspection practice. In the experimental condition; the remaining N= 11 participants visually inspected the same aircraft but used systematic visual search after receiving a 40 minute training session. Defect observation rates were then compared between control and experimental group participants. Systematic visual search improved the mean observation of defects by some 28%. (M=27.50, p = ≤.001, Cohen's d = 2.86). A further finding was that the mean time taken to conduct the inspection task using the novel method was more than double at almost 70 minutes. The limitations of human visual inspection accuracy have been demonstrated in this study. In addition the observation of defects from this group of experienced participants was found to be below expectation. However the use of systematic visual search did improve visual performance and thereby offers the potential to improve the observation of defects by aircraft maintenance engineers. This holds the promise of potentially improved visual inspection accuracy rates for the aviation industry as a whole, as well as for the wider industrial quality control community.

Introduction

Visual inspection is extensively practiced within the industrial quality control sector. It is used to find defects including faults, imperfections and hazards. However when tested empirically, visual inspection accuracy reveals detrimental effects from the many sensory perceptual, cognitive bias and organisational causes of visual inspection error. Basically, we humans are not particularly well suited at seeing all the observable defects a complex task such as aircraft inspection may bring. As a result wide variations in visual inspection accuracy have been reported. Gallwey, (1998) found that for the industrial sector as a whole, the observation of defects ranged between 5% and 95%. These missed defects can result in product recalls, increased maintenance and production costs, harm reputations cause flight delays aircraft damage as well as fatalities. (See, 2012; Usanmaz, 2011). See, (2012) reports that the 111 fatalities from an aircraft crash in 1969, was caused by a fault not seen during visual inspection.

A review of the visual psychophysics and human factors literature reveals that there are many sensory perceptual, cognitive bias and organisational causes that can explain sub-optimal visual inspection performance. In short visual inspection is an error prone task that is difficult to do well. (Biggs and Mitroff, 2013; Cain et al, 2011; Drury & Watson 2002; Gallwey, 1998; See, 2012; Rao et al, 2006; Wolfe, 2005). A summary of these causes is given in Table 1 below

Table 1, Summary Causes of Visual Inspection Error (Hrymak, 2018)

Causes	**Brief Explanation**
Limitations in Memory	Holding data in visual search memory reduces the rate of evaluation of new targets
Interference between memory sets	Mis-interpreting an M6 sized nut and bolt, that is incorrectly stored in an M10 sized storage box
Capacity of memory	Too many objects to memorise correctly
Memory degredation	A decay in the amount of memory from age or disease
Subsequent search misses	The observation of a defect negatively affects the observation of subsequent defects
Target prevalence	Lower observational accuracy is related to very low levels of defect prevalence
Speed accuracy trade off	The speed of visual search and observational accuracy are inversely related
Vigilance and diligence	How well the observational task is conducted affects accuracy
In-attentional blindness	When a given attentional set is adopted, an unexpected object may go undetected if it does not share the same set properties
Hybrid foraging search behaviour	Observational accuracy is influenced by previous mean times taken to observe defects
In-attentional blindness	When an attentional set is adopted, an unexpected object may go undetected if not sharing the same set properties
Expert judgement	The performance of professional judgement varies
Confirmation bias	A tendency to see what you expect to see
Outcome bias	A tendency to ignore warnings or defects that do not cause subsequent problems
Ambiguity in definitions	A lack of precision in defining a defect allowing that object to be mis-interpreted as not of interest
The lack of guidance in visual inspection conduct	Idiosyncratic behaviour resulting in some objects of interest not being observed due to visual inspection conduct

Even though humans are limited in their visual search accuracy, significant improvements in visual inspection performance has been reported in the literature. The most successful interventions have all involved training in both the cognitive and organisational aspects of visual search behaviour (See, 2012). In particular, one promising human factors based line of inquiry involves introducing consistency to visual search behaviour. This can be achieved by adopting a set eye scanning pattern for the object under analysis. By introducing a behavioural visual search algorithm for inspectors, accuracy rates have been shown to improve human performance (Bowling et al, 2008; Hrymak, 2018; Nalanagula et al, 2006; Nickles et al, 2003; Sadasivan & Gramopadhye, 2009; See, 2012).

In this study, the visual search behavioural algorithm developed and trialled consisted of a two stage visual inspection process; the iterative selection of the object to observe, immediately followed by the use of set eye scanning pattern for the object under analysis. The initial results are promising and are presented here. For brevity, this novel visual search behavioural algorithm will be referred to throughout this paper as; systematic visual search.

Methodology

The experimental design consisted of using a randomised control trial to test the efficacy of the systematic visual search intervention. In total, 22 aircraft maintenance engineers were recruited and randomly allocated into control and experimental conditions.

The task set was to write down any observable defects that were seen by aircraft maintenance engineers who were visually inspecting an Allouette III helicopter (see Fig. 1). All participants recruited were male and qualified aircraft maintenance technicians with between 10 and 28 years of experience.

The aircraft under analysis had been pre-inspected before the trial by three senior and experienced aircraft inspectors, including a member of the current research team. Observable defects on the aircraft included those in situ; for example areas of corrosion, as well as defects that were deliberately planted such as missing screws or loose items left in the cockpit. A full list of the defects is presented in Appendix 1. The experiment was designed so that the visual inspection task required was almost identical to a real world aircraft inspection task.

In the control condition, 11 aircraft maintenance engineers inspected the aircraft using their customary visual inspection practice and wrote down the defects they observed. In the experimental condition, the remaining 11 aircraft maintenance engineers received instruction in systematic visual search before being directed to use the method on the same aircraft.

Fig 1, The Allouette III Helicopter

The Systematic Visual Search Method

This behavioural visual search algorithm consists of a two stage process; beginning with systematically selecting the order of elements to observe before applying a set eye scanning pattern to the object under visual analysis. The first stage requires one specific element to be observed to the exclusion of all other areas. For example, the external port side would be one element that would be selected for subsequent and thorough observation. The second stage requires that observational thoroughness is achieved by using a set eye scanning pattern that ensures the object under analysis is viewed exhaustively.

The eye scanning pattern used in this experiment is described as reverse "snakes and ladders" and is shown in Fig 2 below. Basically inspectors using this scan pattern begin their visual search with a fixation in the top left hand corner of the object under analysis. They then direct their field of view to the bottom right hand corner using this reverse snakes and ladder pattern. One participant in previous research described systematic visual search as "painting the object with your eyes" (Hrymak, 2018)

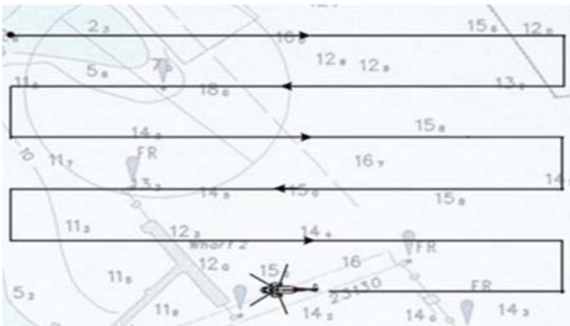

Figure 2 The Reverse "Snakes & Ladders" Eye Scanning Pattern

Instruction in systematic visual search consisted of a 40 minute power point presentation and a practical demonstration of the set eye scanning pattern by the research team. In addition experimental group participants were directed to manipulate the area under analysis to ensure any potentially obfuscated defects were observed for example opening any inspection panels or compartments present.

Experimental group participants were also directed to keep moving as they visually inspected in order to ensure they were in close proximity to the area under analysis. This was intended to promote the use of foveal vision which has been shown to maximise defect observation (Gallwey, 1998). The experimental group defect record sheet was also designed to promote exclusive element selection as it required a strict sequence of visual inspection elements. The order required was to start at the external front of the aircraft and to move around in an anti-clockwise direction. This was to be followed by inspecting the top, bottom and interior of the aircraft.

Defects were further classified into open view and obfuscated. Open view defects were regarded as those that were capable of being observed by direct line of sight. Obscured view defects were regarded as those that required participants to manipulate their environment by for example, opening panels or looking inside compartments. The following table lists the variables recorded for each participant:

Table 2, List of Participant Variables Recorded

Number of years of aircraft inspection experience
Number of defects identified
Number of open view and obfuscated defects
Time taken to complete the visual inspection

Results

Table 3 below, summarises the results of the randomised controlled trial conducted in this study.

Table 3, Visual Inspection Performance Data

	N	Mean % Defects Observed	SD	*p*	Cohen's *d*	Mean Time Taken	SD	*p*	Cohen's *d*
Control	11	40.25	8.25	≤.001		00:26:30	00:05:58	≤.001	
Experimental	11	67.75	10.80	≤.001	2.86	01:09:45	00:16:57	≤.001	2.55

It was demonstrated that experimental group participants observed circa 28% more defects than their control group colleagues (M=27.50, p = ≤.001, Cohen's d = 2.86). In addition, the difference in observation rates as a result of the intervention was highly significant and reflected a large effect size. Also of interest was the time taken to conduct visual inspections in that experimental group participants took more than twice as long to complete their task with a mean of nearly 70 minutes. (M= 69min 45sec, SD= 16min 57sec, p = ≤.00, Cohen's d = 2.55). The distribution of visual inspection performance for treatment groups are presented in the following histograms. The visual inspection performance for the control group is a negatively skewed platykurtic distribution and is presented in Fig 3 below.

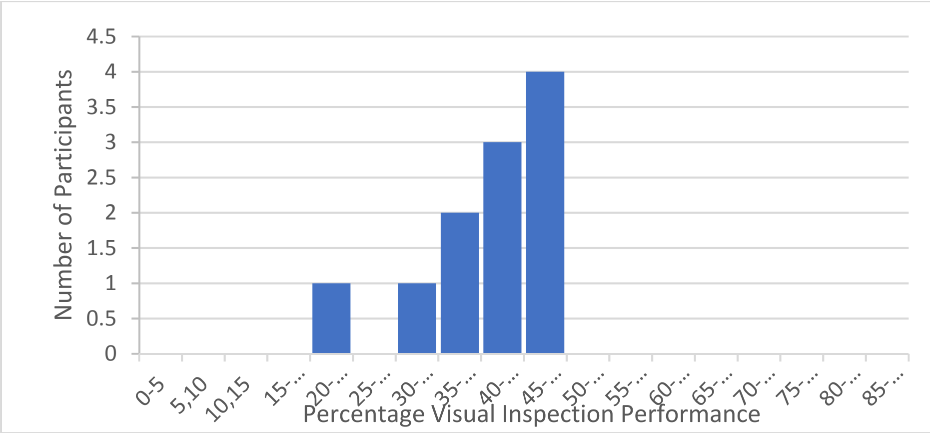

Figure 3 Control Group VIP Distribution

The effect of the systematic visual search intervention in the experimental group distribution is presented in Fig 4 below. The distribution for the experimental group has a more normal platykurtic distribution. The wide distribution in both these histograms also demonstrates human variability in visual inspection performance.

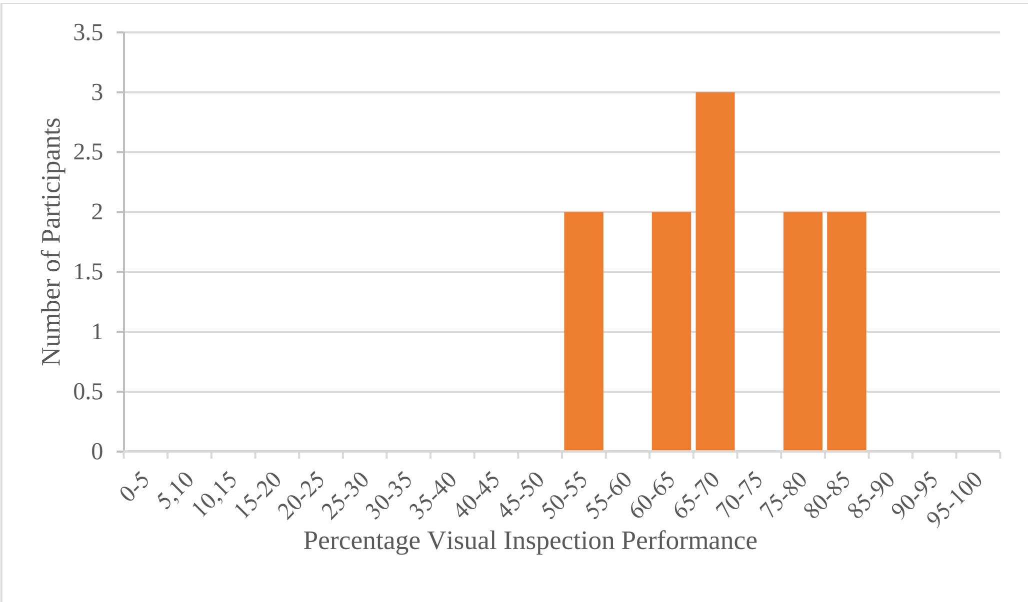

Fig 4, Experimental Group VIP Distribution

Fig 5 below presents a comparison between the visual inspection performance for open view and obfuscated defects. Visual inspection performance by the experimental group participants was again superior in both categories. This demonstrated that using the systematic visual inspection resulted in more defects being observed that required some level of additional effort to view.

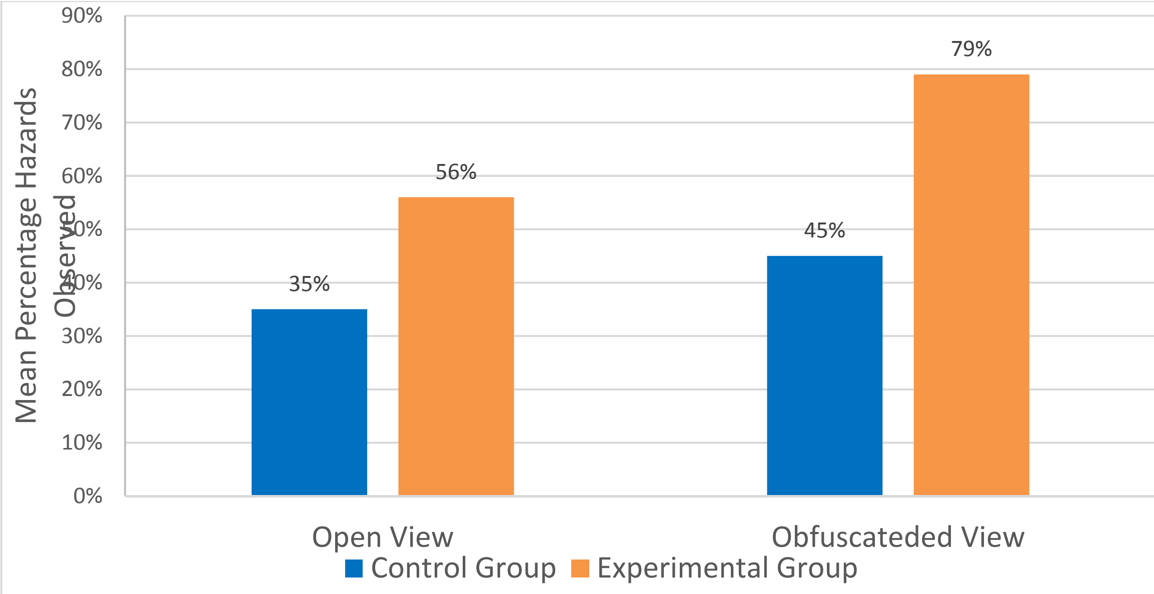

Figure 5 Visual Inspection Performance for Open View & Obfuscated Defects

The Effect of Experience on the Observation of Defects

The correlation between visual inspection performance and experience in terms of years working as an aircraft maintenance engineers was also tested. The result as shown in Table 4 below, demonstrated a highly significant but inverse relationship between control group participants and experience This was an unexpected result indicating that more experience resulted in less defects being observed. Interestingly the systematic visual search users seemed to have negated this potential bias.

Table 4, Correlation between Participant Experience and the Observation of Defects

	Experience in Years
Control group **%age of defects observed**	r = -0.48 $p \leq .001$
Experimental group **%age of defects Observed**	r = 0.11 $p \leq .001$

Discussion

The results from this study prompt two fundamental questions. The first is that even though systematic visual search improved the observation of defects significantly, why were these experienced aircraft inspectors not demonstrating levels of visual inspection accuracy rates in the mid-eighties percentage range and above. Secondly in attempting to improve visual inspection accuracy, what role could systematic visual search play. The results from this study, together with the visual psychophysics and human factors literature can provide plausible explanations.

In terms of why was observational performance was found to be below expectation, there is evidence to show that what was being demonstrated in this study is simply reflective of what it is to be human. The many causes of visual search error as listed in Table 1 above underpin just how error prone visual inspection is and how difficult it is to do well. Another way of looking at the results could be to frame the findings more positively by suggesting how well the participants did, in spite of their inbuilt human limitations. A harder question to answer here would be what proportion of the overall study results can be attributed to individual sensory perceptual, cognitive bias and organisational causes of visual search error The wide distribution of individual scores seen in Figs 3&4 suggest many human factors could be influencing visual inspection behaviour. For example one finding that many may find surprising is that salience, or the noticeability of a defect, did not seem to have promoted observation.

Furthermore there was a counterintuitive finding in that experience for control group participants seemed to be negatively correlated with defects observed. Interestingly, this bias was very much reduced by systematic visual search users. However some caution in these correlational results needs to be exercised. Although r values were highly significant, sample power was not achieved in the trial, so these results may be reflective of the small sample size.

In spite of the overall results from this study which were below expectation, a promising finding was the beneficial effect of using systematic visual search. This prompts the question of how it achieved its large effect size. The study evidence suggests that systematic visual search promotes the observation of defects by improving the thoroughness of the visual inspection. In short, more areas of the object under analysis were being observed more exhaustively, thereby prompting better attentional deployment when the defect was seen. This was evidenced by systematic visual search users demonstrating a higher overall observation rate of defects as well as seeing more of the obfuscated defects present.

The visual search literature offers further explanations as to how systematic visual search may be achieving its beneficial effect. One plausible explanation is the conservation of cognitive resources. Visual inspection is a cognitively demanding task (Biggs and Mitroff, 2013; Drury & Watson 2002; Gallwey, 1998; Rao et al 2006; See, 2012; Wolfe, 2005). During visual inspection tasks, continually returning to areas already searched can use up valuable cognitive resources and result in increased visual errors. Systematic visual search, by preventing the re-observation of areas already searched may be conserving cognitive resources associated with all visual search tasks such as; short term memory use and object recognition processes in the brain (Eckstein, 2011)

A further plausible explanation is the role of cognitive bias which has been shown to be a deep seated cause of decision making error by professionals. (Aronson, 2013; Gilovitch, et al, 2013; Kahneman, 2011; Montibeller & Winterfeldt, 2015). In particular human foraging search, conformation and outcome bias could well have influenced control group participants into limiting their observation of defects. In short, control group participants may have observed less defects due to using less efficient visual search behaviours and limiting their search times due to preconceived expectation (Kahneman, 2011, Wolfe et al 2016,) This leads to the question of what role systematic visual search could play in improving overall visual inspection performance. The visual search literature itemises three strategies for improving visual inspection. Either train the observer to better know what to expect, make the object under analysis easier to search or improve search behaviour (Drury & Watson, 2002; Nickles et al. 2003; Rao et al. 2006; Schwaninger, 2005; Wales et al, 2009).

Given that all aircraft maintenance inspectors are highly trained, more effort in this regard does not seem advantageous. Furthermore making aircraft easier to search does not seem feasible so enabling the visual inspector to search better is left as a viable alternative. As noted by Eckstein (2011) the number of defects prior to the task cannot be known with certainty by the visual inspector and the situation requiring the search cannot be changed. Therefore the visual search accuracy of the inspector is "arguably the weakest link" and thereby offers the best potential for improvement.

Finally systematic visual search offer the potential to standardise visual search behaviour which would be beneficial given that visual inspection behaviour is currently idiosyncratic with very little guidance in terms of how to conduct competent visual inspections (Clift et al, 2011; Hrymak, 2018; Neathey et al 2006). By promoting the visual search algorithm used in this study, the proceduralisation of an important industrial safety and quality task is possible.

Conclusion

The sensory perceptual, cognitive bias and organisational limitations we all possess as humans were demonstrated by aircraft maintenance technicians who were set a real world visual inspection task. The results reiterate a human factors based limitation that we all possess; that visual inspection is an error prone task and is difficult to do well. That observational accuracy was found to be below expectation, should not of itself be surprising considering the many human factors based causes of visual search error.

However, it remains that the results point to the need to improve human performance in this task when considering an industry expected standard for visual inspection accuracy is circa 85% (See, 2012). Therefore the finding that that the use of a human factors based visual search algorithm, was found to significantly improve visual inspection performance is welcome. This improvement is all the more noteworthy given that visual inspection performance was achieved using only a 40 minute training intervention. Furthermore this promising development is currently being researched further to see what other human factors can be manipulated to improve overall visual inspection accuracy in the aviation maintenance sector.

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Appendix 1. Defect List

No.	Description of Defect
1	Debris in pitot tube head
2	Loose panel fasteners underneath cabin
3	Corroded screw on air intake (Front)
4	Inspection torch inside mid compartment
5	Fuselage roof panel not secured Port side (External)
6	Loose battery tray inside mid compartment
7	Electrical distribution box cover removed
8	Silicone tube left in mid compartment
9	Cleaning fluid container inside tail boom
10	Spare part inside mid compartment starboard side
11	Tool left in mid compartment
12	Antenna removed underneath tail boom
13	Vice grips placed in tail boom (Top)
14	Rubber cuff pulled back on tail rotor
15	Exposed wiring to passenger communication panel in cockpit
16	Split pin missing on tail rotor
17	Rivet missing in panel starboard side
18	Rubber bushing unattached in tail boom
19	Rubber on starboard door unattached
20	Loose electrical connector (MGB chip detector) on gearbox
21	Cloth in engine exhaust
22	Split pin missing from main rotor
23	Tool left on top of main rotor
24	Bulb/fastener missing from instrument panel
25	Under pressurised tyre
26	Mobile phone in mid passenger seat
27	Coins under mid passenger seat
28	Pen under pilot seat
29	Large bolt and nut on rear seat
30	Unserviceable spare part under rear seat
31	Lighter in cockpit
32	Gasket debris in engine area
33	Fire Extinguisher out of date
34	Undercarriage leaking
35	Pen in rear cockpit

Appendix 2. Control Group Defect Record Sheet

Location: Casement Aerodrome	Aircraft: Allouette Helicopter

Participant No.________	Date_________________	Time In___:___:___	Time Out___:___:___

Record of Defects or Maintenance Due	
No.	**Defect / Required Maintenance**

Appendix 3. Experimental Group Defect Record Sheet

Location: Casement Aerodrome	Aircraft: Allouette Helicopter

Participant No.________	Date_________________	Time In___:___:___	Time Out___:___:___

Record of Defects or Maintenance Due	
No.	External Front of Aircraft
	External Port Side
	Tail Rotor
	External Starboard Side
	External Top of Aircraft
	Engine and Gearbox
	Main Rotor Head and Rotor Blades
	Underneath Aircraft and Undercarriage
	Interior Cabin

SAFETY RELATED COSTS AND EFFECTS OF AVIATION MAINTENANCE SHORTCUTS

Lara LV., Murtagh C., Caffrey S., Leva MC, Hrymak V.

Technological University Dublin, Ireland

Abstract

Aircraft maintenance is a key safety critical process in the aviation industry with detailed procedures available for all tasks. However human factors present within such working environments have long been known to produce deviations such as shortcusts from set procedures which can in turn affect safety and productivity. This mixed methods study set out to investigate shortcuts and to report any detrimental costs and effects.

The experimental design consisted of a four month fieldwork phase within an aircraft maintenance organisation. The working environment was investigated by using visual inspections. This was followed by a task analysis of three selected maintenance procedures to produce empirical data relating to any shortcuts in work procedures. Semi structured interviews were also conducted and together data was generated that characterised the work environment, shortcuts and resulting costs and effects.

The results revealed a pressurised work environment where a "get the job done" attitude prevailed and shortcuts were tolerated. This was accompanied by widespread housekeeping issues and instances of injuries and production costs due to shortcuts. In short, maintenance engineers perceived themselves to be under pressure to deliver short turnaround times and were willing to undertake 'acceptable shortcuts' to meet production targets. On further analysis it was found that these workplace conditions and behaviours led to quantifiable injuries, costs and delays that offset production gains.

Introduction

Aviation maintenance is a key safety critical process in the aircraft industry with individuals being tasked to performing complex and error prone activities (Boeing, 2003). These tasks demand high levels of expertise and a conducive work environment to do well (Yadav and Nikraz, 2014). However, poor workplace environments, time pressure, insufficient operator competence and inadequate feedback have all been reported in the aviation maintenance sector (Latorella and Prabhu, 2000). Consequently, taking shortcuts is a recognised cause of safety related incidents in aviation maintenance (Boeing, 2003; Hawkins, 1993).

Task performance failures have long been found to result in interruptions to scheduled operations together with aircraft and equipment damage (Reason 1990). Fatalities have also occurred, with See, (2012) reporting that the cause of 111 fatalities from an aircraft crash in 1969 was directly attributable to human error. In this case an aircraft maintenance engineer failed to see a cracked engine fan disk during an inspection.

However, the aviation industry has not been slow in implementing rigorous safety management systems to counter human factor causes of sub-standard safety. Hsiao et. al. (2013) lists examples of on-job-training (OJT) programs, quality assurance programs, and standard operating procedures (SOPs). Even so, Mellema (2018) details further human factors issues in aviation maintenance that have caused accidents such as communication, knowledge, teamwork, assertiveness, distractions, fatigue, pressure, awareness, stress, complacency and expected norms.

Methodology

The aim of this mixed methods study, was to empirically evidence any human factors and effects that were negatively impacting safety conditions and behaviours in an aircraft maintenance environment. The experimental design included visual inspections, task analysis, semi-structured interviews and incident report analysis.

The research was conducted over a four month period in 2019 within the hangner of a European based aircraft maintenance organisation. Data collection consisted of six distinct fieldwork phases which are detailed in Table 1 below.

Table 1. Details of methods used

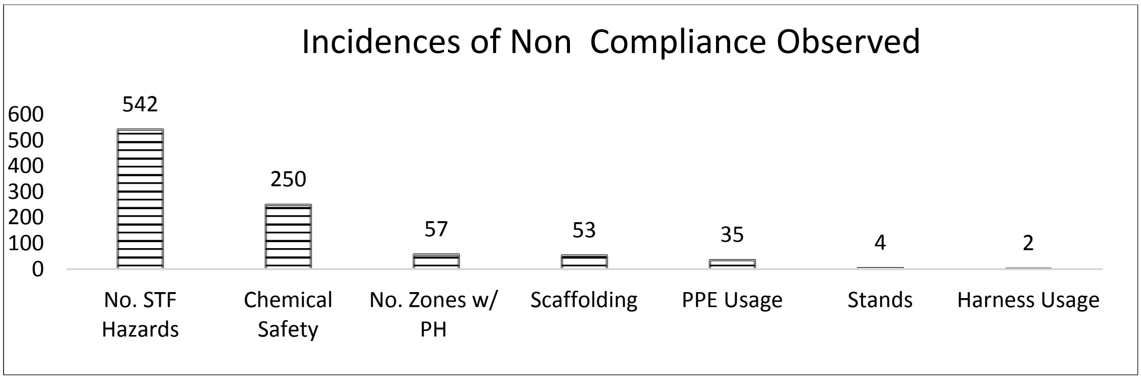
Phase	**Methods Used**	**Rationale**
Phase 1: Company details	Meetings with the Health and Safety Manager who detailed the existing safety management system and presented a statistical incident analysis using data from 2009 to 2018.	To assess safety performance based on human, organisational and management factors.
Phase 2: Semi-structured interviews	Interviews were conducted with 20 maintenance engineers who were selected to represent a cross section of maintenance roles.	To gain a greater understanding of the human factors relating to the specific tasks, and possible deviations expected procedures.
Phase 3: Visual inspection	A total of 77 visual inspections were conducted using methods detailed by Hrymak 2018 and Drury & Watson 2002).	To empirically evidence work conditions and behaviours under the following categories; • Work at heights • Housekeeping; • Fire safety; • First aid; • Chemical safety; • PPE • Electrical safety.
Phase 4: Selection of three work processes	Three maintenance tasks were selected for further analysis. The criteria for selection were procedures engineers reported as frequently causing safety incidents and the feasibility of conducting task analysis	Task analysis was selected for the removal of; • A fuel filter • An electric pump • A fuel tank panel
Phase 5: Task analysis	Actual procedures were observed during the conduct of each task and mapped against expected procedures as defined in operational manuals.	Following Kirwan and Ainsworth, 1992; this method allowed the following to be identified

	The time taken for each task was recorded over five repetitions of to identify mean duration times of the task and that of any deviations. During the timings, engineers were not stopped while executing their tasks. Any questions about the deviations were left until the activity was completed.	• human error • possible hazards • processes deviations; • data for human reliability assessment.
Phase 6: Risk exposure monetising	Cost data from financial year 2018 was selected for specific analysis and included; • salary paid to the injured party for absences • salary paid to the substitute engineers • medical fees	Cost calculations follow the method detailed by ; Hrymak & Perezgonzalez, 2007

Results

During 77 separate visual inspections conducted from January to March 2019; there were 943 incidences of non-compliance with recommended safety practices were observed, This was close to 19% of all conditions and behaviours observed.

Fig 1 below breaks down this overall figure down into specific categories. It demonstrated that slips trips and falls, together with chemical safety requirements represented the two biggest categories of non-compliance. That only two incidences of incorrect harness use was observed shows that some behaviours were relatively highly compliant but that housekeeping issues dominated non-compliance. In short the working environment was not conducive to safe working practices.



Key; STF = slips trips falls, w/PH = areas with poor housekeeping, stands = work platforms

The data from the semi-structures interviews revealed three key themes. There was an constant sense of 'pressure to get the job done'. This overarching theme was continually expressed during interviews. It manifested itself in the belief that maintenance had to be completed by a set time, otherwise financial penalties would kick in for the organisation and themselves.

Poor levels of housekeeping were also concern for both workers and management and this issue had been previously identified as a key issue during company audits.

In addition widespread under-reporting was occurring with near-misses and “small” accidents (categorised as low severity or consequence) not being reported by workers.

Task Analysis

Task analysis was conducted for the removal of three items; a fuel filter, an electric pump and a fuel tank panel. Observations of these tasks revealed that shortcuts from procedures were common place. These included; not closing valves, in-sufficient feedback, un-defined direction on the gas regulators, inadequate signage, not wearing ppe, unclear labelling, ambiguous instruction, high noise levels and near misses.

As an example there were four observations of engineers not wearing eye protection, when working with corrosive hydraulic fluid. Eye contact with this particular hydraulic fluid was described as “ being hit in the eye with a bat”. This practice was explained as a “time saver” even though productivity losses from lack of eye protection were known to workers and management.

Monetising Risk Exposure

During 2018, there were twenty-nine lost time accidents together with a throughput of about one aircraft a week. This data provided an approximation of time delays for head injury eye injury and skin irritation incidents from not wearing ppe. The task analysis conducted in this study provided time data on how long a task would take if conducted according to the manual and with shortcuts. Table 2 below presents the findings

Table 2. Duration of Tasks with Correct Procedures and Shortcuts

Task	Potential accident	Correct Procedures	Procedures with Shortcuts	
		Duration of the task	Time Saved	Delay due to Injury
Removal of the fuel filter	Head injury	0.31 hours	7 minutes	2 hrs
Removal of the electric pump	Eye injury	2.44 hours	4 minutes	1.5 hrs
Removal of fuel tank panel	Skin irritation	1.09 hours	4 minutes	2 hrs

What is noteworthy here are the small amounts of time saved by shortcuts. In addition this time saved is greatly dis-proportional relative to time delays caused by accidents. The following table further models these shortcuts effect in monetary values.

Table 3. Monetised risk exposure from accidents

Task	Potential Accident	Likelihood of the accident happening*	Cost saving from the shortcut	Cost of the accident
Removal of the fuel filter	Head injury	*12%*	€1.711	€205
Removal of the electric pump	Eye injury	*30%*	€1197.8	€360
Removal of fuel tank panel	Skin irritation	*10%*	€842.19	€84

***** the probability of an accident was calculated by dividing the number of recorded injuries by the number of aircraft maintained from 2018 lost time accident data.

Conclusion

There are many examples in industry where the use of shortcuts to get the job done is condoned in the interest of productivity. This study presents data that contradicts this widespread assertion that doing the job safely, costs more and will cause delays. Even though the aviation industry highly regulated, it is not immune production pressure. Therefore data to demonstrate productivity gains from safe working practices will be welcome not only in the aviation sector, but by the wider environmental health and safety community.

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HUMAN FACTORS ENGINEERING IN THE DESIGN OF A PRODUCTION LINE IN A BEVERAGE MANUFACTURING COMPANY

M. Carroll and M.C. Leva

School of Food Science and Environmental Health, Technological University Dublin,
Cathal Brugha Street,
Dublin 1, Ireland

Abstract

The present extended abstract introduces the methodological approach to adapt a Human Factors Engineering and user centred approach to the design of a filling line in a beverage manufacturing company.

Introduction

Human Factors Engineering (HFE) focuses on the application of human factors knowledge to the design and construction of socio-technical systems. The objective is to ensure systems are designed so as to optimise the human contribution to production and minimise potential for design-induced risks to health, personal or process safety or environmental performance (OGP, 2011).

The ISO standard ISO 9241-210 (2010), Ergonomics of human-system interaction (Human-centred design for interactive systems), requires that all new facilities projects apply the principles of Human Factors Engineering (HFE) during early design stages. In practice this means ensuring, as a minimum, that every new facilities project is screened in collaboration with the end users to identify whether there are any "hotspots" (risks, issues or opportunities) associated with the scope of the design project that justify further HFE activities. Further standards detail these activities, including physical and cognitive ergonomic assessments of the operator tasks, the equipment they will use to complete those tasks, and the environment in which they will be undertaken. Human Factors Engineering and ergonomic studies can help companies identify practical solutions for issues regarding the Human Machine Interface (HMI) (EU-OSHA, 2006). The intention of these approaches and methodologies is to prevent accidents and eliminate the source of the hazard as well as improving efficiency and well-being. Different industries can learn from each other and historical data can contribute to increasing safety but the learning mechanism needs to have a good understanding of the culture, constraints, objectives and the design procedure of the target industry (Drogoul et al., 2007).

To support the challenging task of the design team there are number of standards which provide some guidance on the minimum requirements in terms of human centred design: for example, ISO 6385 – Ergonomic Principles in the Design of Work Systems (2004) outlines how technological, economic, organisational, and human factors can affect the work behaviour and well-being of people within a work system. The general principle underlying the standard is that interactions between people and the components of the work system (e.g. tasks, equipment, workspace and environment) should be considered during the design stages. Each design stage is described and appropriate ergonomic principles and methods for each stage are listed. ISO 11064 - Ergonomic Design of Control Centres (2006) provides nine principles for the ergonomic design of control centres and guidance on specific aspects of control room design, including layout, workstation design, controls and displays, and environmental requirements. ISO 12100 – Safety of Machinery (2010) suggests a five steps methodology to perform risk assessment at design stage and the overall strategy requires designers to take into account the safety of machinery for their whole life cycle, considering usability, maintainability and cost efficiency.

Those approaches have traditionally been used in Oil and Gas and process industry (Leva et al. 2015). However, in the present case study the objective is to try and adapt a HFE approach to the design of a production line in the beverage-manufacturing sector.

The line under review is a returnable container filling line for the processing and packaging of beverages across four different sizes.

Proposed approach in summary

The approach proposed is to offer a HFE informed user centred design review following the methodology highlighted in Figure 1 and Figure 2.

To ensure the design review can involve operators the company will request a 3D model of the proposed design. A 3D model is a more natural representation that does not require decoding of 2D technical drawings and thus facilitates the operator in identifying potential issues regarding the proposed design. This approach can be considered as an example of human centred participatory design, able to support a better understanding of the user's needs and a more solid starting point for the designers to deliver a safer design. Such participatory reviews of designs do not negate the need for guidance for designers at an earlier stage as they should be facilitated as early as possible in optimising their design for human operation. The above-mentioned standards can be used in combination with 3D participatory review, however the process has not been detailed or suggested clearly in any of the before mentioned standards. So while on the one hand the ISO 9241-210 (2010), Ergonomics of Human-System Interaction, requires participatory human centred approaches it does not provide technical details on what specific aspects should be considered and how to concretely carry out such a process. The link with the more specific standards such as ISO11064 for the Ergonomic Design of Control Centres and or the ISO 12100 (2010) on Safety of Machinery is not structured or suggested in any clear way and as a result companies must introduce internal standards or customise a suitable set of criteria to tackle the problem.

Figure 1: General Methodology

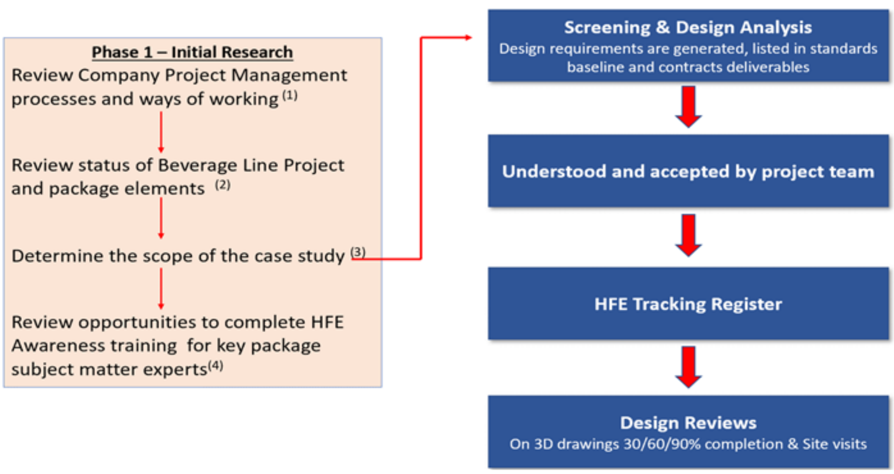
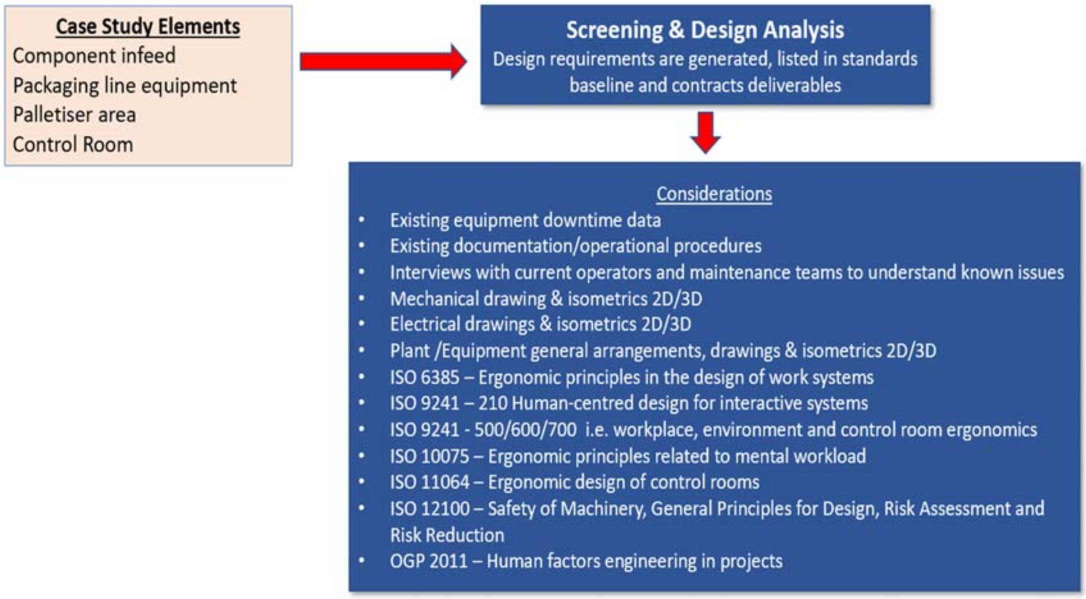


Figure 2: Considerations during HFE Screening



The objective of this case study is to determine the steps required to apply a user centred HFE informed design process and deliver benefits in terms of safety, quality and productivity of the final production line.

Conclusions and way forward

The main milestones for the proposed approach can be summarised as follow:

1) Review of critical tasks and activities the new design has to deliver and support highlighting a screening of the basics HFE elements to be considered (such as accessibility, maintainability, HMI etc.).
2) Integration of HFE principles within broader technical engineering and design requirements.
3) Set up reviews with end users as a systemic approach in design processes and collect feedback from operations.
4) Structured risk assessment at design stage for operability and maintainability including analysis of issues related to processes and tasks for which the system is designed or connected to the system being designed.

The key benefits that such a process aims to demonstrate are:

a) Improving the quality of the end-products.
   This will provide more effective and quicker intervention, support an improved personnel performance with respect to man-machine interface thus resulting in a higher quality product.
b) Preventing damage/risk to plant.
   By improving access for the use of required equipment and tools it is possible to reduce the risk of damage to piping and instrumentation.
c) Preventing illogical valve position indicators, sample points, access stairs etc.
d) Reducing/preventing errors.
   An example of this would be a HMI able to enhance diagnostic operations to support more effective intervention in the event of potentially undesirable deviations, reduction of waste through increased reliability, preventing unintended actions, etc.

e) Reducing/eliminating physical/mental stress.
Reduce pulling, pushing, lifting, bolting effort, fewer adverse working postures, more convenient operation of equipment, improved presentation of information etc.
f) Reducing training costs (requirements/time).
The delivery of simple and logical designs makes it easier to delegate work to less trained personnel ensuring participation of the end-users in the design process.

To achieve the above benefits the process is entering its' screening phase and about to engage with the 3D modelling and review phase. The key findings will be documented and a cost benefit analysis for the key user centred design recommendations will be documented and collected to demonstrate the potential benefits and or inefficiencies the review was able to prevent and/or initiate.

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THE RELATIONSHIP BETWEEN CIRCUMFERENTIAL TISSUE COMPRESSION, DISCOMFORT AND TISSUE OXYGENATION AT THE LOWER LIMB: APPLICATION TO SOFT EXOSKELETON DESIGN

Tjaša Kermavnar, Kevin J. O'Sullivan, Adam de Eyto, Leonard W. O'Sullivan

School of Design
University of Limerick
Limerick

Abstract

Background. Excessive external mechanical loading of soft tissues at the human-exoskeleton interface can lead to pressure-related deep tissue injury that is associated with tissue ischemia and discomfort/pain. The risk of soft tissue damage depends on the characteristics of the external loading (magnitude, direction, distribution, duration, loading cycle frequency) and the characteristics of the loaded tissue (thickness, tone, mechanical stiffness, integrity, and the proximity of bony prominences). Thus, when establishing safe thresholds for mechanical loading of soft tissues, measures additional to interface pressure need to be employed.

Methods. Three widths of pneumatic cuffs were inflated by a computer-controlled pneumatic rig at the dominant thigh and calf of healthy participants using two inflation patterns (tonic and phasic). Participants rated their discomfort on an electronic Visual Analog Scale (VAS), and deep tissue oxygenation was monitored using Near Infrared Spectroscopy (NIRS).

Results. Circumferential compression with pneumatic cuffs triggered discomfort and pain at lower pressures at the thigh, with wider cuffs, and with tonic inflation pattern. Phasic compression caused an increase in deep tissue oxygenation, whereas tonic compression decreased it.

Conclusions. Discomfort and pain during circumferential compression at the lower limb is related to the width of pneumatic cuffs, the inflation pattern, and the volume of soft tissue at the assessment site. The occurrence of pain is also possibly related to the decrease in deep tissue oxygenation during compression. These findings can be used to inform safe and comfortable design of soft exoskeletons to avoid discomfort and possible soft tissue injury.

EXOSCORE – A DESIGN TOOL TO EVALUATE FACTORS ASSOCIATED WITH TECHNOLOGY ACCEPTANCE OF SOFT LOWER LIMB EXOSUITS BY OLDER ADULTS

Linda Shore[1], Valerie Power[1]*, Bernard Hartigan[1]*, Samuel Schülein[2], Eveline Graf[3]Adam de Eyto[1]and Leonard O'Sullivan[1]

[1]*Design Factors Research Group, School of Design and Health Research Institute, University of Limerick, Limerick, Ireland*
[2]*Geriatrics Centre Erlangen, Malteser Waldkrankenhaus St. Marien, Erlangen, Germany*
[3]*Institute of Physiotherapy, School of Health Professions, Zurich University of Applied Sciences, Winterthur, Switzerland*

Abstract

Introduction Exoskeletons and exosuits are types of robotic mobility assistive devices that have the potential to assist a person's mobility in numerous settings (Borisoff *et al.* 2017). There is increased focus on exoskeletons as mobility aids for specific cohorts, such as older adults (O'Sullivan *et al.* 2015). Based on these findings and previous relevant studies by the authors (Shore *et al.* 2019) we generated a new design model that has been created to apply during development of a soft robotic exoskeleton with older adult participants as a means to measure attitudinal insights towards exosuits. Figure 1 details our Iterative Design Assessment Model (IDAM, Shore et al, 2019), which incorporates methods of usability and Technology Acceptance Models (TAMs) as a combined hybrid-design approach for the development of exoskeletons and exosuits. IDAM captures reflective practice, interactions and engagement between designers and participants throughout each evaluation phase.

As part of IDAM, we present the Exoscore evaluation tool and results from a pilot study using the Exoscore tool with users as they performed tasks and experiences of a soft lower limb exoskeleton concept. Exoscore gauges older adults' perceptions and perceived impact of exoskeletons as assistance options for enhanced/increased mobility. Figure 1 also displays how Exoscore fits within the Iterative Design Assessment Model. It is a three-phase tool: 1) Perception, 2) Experience and 3) Perceived Impact. Exoscore is a design and prototype stage evaluation method to assess factors related to perceptions of the technology, the aim being to optimise technology acceptance.

Method In this pilot study, we applied the three-phase Exoscore tool during testing with 11 older adults. The aims were to explore the feasibility and face validity of applying the design evaluation tool during user testing of a prototype soft lower limb exoskeleton.

Results Exoscore was applied during an exoskeleton design R&D project. The data revealed the aspects of the concept design which rated favourably with the users, and the aspect of the design which required more attention to improve their potential acceptance when deployed as finished products.

Conclusions Exoscore was effective to apply during three phases of evaluation during a testing session of the soft exoskeleton. This study reveals how the introduction of Exoscore to exoskeleton development will be advantageous when assessing technology acceptance of exoskeletons by older adults.

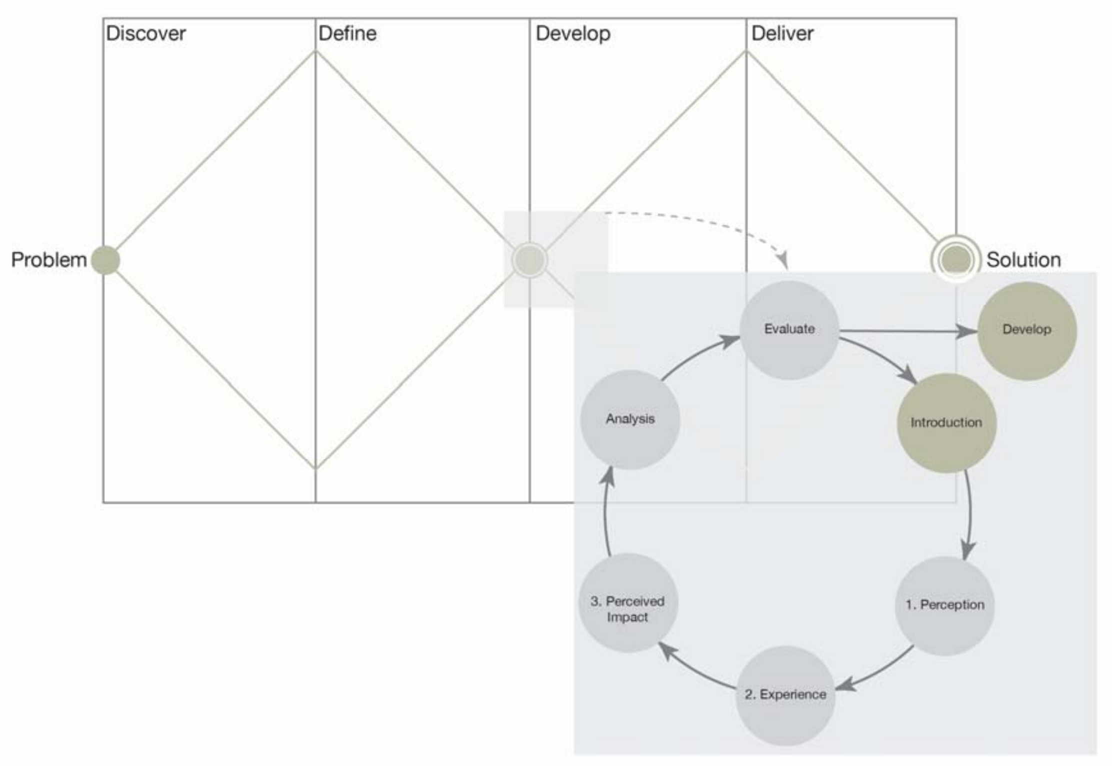

Figure 1. IDAM & Exoscore stages and work phases

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