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THE ROLE OF SITTING POSTURE IN CHRONIC MUSCULOSKELETAL DISORDERS

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Abstract

Sitting is a very common aggravating factor for people with musculoskeletal disorders (MSDs), and alterations in sitting posture are commonly proposed to contribute to the development and aggravation of MSDs. However, the relationship between sitting posture and MSDs is not simple. This paper briefly reviews the relationship between sitting posture and the most common MSD - low back pain (LBP) - and considers the implications of this for the future of ergonomics in the prevention and management of MSDs.

Background

Low back pain (LBP) is the most common and costly musculoskeletal disorder (MSD) (Woolf and Pfleger, 2003, Briggs *et al.*, 2016). Prolonged sitting is a common aggravating factor for many people with LBP (Williams *et al.*, 1991). Consequently, it is unsurprising that people with LBP are commonly advised to adjust their sitting posture (Poitras *et al.*, 2005). It is important that strategies used to prevent or reduce the incidence and impact of MSDs are evidence-based. Consequently, it is appropriate that the role of sitting posture in MSDS such as LBP is critically evaluated, which is the focus of this article.

Reviewing the evidence

Does sitting for longer cause LBP?
Contrary to popular perception, people who sit longer do not appear to be more at risk of developing LBP (Lis *et al.*, 2007, Roffey *et al.*, 2010). There may, however, be a slightly increased risk of developing LBP if there is combined exposure to prolonged sitting, awkward postures and vibration (Lis et al., 2007). There is also no doubt that prolonged sitting often aggravates LBP (Dankaerts *et al.*, 2006b), but this aggravation is not necessarily causative. Therefore, while reducing sitting time might be useful in targeting a range of other health conditions (Katzmarzyk *et al.*, 2009), it is not likely to be the single most effective intervention for LBP.

What are "good" and "bad" sitting postures?
While sitting involves greater lumbar flexion than standing (De Carvalho *et al.*, 2010, Scannell and McGill, 2003, Dunk *et al.*, 2009), there is considerable debate on what constitutes an optimal degree of seated lumbar flexion (Claus *et al.*, 2009b, O'Sullivan *et al.*, 2006). Increased

lumbar flexion in sitting, or slumped sitting, has been to some extent demonised by healthcare and ergonomics professionals (O'Sullivan *et al.*, 2012b), such that members of the public now commonly perceive upright postures as "good" and flexed sitting postures as "bad" (O'Sullivan *et al.*, 2013a). Many of the proposed risks associated with sitting, and in particular sitting in flexion, such as increases in intradiscal pressure are no longer considered valid (Claus *et al.*, 2008). Furthermore, it is clear that sustaining upright sitting postures can be associated with uncomfortably high levels of paraspinal muscle tension (Reeve and Dilley, 2009, O'Sullivan et al., 2006, Claus *et al.*, 2009a). Therefore, it is important that decisions on what an optimal sitting posture looks like are based on empirical data in clinical populations, rather than simple anecdotes or experimental analysis of secondary outcomes such as muscle activation or posture.

Do people with LBP sit differently?
There is no evidence that more flexed sitting (or standing) spinal postures cause LBP or other health conditions (Christensen and Hartvigsen, 2008). On average, people with LBP do not appear to adopt sitting postures that differ from matched pain free controls (Murrie *et al.*, 2003) (Dankaerts et al., 2006b). However, it appears that people with LBP can adopt postures which are closer to the end-range of flexion and extension of the lumbar spine (Dankaerts et al., 2006b, Van Dillen *et al.*, 2009). For example, some people with LBP adopt very flexed sitting postures while others adopt very extended sitting postures, with both of these options being potentially provocative (Dankaerts et al., 2006b, O'Sullivan *et al.*, 2013b, Van Dillen et al., 2009). This individual variation between patients is not typically considered in clinical trials which examined posture in people with LBP.

Does changing a person's posture help LBP?
While it is true that at least some people with LBP report less symptoms in upright sitting postures (Womersley and May, 2006, Williams et al., 1991), it appears that other people with LBP report greater discomfort when assuming upright postures (Dankaerts et al., 2006b, Dankaerts *et al.*, 2006a). This overlaps with the aforementioned point that not all people with LBP are the same, and thus they might not all require precisely the same treatment. Consequently, generic postural advice and changes are not effective in treating LBP. Key to establishing whether postural advice is likely to be of benefit for a person with LBP might be (i) selecting those patients where their LBP is more closely related to spinal posture and movement rather than systemic sensitivity (Smart *et al.*, 2011) and (ii) matching the type of postural advice provided to their own individual movement pattern. The first aspect relates to identifying, based on a simple, yet thorough history, those people whose pain involves a considerable input from spinal tissues, as opposed to those whose pain appears to be primarily mediated by the chronic sensitisation of the nervous system. The second aspect involves providing simple postural feedback to help reduce seated discomfort (O'Sullivan et al., 2013b) by matching the feedback to the individual movement patterns of each person. Specifically, this involves facilitating less flexion in those who are very flexed in their sitting posture and whose pain is aggravated by flexion, and facilitating more flexion in those who are very upright and whose pain is aggravated by extension. This can be done using a variety of options (e.g. software, mirrors, videos) according to availability, technological capacity and preference.

Does changing seat design help LBP?
Despite the very large amounts of money spent on changing seating design, in a wide variety of ways, the evidence that these changes lead to meaningful reductions in the level of LBP reported is very underwhelming. For example, the use of a range of dynamic or "wobbly" surfaces to sit on has gained popularity. However, systematic reviews (O'Sullivan *et al.*, 2013c, O'Sullivan *et al.*, 2012a) demonstrate that they have no effect on LBP, and minimal effect on

changing posture or muscle activation. Chairs which involve less hip flexion facilitate a more upright lumbar sitting posture and often receive positive ratings in terms of comfort from people, at least initially (Saarni *et al.*, 2009a, Saarni *et al.*, 2009b). However, they do not reduce LBP incidence or impact, with some evidence that they might actually make people more uncomfortable on average (Curran *et al.*, 2015). Once again, the need to match treatment and advice to the needs of each individual person is clear when we consider that the same type of chair (a dynamic saddle chair) has been shown to increase LBP in some subjects and decrease LBP in other subjects, and that whether their LBP was increased or decreased by the chair was related to the person's presentation (Curran *et al.*, 2014, O'Keeffe *et al.*, 2013). Perhaps the most simple aspect of chair design – having backrests on a chair – at least have some evidence suggesting they can reduce paraspinal muscle activation, and some more limited evidence that they reduce LBP (Curran et al., 2015). The effect of varying backrest inclination on LBP is once again not fully established in the long-term.

Interpreting the evidence

How strong is the available evidence?

There are several concerns regarding the available evidence. The most common of these are;

- A lack of randomised clinical trials or longitudinal design studies, limiting the ability to make definitive conclusions about causality.
- Many studies investigate the effect of several changes in chair design simultaneously, such that it is difficult to determine the effect of one specific aspect
- Many studies examine only people without LBP
- Many studies are very brief, looking only at short-term changes
- Most studies investigate the effect of changing posture or chair design in isolation, rather than as part of a more comprehensive LBP programme

Why might the evidence be so underwhelming?

One likely reason why interventions aiming to change a single physical aspect such as sitting posture seem to have limited effectiveness on LBP, is that physical factors are only one part of complex disorders such as LBP (O'Sullivan, 2012). We see the same, very weak, evidence of effectiveness when we examine interventions such as massage (Furlan *et al.*, 2015), injections (Furlan et al., 2015) and surgery (Kamper *et al.*, 2014, Phillips *et al.*, 2013). This does not mean that these interventions never have anything to offer – merely that they cannot, as unidimensional interventions, address the complexity of a bio-pycho-social disorder like LBP. It is possible however, that such interventions could play a role, for some patients, once these patients are appropriately selected (O'Sullivan et al., 2013b, O'Keeffe et al., 2013) and integrated into a more comprehensive rehabilitation programme that also considers how to de-sensitise the person's central nervous system. Such a comprehensive rehabilitation programme is likely to require consideration of a range of other cognitive, psychological, social and lifestyle factors (O'Keeffe *et al.*, 2015). Ideally this would involve contributions from multiple stakeholders – employees, employers, union, insurers, as well as health service and social welfare agencies. This is a considerable challenge, and one which current management of MSDs struggles to achieve.

Are there any potential downsides to providing advice on spinal posture?

Providing advice on "good" sitting posture is intuitively appealing, to employees, employers and healthcare professionals. However, unlike several others aspects related to health and safety

in workplaces, evidence that providing such advice enhances the health and/or productivity of employees is lacking. Therefore, it could at the very least be questioned whether it is a good use of resources. Secondly, and more importantly, it is worth considering whether there is any potential for harm with such advice. For example, a recent study has shown that manual handling training leads to a deterioration in employee beliefs about LBP, such that they develop unhelpfully fearful beliefs about the dangers of lifting relatively trivial loads (Horgan and O'Sullivan, 2015). While the effect of providing sitting posture advice on employee beliefs has not been specifically examined, the wider literature on LBP and other MSDs demonstrates that factors such as fear and hypervigilance are associated with persistence of pain and disability. In addition, the potential for ergonomics suggestions, which may or may not be feasible for employers to implement, to exacerbate employee feelings of anger and perceived injustice should at least be reflected on.

This raises an important question for healthcare and ergonomics professionals, with implications for employers, employees and indeed wider society - are we comfortable with the idea that prevention is not always best, that experiencing LBP for a short period at some point in life is actually normal and that well-intentioned attempts to remove perceived "risks", e.g. seated lumbar flexion, "heavy" school bags etc. might actually be problematic and increase the perception that the body is vulnerable and must be "protected" for fear it ever experiences any pain?

Conclusion

MSDs such as LBP remain common, costly and disabling. Sitting clearly aggravates LBP for many people, but neither sitting duration nor sitting posture seem to be clear causes of getting LBP. In the short-term, considering changes to sitting posture to alleviate discomfort while sitting may be justifiable. However, such changes are likely to have more effect among certain patients, and when it is matched to their individual needs. In the long-term, wider bio-psycho-social factors need to be considered in LBP, as these are more closely related to LBP than purely physical/ergonomics factors. Whether providing prophylactic advice to pain free people on their sitting posture reduces their risk of LBP, or actually contributes to the problem, is debatable at the moment.

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THE ROLE OF ERGNOMICS IN THE DEVELOPMENT OF INNOVATIVE SOLUTIONS

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Abstract

The most recent data produced by the ESRI (Research Series Number 40, ESRI, 2015) indicates that occupational illness rates have increased from 21.7 per 1,000 workers in 2001 to 27.1 per 1,000 workers in 2012 and that musculoskeletal ill health accounts for over 50% of illnesses recorded. There is a similar picture across the EU and the EU commission has recommended that member states need to develop and strengthen legislative measures to minimise exposure to risk factors originated by poor ergonomic conditions in the workplace. The Health and Safety Authority has published a three year strategy (Strategy Statement, 2016) and for the first time there is a specific strategy for health. The key goals are to increase knowledge and understanding of work-related health, raise awareness of the need to identify and assess health risks and ensure legal compliance through proportionate enforcement. Ergonomics has an important contribution to play in achieving these goals. The Authority made contact with external stakeholders and work was completed on the development of a publication on Ergonomic good practice in the Irish workplace to showcase examples of innovative engineering solutions put in place in workplaces which were cost effective and improved worker health and increased productivity. The five case studies in the publication illustrate how the use of ergonomic tools and skills can create the appropriate environment for effective data collection on tasks, critical analysis and solution development.

Introduction:

In recent years the EU considered the development of a new Directive specifically focused on the management of musculoskeletal disorders in the Workplace. However a decision was taken in 2013 not to pursue a new Directive but rather to publish a Council Recommendation for member states. The main recommendations were that member states needed to develop and strengthen legislative measures to minimise exposure to risk factors originated by poor ergonomic conditions in the workplace and ensure the effectiveness of these measures by providing adequate instruments and resources to implement and enforce them. It was agreed that the existing regulatory framework had the appropriate provisions to proactively address the risk of musculoskeletal injury and ill health. The

regulatory requirements concerning manual handling are geared towards providing mechanical equipment or changing the way work is done to avoid the need for manual handling, where manual handling of loads cannot be avoided, taking steps to reduce the risk involved by using appropriate mechanical equipment or changing the way that work is done and risk assessing work activities in order to identify the risk factors and then taking steps to reduce the risk of injury. Historically the Health and Safety Authority has published solution focused sector specific case studies in order to create a better understanding and awareness of measures that should be considered to meet regulatory requirements both in terms of risk assessment and solution development. However it was recognised that there was a need to develop a publication on Ergonomic Good Practice in the Irish workplace which would showcase examples of innovative engineering solutions and underline that ergonomic risk management has many benefits besides risk reduction. It was agreed that as part of the programme of work of the H.S.A. for 2015 that a resource would be developed demonstrating examples of good practice, where engineering interventions minimise exposure to risk factors caused by poor ergonomic conditions in the workplace. This paper will outline the how this objective was achieved and how ergonomics contributes to the development of innovative solutions.

Case Study Development

The initial step in case study development involved making contact with professional bodies and inspector colleagues in order to identify workplaces that would be in a position to showcase examples of interventions that they put in place to address unfavourable ergonomic conditions in order to avoid or reduce the risk of musculoskeletal ill health or injury. It was important for this project that the case studies could underline the many benefits of ergonomics in enhancing and fostering innovation, creative thinking, effective communication, consultation, team work and problem solving. Following consultation, it was decided to follow up with a number of workplaces in different sectors that had introduced ergonomic interventions in the workplace and eventually five workplaces agreed to participate in the project. In order to present examples of good ergonomic practice effectively it is necessary to use visual presentation of both problems and solutions to assist understanding of the nature of risk itself and risk reduction. It was decided that as part of the publication design, it would be necessary to complete photoshoots at all five sites using a professional photographer in order the maximise the quality of the finished product. The next step involved initial meetings with each of the five workplaces involved to explain the project objectives and desired outcomes. It was important to that the case studies would present a story of the journey or process from problem identification to problem solving and finally the outcome and results. Each of the case study participants was asked to complete a questionnaire in order to collate important information on the process as a means of teasing out and exploring the range of skills, work methods, human interaction and tools that contributed to the development of a robust, well tested and satisfactory outcome. The case study questionnaires informed the photoshoot design in that it gave an insight to the aspects of the job or task that presented difficulty for the workers and the benefits of the engineering solution. The photo shoots took place over a two month period and there was great involvement from both workers and management and it was evident that those involved in the solution development took pride in the work they do and the solutions that they developed. Once the photoshoots were completed there was ongoing correspondence in order to finalise the case study content based on the information supplied in the questionnaires. The final fives case studies were agreed and the publication was submitted for final design and it was released in December 2015.

Results

Ergonomics is concerned with the study of work practices, using available data and research to assess existing work practices in order to develop better ways of working that can improve job performance both in terms of worker health and productivity. Ergonomics also has a contribution to make in encouraging the development of innovative engineering solutions and this was one of the main reasons why this publication was completed. There were five case studies produced and Table 1 below presents a picture of what was achieved by the workplaces involved through good Ergonomic practice. The companies involved were, John Crane (Ireland) Ltd, Rusal Aughinish, Green Isle Foods, Johnston Mooney & O Brien and MFP Plastics Limited.

Table 1 Case study summary

Company	Problem Identification	Outcomes	Results
John Crane	Manual Loading of heavy (20-130kg) metal billets into a CNC machine while engaged in awkward posture.	A custom engineered billet loader was fixed to the floor. Scissors table installed for transport of billets Purchasing vendor arranged for material vendor to supply billets with a 1" hole drilled into the billet Training in the use of new loader provided.	Cost of engineering solutions €800/machine. Billet can now be loaded in less than one minute as opposed to 5 to 10 minutes. Team more aware of the contribution of ergonomics during the process.
Rusal Aughinish	Large pipes had to be welded at different points resulting in awkward posture for the welders and the pipes had to be lifted with slings requiring at least 64 interruptions.	The Agreed changes were to utilise equipment (rollers) which had adjustable wheel spacing to suit different pipe diameter, adjustable height and a motorised stand so that the pipe could be rotated.	One welder can now complete the welding task in a neutral posture There are fewer changeovers required. The weld quality has improved. Innovative and creative thinking was evidenced by changing a 30 year old practice of pipe welding.
Green Isle Foods	Operators raised concerns about the difficulty in lifting tasks involved in a process changeover as the load weight was 45-55kg, and the lifting activity required operators to engage in lifting the load above shoulder height.	A new structure was fabricated and fitted into position above the production line. The load (positioner head) that had to be changed over was placed on the new framework and held in place. When this head was needed, clips were released and the heads were rolled down along the framework into position.	The engineering solution eliminated the lifting of the positioner head while engaged in an awkward posture. The design was developed by in-house staff through creative thinking and innovation. The changeover time is considerably less now so efficiencies have being improved.
Johnston Mooney & O Brien	Large buggies which contain baking trays are manually moved	A new tug was sourced and modified so that the new tug could meet the task	Maintenance and engineering were involved in a creative problem solving process.

	by two operatives from a holding area resulting in significant pushing of a large load over a distance while engaged in awkward posture	requirements. This tug eliminated the two person manually pushing of the large buggies.	The task is now a one person task and there were increased efficiencies on changeovers.
MFP Plastics	Bags of raw material had to be lifted from a storage location, placed on a trolley and then lifted from the trolley into a weigh station. This resulted in lifting heavy loads above shoulder height and below knee height	A specialist handling equipment supplier was commissioned to supply a power vacuum lifted and a scissor lift table. Training was provided to employees in the new system of work.	The risk of injury has being reduced as there is reduced lifting of loads required and activities can be carried out with good neutral posture. A combination of various stakeholders brought experience and ergonomic knowledge to the project. The employees expressed appreciation for the investment,

Conclusions:

Ergonomics has an important contribution to play in the design of workplaces and work tasks, the case studies in the Ergonomic Good Practice publication underline the potential for the development of innovative cost effective solutions through the application of ergonomic risk management principles. These principles include, knowledge of the nature of work, competency in the application of ergonomic risk assessment tools, competency in the development of innovative engineering or organisational interventions to manage ergonomic risk, good communication and consultation and management commitment. According to Caple, 2007, to be effective in practice, those that work in Ergonomics need to be good communicators and "agents for change" who can mentor others to develop cost effective interventions. He also says that "sustainable positive outcomes based on a holistic approach will result in a broad uptake in ergonomic findings". It may be worth exploring this vision further into the future and considering new opportunities to raise awareness on the positive contribution ergonomics can make at workplace level.

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RELATIONSHIP BETWEEN SOCIAL SUPPORT AND UPPER LIMB PAIN IN EMPLOYED AND SELF-EMPLOYED CHARTERED PHYSIOTHERAPISTS, PHYSICAL THERAPISTS AND ATHLETIC THERAPISTS IN IRELAND

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Abstract

Within the international literature, self-employed workers appear to be more at risk of suffering WRMSDs compared to their employed counterparts. This indicates the need to assess psychosocial work factors, specifically social support, in employed and self-employed workers in relation to the development of WRMSDs. This paper used data from the HITS study, which was a cross sectional study investigating upper limb (UL) pain/discomfort in chartered physiotherapists and physical/athletic therapists in Ireland. This paper indicates the importance of supervisor support in relation to the prevention and/or reduction of work-related UL pain/discomfort prevalence in employed therapists and peer support in employed and self-employed therapists for prevention and/or reduction of incapacitating UL pain/discomfort prevalence. This indicates that social support, both supervisor and peer, needs to be taken into account when investigating the development of WRMSDs along with physical and organisational work factors.

Introduction

The international literature indicates that psychosocial factors; such as low job satisfaction, highly monotonous tasks, low supervisor support, high job demands, low job control, low decision authority and high job strain; influence work-related musculoskeletal disorders (WRMSDs) (Lang et al., 2012, Hauke et al., 2011). Evidence from a systematic review of longitudinal studies shows that a lack of support from immediate supervisors along with work or time pressures, are important contributors to WRMSDs, specifically low back, neck and/or shoulder symptoms, among workers across a range of industries (Lang et al., 2012). High levels of work-related social support can compensate for work-related strain which workers have to contend with in the workplace (Eurofound, 2012).

Within employed workers, low supervisor support is a relevant risk factor for the development of WRMSDs, however, low peer support does not appear to predict the

development of WRMSD symptoms (Lang et al., 2012). Within the current literature, self-employed workers appear to be more at risk of suffering WRMSDs compared to their employed counterparts (Eurofound, 2012). It can be hypothesised that self-employed workers lack any supervisor support and generally only have the support of fellow self-employed workers in their field. However, there is a dearth of research evidence in this area for self-employed workers. This indicates the need to assess psychosocial work factors, specifically social support, in employed and self-employed workers in relation to the development of WRMSDs.

One occupational grouping of interest, with employed and self-employed workers, are physiotherapists, physical and athletic therapists. Employed and self-employed chartered physiotherapists, physical and athletic therapists in Ireland report a higher prevalence of reported LBP than the national working population suggesting that this group may be involved in work practices that place them at increased risk (Hogan et al., 2016). Therefore, further research to investigate workplace risk factors, including psychosocial work factors, affecting employed and self-employed therapists in this specific occupational grouping is warranted.

Whilst internationally the terms *physiotherapist* and *physical therapists* are used interchangeably, in Ireland, there is a distinct difference in the use of these terms and they have been historically organised as two separate professions. Chartered Physiotherapists and Physical/Athletic Therapists will be described as *therapists* in this paper.

The objectives of this study were [1] to establish and compare the prevalence of upper limb (UL) pain/discomfort, along with incapacitating UL symptoms, among both employed and self-employed therapists in Ireland [2] to determine the relationship between social support and UL pain/discomfort, along with incapacitating UL symptoms, by employment status and [3] to estimate and compare the adjusted odds of developing UL pain/discomfort, along with incapacitating UL symptoms, based on exposure to social support for employed and self-employed therapists in Ireland while adjusting for relevant socio-demographic, physical and other psychosocial work factors.

Methods

Study Design

The Health In Hand Intensive Tasks and Safety (HITS) study was conducted in 2011 (Nolan et al., 2012). This was a cross sectional study design investigating UL pain/discomfort in practicing chartered physiotherapists, physical therapists and athletic therapists in Ireland.

The sampling of Physical Therapists and Athletic Therapists was completed through three databases aiming for a representative Irish sample. Chartered Physiotherapists were sampled from two different populations; the population of chartered physiotherapists in private practice and from the population of chartered physiotherapists employed in hospitals. Study participants working in private practice were randomly selected from two databases. To sample chartered physiotherapists in private and public hospitals, one-stage proportionate clustered sampling was used. Hospitals were selected based on bed capacity to ensure representation of physiotherapists working in different size hospitals reflecting approximately the proportionate distribution of different hospitals sizes in Ireland. Each study participant was sent an invitation letter to participate in the study which included an information sheet and a self-administered questionnaire along with a self-addressed stamped envelope.

Questionnaire

The HITS questionnaire was pilot tested for content validity and question clarity by therapists in all work settings. Respondents provided self-reported data relating to the occurrence of UL pain/discomfort (shoulders, elbow, wrist, finger and thumb pain) and incapacitating symptoms in the past 12 months. The questions on pain/discomfort in each above body part were part of the administered Nordic Questionnaire on MSDs (Kuorinka et al., 1987). The contribution of psychosocial work factors specific to therapists was measured by selected scales from the Copenhagen Psychosocial Questionnaire (COPSOQ) (long version) (Pejtersen et al., 2010). For self-employed therapists, the social support scales of the COPSOQ questionnaire were modified which allowed for separate scales for both employed and self-employed therapists. For data analysis, each of the scales were analysed as continuous variables. In relation to other psychosocial work factors, respondents completed the 12-item General Health Questionnaire (GHQ), which investigated how respondents felt their health has been in general, over the last few weeks. For the data analysis, we used the binary scoring method (with the two least symptomatic answers scoring 0 and the two most symptomatic answers scoring 1). For the 12-item GHQ, a threshold value of 3 is classed as achieving 'psychiatric caseness'. (Jackson, 2007). Data were analysed using the Statistical Package for Social Science (SPSS) Version 22. Descriptive analysis, cross tabulations, one way ANOVA analysis and Logistic regression models were used.

Ethical Approval

Ethical approval for the HITS study was received from The Clinical Research Ethics Committee of the Cork Teaching Hospitals, Cork, Ireland. Informed consent was sought from all participants.

Results

The final sample size for data analysis in the HITS data was 347 therapists. This included 141 currently practicing physical therapists and athletic therapists (response rate: 76 percent), 135 chartered physiotherapists in private practice (response rate: 54 percent) and 71 hospital-based chartered physiotherapists (response rate: 31 percent). During data analysis, it became clear that there was a systematic respondent error in completing the social support scales i.e. some respondents were clearly employed, however, they completed the self-employed social support scale. This occurred with 30 respondents, of which 29 were employed and one was self-employed. These 30 respondents had to be removed from the final sample size for data analysis, which left 317 therapists. The final sample size consists of 115 employed therapists and 202 therapists, however, six of these didn't answer the social support scales.

Table 1 shows the prevalence of UL pain/discomfort and incapacitating UL symptoms in the past 12 months for employed and self-employed therapists. Self-employed therapists had a significantly higher prevalence of combined UL pain/discomfort and pain/discomfort in any UL (84.7 percent and 86.6 percent, respectively) compared to their employed counterparts (68.7 percent and 76.8 percent) ($P \leq 0.01$ and $P=0.04$, respectively). Contrary to this, employed therapists had a significantly higher prevalence of incapacitating UL pain/discomfort (32.7 percent) compared to their self-employed counterparts (21.5 percent) ($P=0.04$).

Table 1: Prevalence of UL pain/discomfort in the past 12 months for employed and self-employed therapists

	Combined UL Pain /discomfort		Pain/discomfort in any UL[a]		Incapacitating UL pain/discomfort[b+c]	
	n (%)	95% CI	*n* (%)	95% CI	n (%)	95% CI
Employed Therapists (n=115)	**79 (68.7)**	**60.2-77.2**	**86 (76.8)**	**69.0-84.6**	**36 (32.7)**	**23.9-41.5**
Self Employed Therapists (n=202)	**171 (84.7)**	**79.7-89.7**	**175 (86.6)**	**81.9-91.3**	**43 (21.5)**	**15.8-27.2**

[a] 3 missing values in employed therapists
[b] 5 missing values in employed therapists
[c] 2 missing values in self-employed therapists

Table 2 shows the results of the one way ANOVA for social support and UL pain/discomfort. Within employed therapists, those who indicated suffering from incapacitating UL pain/discomfort reported significantly lower peer support than those employed therapists who did not report incapacitating UL pain/discomfort (P=0.03). Those employed therapists who indicated suffering from combined and any UL along with incapacitating UL pain/discomfort reported significantly lower supervisor support than those employed therapists who did not report these forms of pain/discomfort (P=0.05, P≤0.01, P≤0.01 and P=0.03, respectively). For self-employed therapists, those who indicated suffering from combined and any UL along with incapacitating UL pain/discomfort reported significantly lower self-employed peer support than those self-employed therapists who did not report these forms of pain/discomfort (P≤0.01, P≤0.01 and P≤0.01, respectively). Social support from other professionals for self-employed therapists doesn't show any significant findings.

Table 2: UL pain/discomfort in the past 12 months by social support for employed and self-employed therapists

	Employed Therapists				Self-employed Therapists			
	Social Support Peers (Scale Range 0-12) (N=110)		Social Support Supervisors (Scale Range 0-12) (N=108)		Social Support from self-employed peers (Scale Range 0-12) (N=201)		Social Support from other professionals (Scale Range 0-12) (N=201)	
	M (SD)	p-value	*M (SD)*	p-value	*M (SD)*	p-value	*M (SD)*	p-value
Combined UL Pain /discomfort								
Yes	7.53 (2.44)	0.17	**5.87 (3.05)**	**≤0.01**	**5.62 (3.07)**	**≤0.01**	4.86 (3.04)	0.98
No	8.18 (1.72)		**7.73 (2.55)**		**7.10 (2.45)**		4.87 (2.99)	
Pain/discomfort in any UL								
Yes	7.57 (2.38)	0.20	**5.85 (3.08)**	**≤0.01**	**5.61 (3.06)**	**≤0.01**	4.88 (3.02)	0.83
No	8.23 (1.75)		**8.29 (1.88)**		**7.37 (2.36)**		4.74 (3.13)	
Incapacitating UL pain/discomfort								
Yes	**7.09 (2.32)**	**0.03**	**5.51 (2.96)**	**0.03**	**4.47 (3.30)**	**≤0.01**	4.09 (3.12)	0.07
No	**8.07 (2.16)**		**6.83 (2.98)**		**6.24 (2.86)**		5.06 (3.00)	

Table 3 shows the results of the logistic regression models. Employed therapists who reported higher levels of peer support were significantly less likely than those employed therapists who reported lower levels of peer support to report incapacitating UL pain/discomfort following adjustment for relevant socio-demographic, physical work factors and other psychosocial work factors [OR 0.77, 95% CI (0.60-0.97)]. Employed therapists with exposure to supervisor support were significantly less likely than those employed therapists without supervisor support to report combined UL pain/discomfort and pain/discomfort in any UL following adjustment for relevant socio-demographic, physical work factors and other psychosocial work factors [OR 0.78, 95% CI (0.64-0.94) and OR 0.67, 95% CI (0.52-0.87), respectively]. Self-employed therapists with exposure to peer support were significantly less likely than those self-employed therapists without peer support to report combined UL pain/discomfort, pain/discomfort in any UL and incapacitating UL pain/discomfort following adjustment for relevant socio-demographic, physical work factors and other psychosocial work factors [OR 0.83, 95% CI (0.71-0.98), OR 0.81, 95% CI (0.68-0.96) and OR 0.67, 95% CI (0.73-0.93), respectively]. There was no significant association between social support from other professionals for self-employed therapists and reported pain/discomfort in employed or self-employed therapists.

Table 3: Logistic Regression – the association between pain/discomfort in ULs and social support in employed and self-employed therapists

	Combined UL Pain /discomfort		**Pain/discomfort in any UL**		**Incapacitating UL pain/discomfort**	
	OR (95% CI)	p-value	*OR (95% CI)*	p-value	OR (95% CI)	**p-value**
Employed Therapists						
Social Support Peers						
M1	0.87 (0.72-1.06)	0.17	0.89 (0.72-1.09)	0.25	**0.81 (0.66-0.98)**	**0.03**
M2	0.86 (0.69-1.08)	0.19	0.87 (0.69-1.12)	0.28	**0.77 (0.62-0.96)**	**0.02**
M3	0.88 (0.70-1.11)	0.29	0.90 (0.70-1.17)	0.44	**0.77 (0.60-0.97)**	**0.03**
Social Support Supervisors						
M1	**0.76 (0.65-0.92)**	**≤0.01**	**0.70 (0.56-0.86)**	**≤0.01**	**0.86 (0.74-0.99)**	**0.03**
M2	**0.77 (0.64-0.93)**	**≤0.01**	**0.67 (0.52-0.86)**	**≤0.01**	0.88 (0.76-1.03)	**0.10**
M3	**0.78 (0.64-0.94)**	**≤0.01**	**0.67 (0.52-0.87)**	**≤0.01**	0.88 (0.75-1.03)	**0.10**
Self-employed Therapists						
Social Support from peers						
M1	**0.86 (0.75-0.99)**	**0.04**	**0.83 (0.71-0.97)**	**0.02**	**0.82 (0.73-0.92)**	**≤0.01**
M2	**0.85 (0.73-0.99)**	**0.03**	**0.83 (0.70-0.98)**	**0.02**	**0.81 (0.72-0.92)**	**≤0.01**
M3	**0.83 (0.71-0.98)**	**0.03**	**0.81 (0.68-0.96)**	**0.02**	**0.82 (0.73-0.93)**	**≤0.01**
Social Support from other professionals						
M1	1.00 (0.87-1.14)	0.95	1.02 (0.89-1.17)	0.81	0.91 (0.80-1.01)	0.08
M2	0.97 (0.84-1.11)	0.62	0.99 (0.86-1.15)	0.92	0.89 (0.79-1.001)	0.052
M3	0.94 (0.81-1.09)	0.39	0.96 (0.83-1.12)	0.61	0.89 (0.79-1.01)	0.07

M1: Adjusted for age and gender
M2: Adjusted for age, gender, time spent as a therapist, direct patient hours per week, time providing manual therapy per week and occupational group
M3: Adjusted for age, gender, time spent as a therapist, direct patient hours per week, time providing manual therapy per week, occupational group and total GHQ score

Discussion

The international literature states that self-employed workers appear to be more at risk of suffering any WRMSDs than their employed counterparts (Eurofound, 2012). Our findings support this in relation to UL pain/discomfort. However, contrary to this a significantly higher percentage of employed therapists (32.7 percent) reported suffering from incapacitating UL symptoms compared to self-employed therapists (21.5 percent). Our findings, further, support the current literature, as we indicate that a lack of supervisor support is a risk factor to the development of UL pain/discomfort in employed therapists, whilst low peer support does not appear to have any prediction towards the development of any UL pain/discomfort (Lang et al., 2012). Interestingly, both employed and self-employed therapists with higher levels of peer support are significantly less likely than those with lower levels of peer support to report incapacitating UL pain/discomfort. Our findings also add to the limited research available in relation to self-employed workers in general, as they indicate that low self-employed peer support is a risk factor to the development of UL pain/discomfort in self-employed therapists. However, low social support from other professionals does not appear to have any prediction towards the development of any UL pain/discomfort for self-employed therapists.

The key strengths of this study were the careful sampling method and the inclusion of self-employed workers. Research including self-employed workers is generally very sparse across all occupations. Previous research on this sample investigating low back pain indicated there were no significant differences for employment status within the sample population of therapists (Hogan et al., 2016). A significant difference would have been expected, in this previous research, as the literature indicates that self-employed workers seem to be more exposed to musculoskeletal disorders risk factors, such as repetitive movements, carrying/moving heavy loads, prolonged standing or walking, painful and tiring positions, and are more affected by the related health problems than their employed counterparts (European Agency for Safety and Health at Work, 2010). These expected significant differences in employment status have been found in this study in relation to UL pain/discomfort, which further strengths the importance of further research investigating self-employed and employed therapists and the organisational work factors available to them to aid in prevention and/or reduction of UL pain/discomfort and incapacitating UL pain/discomfort.

This paper also has some key limitations. This study was a cross-sectional study design using self-reported data. Therefore, the prevalence rates reported need to be interpreted with caution due to the possibility of recall and reporting bias. The response rate for the physical therapists was high making us confident that this sample was fairly representative of the population, however, in chartered physiotherapists working in hospitals it was very low at 31 percent, for further detail see (Nolan et al., 2012). One possible contributing factor to this low response rate from hospital based physiotherapists is the negotiations with the Irish Minister for Health in relation to the title of ‘physiotherapist’ and ‘physical therapist’, which were ongoing at the time of the study. With lower response rates, the possibility of selection bias needs to be taken into account. It is unclear if the potential systematic selection bias inflated or deflated the prevalence rates for specific groups. However, potential systematic selection bias, by gender and province of residence/professional practice, was investigated. No systematic response bias was detected by gender or province (Nolan et al., 2012).

In conclusion, this paper indicates the importance of supervisor support in relation to the prevention and/or reduction of work-related UL pain/discomfort prevalence in employed therapists and peer support in both employed and self-employed therapists for prevention and/or reduction incapacitating UL pain/discomfort prevalence. This indicates that work-related social support, both supervisor and peer, needs to be taken into account when investigating the development of WRMSDs along with physical and organisational work factor

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ADDRESSING HUMAN PERFORMANCE IN AUTOMOTIVE INDUSTRY: IDENTIFYING MAIN DRIVERS OF HUMAN RELIABILITY

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Abstract

This paper presents the initial framework adopted by an industry/academia partnership project to address an expressed end user need to improve human performance and operational safety in heavy industrial vehicles production plants. The project will provide a set of coherent innovative approaches for (a) screening operations to identify safety critical areas (especially focusing on activities where human performance implications have higher impact, (b) perform participatory hazards identification studies, (c) formulate an innovative approach for modeling man-machine functions to test main performance impact factors, (d) validate the study on the basis of field data to be collected and then (e) propose production line improvements/reconfigurations and validate model results against empirical data.

Introduction

Nowadays, the importance of adopting socio-technical outlook in evaluating the effectiveness of Managerial and pure Technical measures is recognized by most organizations operating in manufacturing fields (Hong et al 2007).
Even in manufacturing most operators can engage in some kind of dangerous events every day and this ubiquity has prompted a substantial effort within researchers to understand how people perceive and respond to risk"(Sjöberg et al. 2004). Human performance in scenarios that can lead to potential risk towards operational safety is a key topic for industry, as data shows that 60–90% of accidents in the energy sector, for example, are caused by human factors (Xu-Hong and Xiang-Rui 2007). The study of the human element in risk and operational performance in general has mostly been limited to post-hoc accident analysis and observation of performance in normative circumstances. It has not previously been possible to experimentally manipulate contextual factors in a range of risky tasks that affect performance and measure their impact on behaviour, cognition and physiology.
key research questions in this area are:

- What needs to improve to achieve better operational safety in man-machine integrated functions for manufacturing?
- How can we assess operators' ability to detect and respond to safety critical issues?
- How is it possible to collect unbiased data on human performance to support risk assessments?
- How can we change production lines, procedures and training to utilise our new understanding of human performance to decrease injuries, accidents and increase productivity?

The paper presents the initial phases of a project aimed at providing a set of coherent innovative

approaches for (a) screening operations to identify safety critical areas (especially focusing on activities where human performance implications have higher impact, (b) perform participatory hazards identification studies, (c) formulate an innovative approach for modeling man-machine functions to test main performance impact factors, (d) validate the study on the basis of field data to be collected and then (e) propose production line improvements/reconfigurations and validate model results in time against empirical data to be collected.

Case study

Relying on the commitment of the industry partner, the objective of this research is to make available an innovative contribution towards the promotion of Human Performance in the field of manufacturing for the integrated effects it has on Operational Occupational, Health and Safety (OH&S) and Quality. The mission is promoted by the Industrial group who is a global leader in the capital good sector producing and selling agricultural/construction equipment, trucks, commercial vehicles, buses and specialty vehicles, in addition to a broad portfolio of powertrain applications.

The organization applies principles of World Class Manufacturing (WCM), striving for consolidating and maintaining high standards of excellence in its manufacturing systems. Aligned with Lean Production philosophy and experiencing the economic success of Japanese manufacturers since 1960, the term of WCM was first coined by Schonberger in 1986, referring to the pursuance of the best practices in manufacturing by any *world-class* organization. The leading principle is to continuously improve production performance, seeking a progressive elimination of waste, in order to ensure product quality and maximum flexibility in responding to customer requests, through the involvement and motivation of the people working in the establishment.(De Felice et al. 2015). Particularly, the WCM Program has been launched in the organization from 2005. The WCM approach was customised to the needs of the specific organizations, by implementing the model through two lines of action: 10 Managerial Pillars and 10 Technical Pillars. Each pillar stands for a particular functional area of the organization – i.e. Safety, Quality, People Development, Workplace Organization, etc. Essentially, WCM provides standardized guidelines in each *pillar* towards the theoretical final achievement of the relevant *"zero" deficiency*. Indeed, the general reference scheme depicted inside each pillar is a 7 steps escalation regulated by firm KPIs achievement and other conceptual criteria (e.g. extension of implementation of certain good practice). A system of periodical audits is established in order to verify the implementation level of the pillar and consequently assign the world-class score to each pillar at the specific plant unit. The KPI definition for the pillar escalation reflects the general progression from a reactive attitude to a proactive one. This stands for the centrality of front-line workforce engagement as the core for a successful and continuously improving organization. Indeed, one of the main features of WCM is the way it incentivizes employees to engage and take responsibility, contributing directly to process optimization through a consistent system for collecting suggestions spanning in all organization areas. This allows individuals to acquire and develop skills and good practices that are then shared across plants, forming a network of expertise and knowledge useful for the Group (CNH 2014). Finally, the main goal of this research is to develop a set of methodologies and KPIs able to quantify, control and predict Human Performance in the field of manufacturing. Essentially, each KPIs will be both a measure for the final operator performances and a measure for each factor positively/negatively affecting them. The methodology will consequently describe the relationship between KPIs, standing for a guideline to pinpoint any direct and/or latent socio-technical deficiencies affecting performance.

A toll like the one aimed to be developed by this research will enable Operational Management to efficiently and effectively tackle the losses currently attributed to Human Performance, implementing focused countermeasures with respect to one or more specific drivers of operator performance. In the long-term vision, the methodology could be exploited as a predictive tool able to anticipate and prevent human errors on production floor assessing any design change in the tasks of workstations on production lines before they are fully implemented. Consequently, the effective management of Human Performance beneficially fosters workforce motivation and empowerment with respect to organization targets, posing operator and his/her activity at the very core of a well-organized system. On the other hand, the methodology will be developed and continuous refined based on the field data. This in turns offers the possibility of empirically verifying some of the theoretical hypotheses on Human Performance modelling, an empirical validation that is much needed in the scientific community of Human Reliability Analysis.

State of the art of Human Nature investigation in World Class Manufacturing

Currently, the state of the art about Human Performance Management in World Calss Manufacturing (WCM) turns out to be very fragmented. This fragmentation is both vertical and horizontal. The vertical fragmentation refers to the gap existing between the standardized formats (e.g. ad hoc check lists) exploited at the front-line level for the daily process management and the standardized models used for the assessment of the main priorities of the plant; indeed, it is very unlikely that the whole amount of information gathered through the formats will constitute the full basis for a further remote analysis. As a result, the criticalities are often fully managed and solved at front-line level without requiring any structured modelling. Whether effective, this is totally aligned to the final purpose of proactivity attempted by WCM; however, this gap is a proved redundancy adverse to the principles of lean management. Plus, this gap implies a significant amount of loss information emerging directly from field, which instead would be valuable for further predictive tools developing.
The horizontal fragmentation refers to the fact that information referred to Human Performance are often split between different pillars under the theoretical WCM framework. For instance, People Development pillar aims at providing some indicators as targets about proactivity level (e.g. number of suggestions by front-line operators), expertise level of the workforce or engagement level (e.g. absenteeism rate) and it is able to come up with the profiling of the workforce (i.e. age shares, genre shares, etc.). Also, Quality pillar is continuously interested in monitoring the defects on the product along the manufacturing line and jointly reporting the causes of a certain defect, i.e. human error. Finally, Safety pillar continuously strives for recording Unsafe Acts and identify the causes triggering the incompliant behavior (i.e. lack of knowledge, inattention, etc.). As a result, the set of information useful for a very comprehensive Human Performance Analysis are very spread out different pillars and usually not straightforward comparable due to the different recording standards.
Beyond standardized formats collecting information about Human Performance on a daily basis, WCM also suggests a remote assessment of Human Reliability, under the chapter of Human Nature. This latter is a crossed-functional valuation between People development and Safety pillar, intended to respond to the key question: “The matching between a specific workstation and a specific operator, is it adequate?”. To this end, the characteristic of the workstation is assessed by a workload quantification and the characteristic of the operator is assessed through a questionnaire administrated to his/her direct supervisors. By a final criticality matrix, the adequacy of the matching between a particular operator and a particular workstation is identified; eventually, the operator is moved to another workstation, characterized by a proportionate workload.

The current Human Performance practice under WCM shows three main weaknesses. First, the operator reliability assessment is only based on a checklist to be filled-in by the supervisors; this implies a high level of contingency of the quantification, mainly depending on the subjectivity of the assessor (i.e. the operator's supervisor), the specific observation time and place. This contingency is not comparable with the purpose of the final analysis which is attacking the human errors/un-compliances exhibiting a pure random nature. Thus, an objective semi-quantitative scale has to be defined to characterize the main internal factors (e.g. precision, coordination, memory, attention, etc.) affecting human performance and an experiment has to be set in order to repeatedly measure these internal factors. This would allow to come out with a distribution of the internal factors affecting the analysis rather than a determine subjective assessment.
Second, the workload assessment of the workstation is based on four main parameters accounting for: the type of the activity, the working load, the anxiety induced and the environmental conditions. Although this approach contains some useful guideline for the identification of the relevant drivers of Human Performance, a rearrangement of the factors is required since some of them are related to technical (objective) issues and other are purely subjective and depending also on the operator characteristics. Also, the model lacks the calibrations of the coefficients assigned to each parameter with respect to the data coming from field.
Third, looking at the final assessment by the criticality matrix, one of the underpinning hypothesis of such approach is that the operator reliability and the workstation workload are totally independent. Adversely, the new model expects to describe any Human Performance deficiency at the interaction level between the operator and the workstation; meaning that the reliability of a person is strictly dependent also on the external factors and it is not merely an intrinsic characteristic of the individual.

Description of the test-beds

The action based research is benefiting from the opportunity to pilot its entire progress on 4 manufacturing plant units, dislocated around Europe. The specific choice of the plants was guided by the Industrial Managers promoting this research; the main criteria beyond is to introduce the new Human Performance Management at the most advanced plants with respect to WCM score. Furthermore, the selected set is very exhaustive referring to the organization business; indeed, each plant is producing 4 different types of final product: tractors, trucks, engines and commercial vehicles. This gives the chance to come up with a methodology tailored to the eventual diverse requirements of the whole business corporate.
The commonality of all plants is that they are very labor intensive unit, meaning that most of the process requires manual/semi-manual assembly activities. Consequently, the process asks for the employment of a huge amount of workers and also the quality of human expertise greatly impacts the characteristic of the final products. In general, the most critical characteristic with respect to Human Performance has declared to be the high complexity level of the operations. The complexity level is the direct result of the huge amount of handled parts in each task (i.e. order of magnitude of 10.000 PNs for the whole process) and the high customization level of the final product imposed by the market (e.g. the annual repeatability rate for a specific model could also reach 3 same item/year). Consequently, a large range of variance of the parts and even of the operations is experienced at most workstations. This requirement on the final output diversification - whether not adequately tackled - is one of the most critical factor disadvantaging Human Performance.

Conceptual Framework

The conceptual framework leading the development of this action based research is articulated in 4 different steps: (a) screening operation activities to identify those where Human Performance implications have higher impacts, (b) formulate an innovative approach for modeling the factors affecting human performance, validating the study on the basis of field data collecting in pilot plants, (c) propose production line improvements/reconfigurations, so as to validate model results against empirical data and (d) extend the methodology to an upgraded level. This scheme reflects the general Kaizen approach of Plan – Do – Check - Act for any new implementation in Lean Production system.

The strength of the this framework is that it expects to rely on a very solid participation and commitment of both Management and shop-floor levels at each step of the analysis. In particular, the information collection strategy would rely on the establishment of a straightforward interaction with operators during any on-site survey period, through direct observations, structured and semi-structured interviews. In other words, the main intention is to adopting and continuously guaranteeing a bottom-up approach aimed at raising any issues/weaknesses directly from the initiative of the operators daily facing their activities. The clear benefit is that one is able to retrieve some latent criticalities, which may be not perceivable unless one is working at a particular workstation or is performing a specific task.

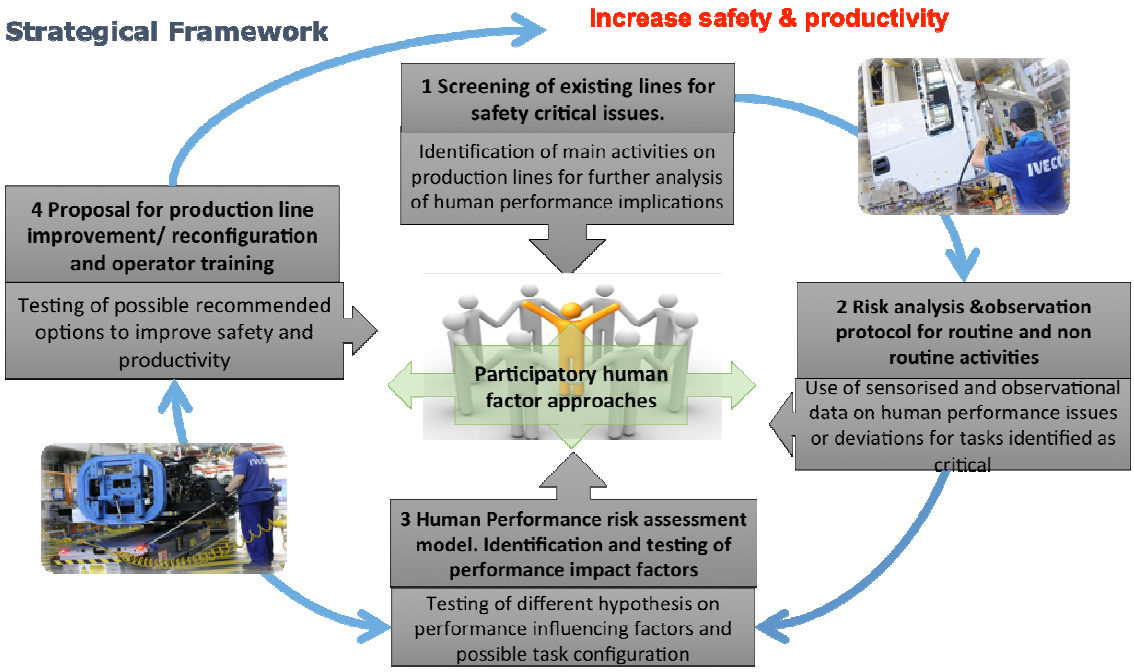

Figure 1: Methodological framework

To contain the efforts for an exhaustive observations maximizing its effectiveness with respect to resources at disposal, the initial analysis will be conducted at task level in the single workstation; therefore, once the methodology is calibrated, it will be also expanded to other areas for monitoring and prediction purposes.

Having already mentioned the importance of spanning through all pillars, the investigation on Human Performance will be a crossed functional analysis reflecting the interrelation existing between different organization targets by the operators performing a certain activity. Indeed, if a certain workstation (or area) is critical from the point of view of safety compliant behavior (i.e. the number of unsafe Acts is significant), it turns out to be also critical from the point of view of quality (i.e. the number of defects due to human errors is high). Consequently, some indicators

can be identified to measure, monitor and control Human Performance with respect to the goals set for each relevant pillar. In this sense, such indicators are both the criteria to identify criticalities among the plants (i.e. for initially selecting the area where the deterioration of Human Performance is significant and focus on them) and the KPIs to further adopt a proactive management (i.e. setting thresholds for these indicator and identifying the main measures to put in place for balance them). The Human Performance Indicators are inherited and adapted from a similar case study conducted by Baines et al.(2007) in an automotive assembly line in UK:

- Relative variance of the actual takt-time at the workstation: the takt-time is usually established at initial project level of the manufacturing line with respect to the optimal production configuration from a range of possibilities. People are treated as simple production resources, with a defined parameters and figures describing their operations at the workstations. As a result, for the unpredictable nature of the human behavior, a gap between the design takt-time and the actual takt-time is often observed in reality. This Human Performance Indicator can be seen strictly related to productivity purpose and a threshold can be set coherently with the target for the whole system.
- Number of Unsafe Acts at the workstation: for definition, Unsafe Acts are those operator behaviors which can endanger their health and safety and the one of their colleagues around (e.g. incorrect use of PPEs, incorrect use/disposal of working tool, incorrect practices while driving for logistic purposes, etc.). These information are already collected at operation level for the EHS office of the plant unit through some standardized forms. However, the introduction of a metric to quantify the severity of the specific Unsafe Acts would be very beneficial for having a more complete rendering of the safety level created by operators themselves.
- Number of Human errors at the workstation: the errors on the product can be retrieved from Quality standardized forms exploited at the shop-floor for monitoring purposes. As for Unsafe Acts, it is useful to include in the indicator a severity measure; at this purpose, the recovery time of the defect can be used as an indication.
- Absenteeism rate at the workstation: this indicator can monitor the level of engagement and commitment of the operators with respect to their jobs.

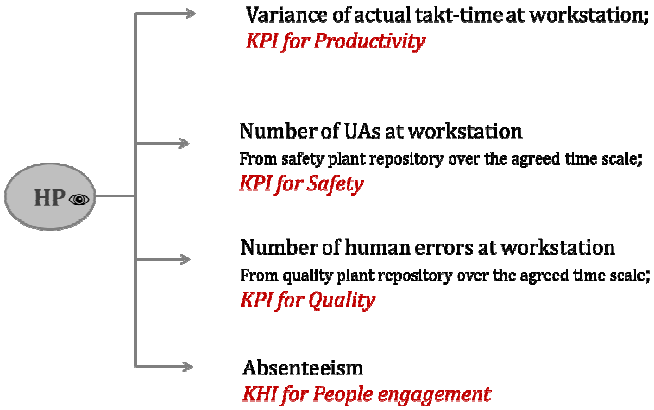

Figure 2: KPIs for monitor Human Performance

These indicators are still under verification by the plant units, in order to understand whether or not there is the possibility to derive them at workstation level and eventually which would be the new effective procedure to set for recording them.
On the other hand, it is also important to identify the KPIs representing the drivers of Human Performance. Aligned with J. Reason Swiss Cheese Model (1990), the identification of these factors should be carried out adopting a systematic approach. Error causes are both related to front-line conditions and to latent conditions. These latter stands for Management and Organizational Factors (MOFs), which may imply some deficiencies at organization workplace levels, triggering the degradation of human performance.
Baines & Benedettini (2007) conducted a body review about factors driving Human Performance in order to depict their investigation conceptual framework (i.e. identification of the parameters affecting performance in order to model the relationship with final human output). As suggested, it is of great importance considering the multidisciplinary contributions from Sociology, Phycology and Engineering to be consistent on the human nature representation. However, a starting point for the purpose of identify the factors affecting the performance could be the Human Reliability Assessment branch. As part of HF discipline, Human Reliability Analysis (HRA) is mainly aimed at the identification, modelling and quantification of Human Error Probability. Historically, HRA responds to the need of major risk assets (e.g. nuclear power generation plants) to integrate the quantification of human error probability into the traditional Probabilistic Risk Assessment tools. Essentially, HRA is a collection of different semi-quantitative methodologies which enable to assess human error probability considering a wide range of "favourable" or "unfavourable" corrective factors, called Performance Shaping Factors (PSFs). In a broader sense, Human Reliability Assessment can be interpreted as the quantification of Human Performance against a certain average context, pictured by a set of physical, organizational and cognitive factors. In this sense, huge efforts have been put by researcher towards the most comprehensive and most effective representation of Human Performance influencing parameters (Groth & Mosleh 2012).
For the purpose of this specific case study, the strategy of identifying the relevant influencing factors relies on the three different contributions: practices already established on pilot plants, on-field investigation and literature review. As Baines & et al. (2002) suggested, some criteria exist to verify the selection of these drivers, enabling further analysis: general relevance, specific relevance, robustness and measurability. Thus, the aforementioned integrated strategy would guarantee the compliance to each of these criteria.
A first attempted for theoretical conceptualization of the KPIs framework was discussed with some plants. This is based on Bayesian Belief Network. Indeed, during last decade the investigation about the possible advantages of introducing Bayesian Belief Network (BBN) in HRA has been experienced a vivid increase. The worth of the BBN model lies in its graphical formalism, which conveys a prompt picture about the relationships between all relevant random variables. Once all the relevant random variables are selected, they are characterized by defining a set of mutually exclusive states (if the random variables are in a discrete form) or a continuum interval domain (if the variables are in a continuum form). Specifically, BNs appear appealing in dealing with HRA due to their ability:

- to support decision making and problem solving in that field characterized by a large impact of epistemic uncertainty;
- to represent complex influencing factors relationship in socio-technical systems which can be considered strongly non-linear system;
- to combine and simultaneously validate different sources of information (e. g. put together some hints from cognitive theory and some empirical data) in order to achieve more reliable HRA. The structural design of the network (including the selection of the

variables and the interconnections) shall be performed considering linking the relevant variables towards the ones for which it's possible to collect as much as possible empirical data (Leva et al 2007).

- to handle data scarcity and their major limit.
    - to create a dynamic - model of Human Performance that can be updated with respect to the relevant drivers, based on the progression of data collection.

In order to create the BBN model to correlate Human Performance with the driving factors, it is important to identify them and to establish relevant metrics to allow effective data collection. Furthermore, for sake of simplification it is useful to group all the factors in a meaningful yet effective way. At this purpose, a first proposal is to assume Human Performance directly dependent on two "major" variables: *task complexity* (i.e. external drivers) and *operator characteristics* (i.e. internal drivers). These two are in turns representing a set of other observable variables to be identified in terms of metrics and to be then quantified directly on field. Having set the direct dependence of Human Performance only on *complexity level* and *operator characteristics*, it will be possible to empirically derive a model for initializing Human Performance values in the Bayesian Network. The assumed model between *Human Performance* vs *task complexity* and *operator characteristics* is based on an extension of the so called Rasch model (Rasch 1980) as used by Straeter (Straeter O. 2000) to forecast possible errors due to the mismatching of individual capability with the complexity requirement of the task. The model can be named TERM (Task Execution Reliability Model) and the suggestion is to define a common set of criteria to measure both the capability of the operator and the task complexity potentially based on the Information processing model of Rasmussen or on the simplified model of human cognition such as PIPE (Perception, Interpretation, Planning and Execution). The more the task required passages across all the various steps of the information processing ladder the more the task is complex.
On the other hand, the capacity of an operator can be rated on a more objective basis using potential tests as indicator of execution of indicative tasks that can be considered representative of skills in all those areas.
This suggestion came from the potential reuse of the paradigm previously developed in some plants for training in the so called "Ability Corner", made up four panels verifying four areas of the operator capability in the training phase: memory, manual skill, coordination and precision. In first instance, they can be used to quantify some internal PSFs, whereof metric has to be coherent with the other Organizational and External PSFs encompassed on the macro - category of Task Complexity.

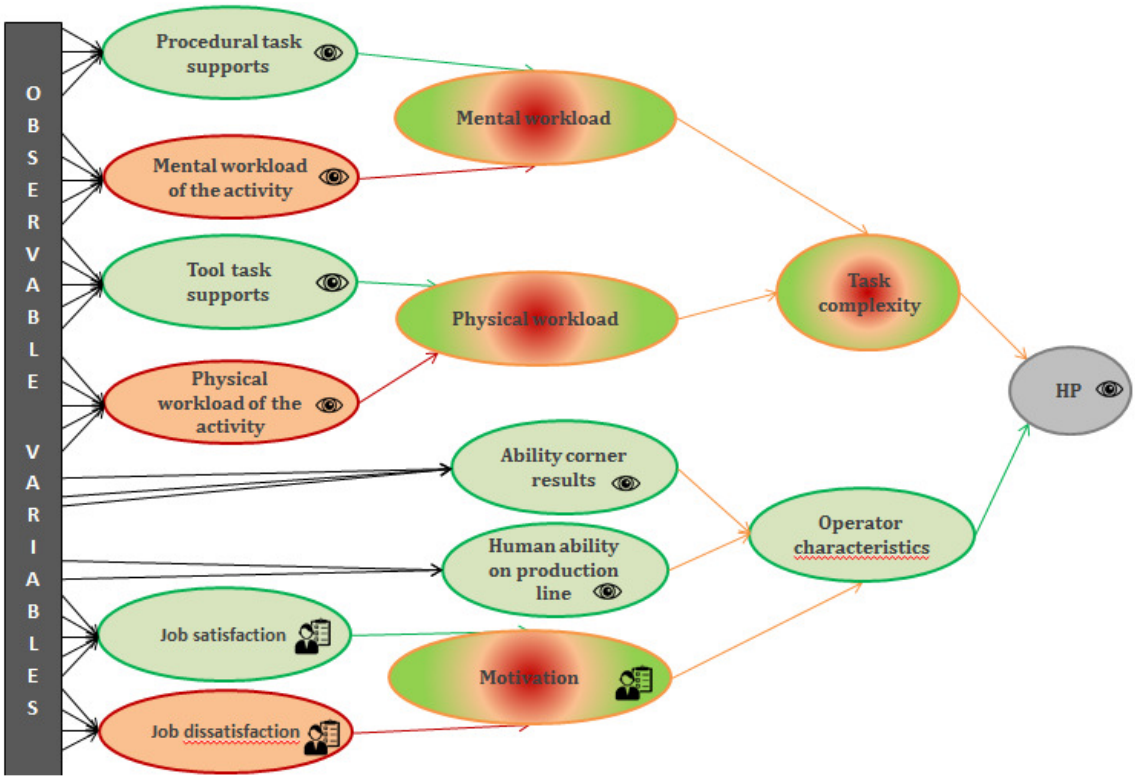

Figure 3: Human performance PSFs modeling framework

Next steps of the analysis

Conclusively, the strengths of the proposed theoretical approach with respect to the WCM Human Performance background can be summarized as following:

- It resembles the existing approach: the framework conceives HP as the ultimate product of the balance between the *task complexity* (driven by all the factors from the environment) and the *operator characteristics*.
- It broadens the ensemble of the factors affecting Human Performance, specifically including Organizational issues (e.g. training, supervision, contractual conditions, promotion, etc.). This will facilitate a sociotechnical approach as basis of Human Performance analysis, rather than a pure technical one.
- The empirical based analysis will enhance the knowledge of the specific process operations at Managerial level, possibly highlighting latent drivers of Human Performance.

One of the key next step to carry on the project is to validate the aforementioned theoretical model with a participatory brainstorming session involving the whole project shareholders; the articulation of this session would be focused on: KPIs validation as HP indicators, validation of the observable variables for HP assessment, validation of the clustering applied for the selected observable variables, validation of the approach for data collection (e.g. questionnaires, direct observation, etc.). Once agreement on the data collection strategy is achieved with relevant operational stakeholders the actual data on existing case study will start. For each case study the team will also work on possible improvement so as to collect data on the "as is situation" for model calibration and the new improved situation for the model evaluation/testing.

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HUMAN BODY SIZE - WORLDWIDE AND REGIONAL DESIGN RANGES FOR USE IN PRODUCT STANDARDS

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Abstract

This paper overviews a new approach for the consideration of human body size as a critical activity in the design of most products, workspaces, and built environments. It discusses ISO 7250-3:2015, an International Standard that provides worldwide and regional tables of design ranges for use with product standards for equipment design and safety that require ISO 7250 body measurement data input. The new approach involves presenting the smallest and the largest values collated from global data sets. A 2012 national research project on Size Data for Universal Design in Ireland developed this approach into an Expanded Design Range. Guidance based on the Expanded Design Range was prepared as Information Sheets, for use by designers and to inform procurement.

Introduction

The consideration of human body size (anthropometry) is a critical activity in the design of most products, workspaces, and built environments. Body size should also be central in the specification of, and eventual selection of, personal everyday products and shared equipment (e.g., public furniture), that are purchased for use in workspaces or public places and spaces. Body size is less commonly considered in purchase decisions than in the design process, although considering size in purchasing activities can also have a significant impact on people.

Human body size is represented by sets of anthropometric data values for mass (weight) and a range of static linear dimensions of people measured when standing, sitting, and with arms relaxed or outstretched. Significant variability in human size exists across age and gender and in different regions of the world. (ISO/IEC Guide 71:2014)

In Ireland, Universal Design refers to the design and composition of an environment so that it can be accessed, understood and used to the greatest extent possible by all people, regardless of their age, size, ability or disability. (Disability Act, 2005) Body size is identified as a critical human factor to be accommodated by Universal Design.

Universal Design necessarily requires accommodating dimensional values representing both very small and very large people, whereas the central points of a distribution are less useful for design. The international literature identifies certain parts of the world as characterized by both larger and smaller body sizes. Both are needed to define a design range that will accommodate as many people as possible. (Bradtmiller et al., 2012)

Standards in the International Organization for Standardization (ISO) are developed to promote international trade, as well as to help make products safe and reliable. The ISO standards for anthropometry are developed to ensure that products and workspaces are designed so they can be used by people around the globe. For example, safety reach guards designed using data for smaller people in Central America might not be safe for northern Europeans with longer arms. A global standard addresses this danger and provides the necessary information to make the workplace safe for users the world over. The goals of the Size Data for Universal Design in Ireland project and the goals of ISO anthropometric standards can be considered complimentary.

The challenge in each of these cases is that anthropometric surveys are generally undertaken within a single country, and sometimes within a single subgroup within a country. None of these published surveys alone would be sufficient to address global variability, and further, the individual statistics from the national surveys are often in conflict with each other. To our knowledge no effort has been previously made to use published summary statistics for developing design value ranges that target a global accommodation. The approach developed and used in both the Universal Design and the ISO project involved analysing the many anthropometric databases that were available from around the world, and organizing the information into a presentation of an expanded design range so it could be useful for designers.

The design range from the Size Data for Universal Design guidance includes 29 commonly used values based on the 5th to the 95th percentiles. The ISO 7250-3 design range is very similar for those 29 values; but it lists 56 values along with the 1st and the 99th percentiles.

Overview of Methods in both Projects

While many designs require that multiple body dimensions are considered, use of single percentile values as design guides is generally not the preferred approach. However, other approaches in setting design requirements require access to raw data (measurements from individual persons), as well as sophisticated statistical skill. The result is that many design guidelines, and certainly many ISO standards, are framed in terms of percentile values from a list of dimensions. (It should be noted that ISO standards developers are currently considering how to develop more appropriate means of addressing the problem of accommodation when multiple dimensions are involved.)

The most common design targets are the 5th percentile female values, and the 95th percentile male values. Although for some safety-related products, 2nd and 98th percentiles, or even 1st and 99th percentiles, are used. When considering a global population, as in ISO standards work, or the various populations included as beneficiaries of Universal Design, creating design guidance is complex.

Size Data for Universal Design

The Size Data for Universal Design in Ireland project was structured in three Parts:

Part 1 was a literature review that outlined several strategies designers might use for obtaining pertinent data. It detailed a number of effective strategies that accommodate the range of human body size and shape within a design and prepared a sample set of size data. (Bradtmiller et al., 2012) The published literature contained anthropometric surveys from around the world, whose summary statistics were necessarily different. In order to make the

information useful for designers and procurers, a method was needed to arrive at a single value for each design point from the several that were available. Since the goal was to aid Universal Design, the method that was developed maximized the inclusion of sizes and shapes of adults.

To create a design range for the most commonly used dimensions, these procedures were generally followed:

1. Compare the smallest 5th percentile values from the published literature from across the globe.
2. Select the smallest 5th percentile value, male or female, for the Small design value.
3. Compare the largest 95th percentile values from the published literature from across the globe.
4. Select the largest 95th percentile value, male or female, for the Large design value.
5. Calculate the design range as, the Large value minus the Small value. The design range is useful in knowing how much adjustability is required for those products or workspaces and where adjustability or other types of accommodation are possible.

Part 2 conducted two surveys among design stakeholders. These surveys supplemented the information obtained through the literature review and provided insight into current practice among design professionals both within Ireland and abroad. (Garneau & Parkinson, 2012)

Part 3 identified specific mechanisms to support designers and procurers in Ireland as they consider body size and shape in their activities. It synthesised the work in Part 1 and Part 2 into recommendations and it also prepared guidelines that were published to the website for the Centre for Excellence in Universal Design in Ireland, as four Information Sheets. Find at: http://universaldesign.ie/Products-Services/Guidelines-on-Body-Size/

ISO 7250-3 "Basic human body measurements for technological design – Part 3: Worldwide and regional design ranges for use in product standards"

The process was slightly different in the ISO setting. ISO is a membership organization whose members are national standards-making bodies. In that case, it was up to member bodies to submit anthropometric summary statistics representing their nation, so the committee did not rely on a review of the open anthropometric literature. In situations where a nation had more than one anthropometric survey, it was up to the member body to determine which survey was most representative of its population.

After a critical mass of member bodies had submitted their information, the committee of expert anthropometrists reviewed the submitted statistics and asked for verification, if there were individual statistics that seemed unusual. When the values were verified, ISO published a technical report containing the summary statistics from all member bodies that had submitted statistics. That report, ISO/TR 7250-2, "Basic human body measurements for technological design -- Part 2: Statistical summaries of body measurements from national populations" can be routinely updated, with a streamlined ISO procedure, as new national data become available.

From the published values in ISO/TR 7250-2, then the largest 95th percentile value for each dimension was selected as the final 95th percentile value for ISO 7250-3. Similarly, the smallest 5th percentile value from among all those published was selected as the 5th percentile value for ISO 7250-3. The process was repeated for the 1st and 99th percentile values, for use in designs where personal safety is at stake.

Complimentary Outcomes from the Projects

The outcomes of the projects are complimentary in that both pursued application of a new approach for representing multiple sources onto a global data set to depict a combined range of smallest and largest values for consideration.

Size Data for Universal Design

The project clarified that Universal Design necessarily requires accommodating dimensional values representing both very small and very large people, whereas the central points of a distribution are less useful for design. The international literature identified certain parts of the world as characterized by both smaller and larger body sizes. Both are needed to define a design range that will accommodate the widest range of people as possible. The procedure followed to establish a sample set of design values for Universal Design resulted in a table listing both the smallest and the largest values as shown in Table 1. Find at: http://universaldesign.ie/Products-Services/Guidelines-on-Body-Size/Range.pdf

Table 1 – Expanded Recommended Design Range for Universal Design
(values in cm)

Dimension	Small	Source	Large	Source	Design Range
Abdominal Depth, Sitting	16.9	Korea	35.8	Netherlands	18.9
Buttock-Knee Length	49.7	Japan	70.3	Netherlands	20.6
Buttock-Popliteal Length (Seat Depth)	41.0	Korea	56.5	Netherlands	15.5
Elbow Grip Length	27.0	Thailand	39.3	Netherlands	12.3
Elbow Height	88.9	Japan	123.9	Netherlands	35.0
Elbow Height, Sitting	18.6	Italy	30.0	Netherlands	11.4
Elbow-Elbow Breadth	32.2	Japan	57.1	Italy	24.9
Eye Height	136.3	Thailand	184.2	Netherlands	47.9
Eye Height, Sitting	66.8	Thailand	89.2	Netherlands	22.4
Foot Breadth	8.1	Thailand	11.6	Netherlands	3.5
Foot Length	21.0	Thailand	29.6	Netherlands	8.6
Forearm-Fingertip Length	38.2	Japan	53.0	Netherlands	14.8
Grip Reach (Forward Reach)	58.8	Japan	82.3	Netherlands	23.5
Hand Breadth	6.3	Thailand	11.0	Italy	4.7
Hand Length	16.1	Korea	22.1	Netherlands	6.0
Head Breadth	13.4	Italy	17.3	Japan	3.9
Head Circumference	51.3	Thailand	60.6	Netherlands	9.3
Head Length	15.8	Thailand	21.2	United States	5.4
Hip Breadth, Sitting	30.1	Thailand	50.1	United States	20.0
Knee Height	41.8	Japan	61.7	Netherlands	19.9
Lower Leg Length (Popliteal Height)	33.3	Korea	53.8	Netherlands	20.5
Shoulder (Bideltoid) Breadth	35.4	Thailand	55.0	United States	19.6
Shoulder Elbow Length	27.0	Italy	41.5	Netherlands	14.5
Shoulder Height	118.2	Japan	162.5	Netherlands	44.3
Shoulder Height, Sitting	50.1	Italy	68.8	Netherlands	18.7
Sitting Height	77.5	Italy	101.2	Netherlands	23.7
Stature	147.3	Thailand	195.9	Netherlands	48.6
Thigh Clearance	11.0	Italy	17.9	Korea	6.9
Weight (Kg)	40.0	Thailand	117.0	Netherlands	77.0

The Part 1 literature survey focused on current research about the consideration of body size and shape in design, whereas, the in-person surveys conducted in Part 2 took a broader perspective. As a result, methods commonly used were identified related to: 1) how accommodation targets are determined, 2) how the spatial dimensions of users are identified, and 3) what means are utilized to accommodate the range of user body size and shape.

The Size for Universal Design in Ireland project produced recommendations and guidance for informing designers and procurers how to consider size in design decisions. Along with the Extended Design Range in Table 1, four Information Sheets were prepared. The sheets are:

1. BACKGROUND: vocabulary and examples of important topics and principles.
2. DATA: a sample set of 29 graphically presented commonly used size data ranges.
3. DESIGN: strategies for considering body size and shape in design. This includes topics like the calculations for determining adjustability ranges and size options (e.g., XS, S, M, L, XL).
4. TESTING: strategies and process for conducting effective user experiments or fitting trials.

The DATA Information Sheet graphically presents the smallest and largest size values related to this new approach of representing an extended or expanded design range. Find the Information Sheets at: http://universaldesign.ie/Products-Services/Guidelines-on-Body-Size/
(NOTE: The Guidelines for Size Information Sheets are under review for format redesign)

ISO 7250-3 "Basic human body measurements for technological design – Part 3: Worldwide and regional design ranges for use in product standards"

The outcome of this project was the published standard. It organised the information from many different data sets from countries around the world into discrete, usable design points readily accessible to users. We cannot reprint copyrighted information here, but the structure of the ISO document is very similar to the format of the Expanded Size Data seen in Table 1. As noted above, it also has annexes specific to two global regions.

The design values in ISO 7250-3 are normative. That means that those values *must* be accommodated in products and workspaces where national regulations mandate adherence to ISO standards. The document has two annexes which are informative, i.e., not mandatory, for designs that are not intended for global use, but rather are intended for a regional market only. These two annexes are specific to Asia and Europe. The process for identifying values in those two annexes was identical to the process used in the main body of the standard, but rather than searching for the smallest 5th percentile value (or largest 95th percentile value) among all the national data sets, only the values from each specific region were considered.

Discussion

As Irish designers seek to be inclusive in their design efforts, they have often been hampered by lack of available data. Many have relied on outdated texts or data from inappropriate populations. Others reported difficulty in obtaining any data. Consequently, tabulated data on body size and shape would be suitable for Universal Design activities.

Similarly, those designing products and workspaces for global use were faced with trying to both research and meet design requirements from many different countries worldwide. The resulting documents allow the non-specialist to effectively use the work of experts to help

in developing products and spaces that have a much greater likelihood of accommodating people whose body size and shape place them on the margins of the population distribution.

Conclusion

The Size Data for Universal Design in Ireland project addresses the needs of designers trying to achieve Universal Design in Ireland, and the ISO 7250-3 standards project addresses the needs of designers trying to produce safe and reliable products for the global marketplace. Both had the challenge of distilling broad and disparate information from multiple sources. Both projects benefitted, for different reasons, from the same basic method, which had not previously been attempted. The outcomes from both projects are information resources that introduce an expanded range of design values. The new approach to representing an expanded size range on data tables can help designers to be aware of the specific human dimensional values they might need to accommodate in new and revised designs. This benefits the designers by saving time and by reducing confusion when referring to multiple resources. Also, it can help to inform the design and purchase of products, workspaces and public spaces that are more accessible, safer and inclusive for the global general public.

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THE HUMAN DIGITAL MODEL "JACK" – A POWERFUL TOOL TO SUPPORT DESIGNERS AND ENGINEERS IN APPLYING A USER CENTERED OR UNIVERSAL DESIGN PROCESS

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Abstract

Jack is a human digital modelling tool, with its development going back to the 1980's, aiming to provide real time feedback for testing a wide range of users against engineering or product designs. It is also commonly used to optimise workplace design such as designing assembly line tasks. It provides an easy to learn and use tool, which can be used by non-ergonomic experts to enable them to test their designs against a large user population early on in the product development cycle. Jack capabilities, shortcomings and general benefits over other more traditional tools are discussed.

Introduction

Jack belongs to the family of human digital modelling tools, which allow to test an engineering or product design against human size and capabilities. Users range from design engineers, product designers, to ergonomist and human factors experts. While anthropometric data tables are widely used in design where available, they are often costly to access, with high usage fees, and mostly only available in large cooperation's with sufficient financial means. They are also time consuming to use, and are mostly used by professional ergonomists or other trained personal. A certain amount of knowledge is necessary for the users to apply the data tables to test their designs. Thus designers and engineers, in particular ones in smaller companies or consultancies at large will not have the means, time and training to apply anthropometric data to their design process effectively.

2 D manikins were used in the early days in an attempt to make fitting the task to the human more easy. They are still often found in design studios as they are less costly and easier to apply. Their main shortcoming is that they only allow static analysis of body size and postures and do not provide means for dynamic analysis for example task assessment.

Usability testing often desired at a later design stage, testing the design with real users, can only be done at a late design stage, when real mock ups or scale models are available. It is time consuming and costly and only relatively few subject can be tested compared to a potentially large end user group possibly spanning different continents or representing a global population, who will use the product or service. User testing needs to be carried out by experts such as ergonomists, human factors or usability experts. Experts are hard to find and are costly.

Human Digital Modelling Tools

In the 1980's first attempts were made to develop 3D virtual human models, which could be animated to perform tasks, in order to overcome these shortcomings. A number of human digital models were developed more or less in parallel. The most well-known ones are Jack, Ramsis, SAMMIE and Safeworks. Jack, SAMMIE and safeworks all started off as tools being used for ergonomics assessments, such a safe limits for manual handling, in production engineering, assembly line task design etc. while Ramsis was specifically developed for the automotive industry, to check for driver's dimensions, reach, posture, visibility and posture prediction. These digital human models allow the user to adjust the size of a 3d manikin to resemble humans with a wide range and variety of human body sizes and thus automatize the tasks of applying anthropometric data tables at the click of a button. Human digital models most importantly also allow user testing without having to have a real mock up or physical model. A human digital model thus offers the advantage of testing a wide variety of users against the design in the very early design phase with little time and cost involved. It provides immediate feedback on how a design has to be changed cutting down development costs considerable.

The different digital human models each have their specific software manikin. They use a particular kinematic linkage for posture and tasks prediction. As they are popular in industry to test in the early design phase as a cost reduction tool they are operated by engineers or ergonomics experts and thus the human digital modelling tools can be difficult, time consuming and cumbersome to learn. Jack, a digital tool by Siemens however can be learned and operated satisfactory in a very short amount of time. Test trials conducted by the author with students showed that engineering students were able to use the tool effectively for their engineering design projects after only been given one tutorial session of 1.5 h.

Jack

Jack was developed by the at the Centre for Human Modelling and Simulation at the University of Pennsylvania in the 1980s & 1990s and was primality used in its beginnings for ergonomic assessment and as human virtual prototyping system for NASA space shuttle development, US navy, US army, US air force and other government and corporate users followed shortly afterwards. Now Jack is used across industries, Jaguar and Auston Martin are among some of the automotive companies, which use it to optimise assembly tasks for assembly line workers or to test the cockpit fit for the largest range of users, while the utility company JCB, a company for manufacturing equipment for construction, agriculture, waste handling and demolition uses it for ergonomic design of their driver cabins.

Jack Functionalities

At the heart of Jack is a male and female digital virtual human, which can be scaled to the user's desires. The user can select from 10 different anthropmetric databases which are ANSUR (Army Natick Survey User Requirements), NHANS (anthropometric data from the National Health and Nutrition Examination Survey), CDN_LF_97: anthropometric data from the Canadian Land NA_Auto (anthropometric data representing the North American automotive working population), CHINESE: anthropometric data representing Chinese adults aged 18-60 (males) and 18-55 (females), Asian Indian Anthropometric Database, German Anthropometric Database: DIN 33402: German Industry Standard, Japanese, Korean and also

provides data on child figures. Further is has a disembodied hand model, which allows to test separately for hand clearance or tasks which predominately involve the hands.

To test a design Jack accepts a number of formats for example from solid works or Autocad, in particular it accepts Vis (.jt) files and can import Vis (.jt), VRML 2.0 (.wrl), IGES(.igs, .iges), stereolithography (.stl), inventor (.iv), and optimizer (.csb). It allows to build your own task with task simulation builder and can show an animated movie of the task sequence, for all involved tasks and postures Jack can calculate stresses and strains on the human body for example low back analysis, comfort and fatigue analysis for repetitive tasks. It further provides a plug in for Microsoft Kinect, which allow the user to do low cost motion capturing and allows scanning a human with Kinect to retrieve anthropometric data from real persons, which Jack can be scaled after. It can also assign weight to objects and test for users associated fatigue. It allows to adjust individual joints to define a Jack or Jill (female version) individuals posture. Jack now also includes an automotive model and can be used for similar task as implemented in Ramsis. It provides facilities for reach analysis and associated fatigue, while is also offers the facility of eye cones, which aloe visibility assessment and field of view.

Discussion of Jack's abilities

Shortcomings of human digital models are traditionally that they mostly rely on a regression between body size and BMI, which restricts the independent scaling of body segments. People vary widely, so do their body parts, so while someone might have a 5th percentile upper body, their leg length might be 95th percentile, thus one person will rarely have a 95 th percentile upper body, arm length, leg length etc. Thus scaling individual body parts is important to achieve realistic body dimensions. In particular in the light of growing obesity, a designer might be interested in scaling a person to different levels of obesity to test for dimensions of a chair or hospital bed for example.

While Jack, similar to the other aforementioned tools also somewhat suffered from some scaling restrictions, it provides some advanced features in the newest version which adress this problem. Reed in 2014 implemented a new feature into Jack, allowing the user to input 11 dimensions which were derived from a study in which body dimensions of real users were used to extract 11 components describing users variability as compared to the two variables of body mass and size previously. Alternatively it also allows predictions with only stature, body mass, and erect sitting height. It allows for example to scale a 5^{h} or 95th percentile male with varying waist circumference thus enabling the user to model users with different patterns of adiposity associated with waist circumference while they can keep stature and body size constant.

Conclusion

Jack is well suited to adjust for future sizing challenges, from obesity, to old age changes in stature and body posture and allows the user to check their designs against extremes. Jack allows a layperson, who is not particular knowable of anthropometrics and biomechanics to test their engineering and product design against the abilities and size ranges of all rage range of users. It thus may be used to test on the click of a button for universal designs ranges or specific testing for obesity or other user groups.
It allows at a very early design stage, where no user testing is available, to test the design for human fit and comfort. In collaboration with the centre of Excellence in Universal design we are

currently conducting a study, on how Jack can be used to generate individual case scenarios for use in testing for universal design requirements. Being an extreme powerful tool it is available in Trinity College since November 2015 for student and academic use. Interested parties are encourage to contact the author.

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USER CENTRED DESIGN OF AN INNOVATIVE OSTOMY CARE DEVICE TO PREVENT SKIN COMPLICATIONS.

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Abstract

The BioInnovate Gastroenterology team at the University of Limerick set out to identify a commercially viable unmet/undermet clinical need during the Identify stage of the Stanford University's BioDesign Process. Following this Ostoform was formed. Ostoform continued to the Invent stage of the BioDesign process. There the team took a user centred design approach to form a product solution that satisfies the unmet clinical need identified. Ostoform is developing an innovative medical device which aims to prevent and reduce peristomal skin complications (PSCs). Ostoform has undertaken two usability studies to assess the users' needs and product satisfaction to support design verification. Identification and Invention stage methods and results are detailed in this paper.

Introduction

Ostoform is a device being developed at the University of Limerick by Dr. Kevin Kelleher and Rhona Hunt for patients with an ileostomy. This patient group is likely to develop peristomal skin complications (PSCs), with incidence rates of up to 63% reported in the literature (1-4). Ostoform intends to reduce these complications. The team followed the Stanford University BioDesign Process of Identify, Invent and Implement (Zenios et al, 2010).

User centred design is used to improve patient product satisfaction. In return this benefits successful adoption of new innovations. There is a mutual value to the patient and to Ostoform. Ostoform is focused on the user. Ostoform, currently based in the University of Limerick is the result of activity in the BioInnovate medical device design fellowship programme. The BioDesign process involves identification of unmet/undermet clinical needs, inventing solutions and the commercialization of the solutions.

Ostoform works on the ethos of clear identification of a commercially viable clinical need, clear dissection of problems and development of solutions through design, user studies and clinical

collaboration. This ethos intends to yield a user centred product design solution that improves quality of life for patients.

The process of identification is carried out through clinical observation, literature research and collaboration with clinicians and patients. The need identified during the Identify stage relates to skin complications that occur around an ileostomy. An ileostomy pertains to the ileum (small bowel), a colostomy pertains to the colon (large bowel), and a urostomy pertains to the bladder. Ostoform's focus is on ileostomies. An ileostomy is an opening created surgically on the abdomen using the patient's own small bowel for the elimination of faecal waste. This is necessary when normal bowel function is not attainable anymore due to Inflammatory Bowel Disease (IBD), cancer, trauma, or other clinical condition. An ileostomy has highly acidic waste which excoriates the skin which accounts for the highest rates of Peristomal Skin Conditions (PSCs). Development of Ostoform continually considers adaption for use with colostomies and urostomies. No current treatment adequately satisfies this need. When a patient has a PSC, they cannot affix their ostomy bag securely which results in poor skin protection. This causes a vicious cycle of leaks which does not allow the skin to heal and hinders ostomy bag adherence. When security is not obtained this can affect the social activity of the patient. Current products are not easily customisable to the person's ostomy shape and size, which results in leaks and causes excoriation of the skin. Current products adhere to the skin by a harsh adhesive (hydrocolloid) which cause mechanical stripping of the epidermis.

Methods

The BioDesign Process was used to identify an unmet clinical need. Once validation of the clinical need materialised, the team entered the invent stage of the BioDesign process. Two user studies were conducted during the Invent stage of the BioDesign Process.

BioDesign Identify Stage

A specific clinical area (Gastroenterology) and anatomy were studied by the team. The Ostoform need was identified through a two month period in clinical immersion, filtering needs and clinical literature and field research.

Clinical Immersion involved the observation of surgery, procedures, ward rounds and multi-disciplinary team meetings. Observations taken during clinical immersion were translated into a need. The BioDesign filtering process verified the commercial viability of the need. For example the need was filtered against a filter called Patient/Clinician Impact. This involves asking; if the problem were solved, then who would benefit from it? If the clinician does not benefit, then there is no motivation for the clinician to prescribe the patient the product. Hence the patient would not get to use the product.

BioDesign Invent Stage

This involved clear problem identification, prototyping, user studies, clinical studies and clinical validation through collaboration with experts in the field. Two usability studies were conducted at different stages of the design development phase.In Q2 2015 a user study called PAS 1

(Practical application Study) was conducted to assess a design iteration. A second user study called PAS 2 was conducted in Q4 2015/Q1 2016 and involved a usability assessment plus pilot clinical data collection. Usability studies methods are summarised in Table 1 and 2.

Table 1. Practical application study phase 1 user centered design testing approach

Subjects	n=6
Aim of Test:	Part 1: Identify user requirements.
	Part 2: Identify user focused design inputs.
Test Method	Part 1: Identify patient's user requirements by recording patient: - History - Ostomy Product Experience - Anthropometric Data.
	Part 2: Observation of the patients' interactions with the current prototype of Ostoform in order to identify necessary changes to the product design. The patients' experience in handling and using the Ostoform device will serve to optimise the product development of Ostoform with a strong user focus.

Practical application study phase 2 involved 6 participants aged 18 years and older with ileostomies. All participants were capable of changing their appliance themselves, had unbroken peristomal skin and had their initial stoma surgery six months or longer from the time of recruitment. Exclusion criteria were damaged peristomal skin with breach of dermis and fistula on or near the stoma. Skin condition was assessed at T=0, T=1 week and T=2 weeks by a clinical research nurse using the Ostomy Skin Tool (OST) (Martins et al. 2008). Participants' experience using Ostoform was evaluated by a questionnaire at T=2 weeks.

Table 2. Practical application study phase 2 user centered design testing approach

Subjects	n=7
Aim of Test:	Part 1: Usability test to inform design decisions. Informing size range, bag opening sizing and shape.
	Part 2: Assess difference in patients' skin condition from the beginning to the end of a two week wear time with the Ostoform device.
Test Method	Part 1: Assess usability through verbal communication and observation of patients using Ostoform over a two week period. Patients' measurements are taken. Patients are scored against a 10 score scale against comfort, security, handling and safety. 10 is the excellent and 0 is very very poor.
	Part 2: Assess patients' skin condition during the two week period while wearing the device. The Ostomy Skin Tool was used to assess skin. The Ostomy Skin Tool is a standardized measuring instrument for assessing the extent and severity of peristomal skin change in terms of discolouration (D), erosion (E), and tissue overgrowth (T) (DET). Patients were assessed at T=0, T=1 week and T=2 weeks. T=2 weeks DET score was compared to T=0 weeks. Skin condition was scored as a dis-improvement (-1), No change (0), improvement (+1). Leakage was marked as Y (Yes) or N (No).

Results

BioDesign Identify Stage

This stage resulted in the identification the following clinical need:

"There is a need for an easier way for a person with an ileostomy to manage their faecal matter in order to prevent and/or reduce peristomal skin complications, improves security in its management and improve quality of life."

BioDesign Invent Stage

Following the practical application study and feedback from clinicians on design iteration 3 it was concluded that specific patient requirements must be met, as detailed in Table 3.

Table 3. Practical application study user centered design requirements

Clinical Needs	The patient needs to effectively drain faecal waste away from the skin.
	Keep faecal waste sealed from contacting the skin.
	Moisture from the ileum lumen and skin needs to be managed to prevent maceration.
	The product must not trap faecal waste as it would excoriate the skin.
	Design iteration 3 would work for optimally surgically created protruding ileostomies. These are not ileostomies that experience the most problems. Clinicians advised that ileostomies that empty onto the skin are the most problematic ileostomies. These problematic ileostomies are either low lying on the skin and/or have a flow that is directed towards the skin. Ostoform defined the target ileostomies as "problematic ileostomies".
User Needs	User defined as: the patient with an ileostomy. A patient's ostomy/general nurse and/or carer
	The patient is restricted to single hand use during ostomy bag change due to the continual flow of faecal waste. Note: If a product needs the heavy use of both hands then the patient's product satisfaction would be reduced.
	All users are restricted by time due to the need for a new ostomy bag to be placed as quickly as possible.
	Product must be intuitive to the process all users have learned prior to useing Ostoform.
	Various abdomen types, ileostomies and skin geography defined.

Design Inputs were defined in order of priority. This works to aid decisional processes regarding design decisions. For example if criteria 2 and 3 are not obtainable in a solution then criteria 2 would be prioritised over criteria 3. Design criteria are detailed in Table 4.

Definition of intended use:

1. Primary Intended Use: The device aims to *prevent* peristomal skin complications by preventing contact of faeces with the skin.

2. Design input criteria which is outside the details of this paper also include business and regulatory requirements:

Table 4. Design criteria

1	Avoid small bowel output contacting the skin.
2	Manage moisture on the skin.
3	Securely attach an ostomy pouch to the body.
4	Discreet.
5	Easy to use.
6	Anatomically adapting.
7	Low cost of manufacturing
8	Sensory engagement.

User satisfaction with the novel device was assessed during the practical application study phase 1 by asking the user to score from 1 to 10 on criteria including 1. ease of use, 2. feeling of security, 3. comfort, 4. device discretion, 5. evidence of leaks and 6. perceived changes in skin condition. In addition, changes in skin condition from T=0 to T=2 weeks, measured using the OST were tested for statistical significance. Usability and clinical results were positive. Publication of actual results will follow in due course. Following completion of the practical application study phase 2, a statistically powered, single arm user trial offering an extensive evaluation of the efficacy of Ostoform will commence in Q3 2016. The next phase of the BioDesign process is implementation. This involves commercialisation of the product.

Discussion

The BioDesign Process has proven to be an effective system, facilitating the Ostoform team in the invention of a product that meets an unmet clinical need. The BioDesign invent stage along with Ostoform's ethos has led to a product that satisfies the usability and clinical needs of the users. At the Implement stage of the process the validation of the commercial viability of the clinical need helps to reduce the risk of failure upon device commercialisation. If the user is satisfied it is conducive to a successful market implementation.

Conclusion

The entire BioDesign Process accompanied by a user centred approach lends itself well to innovating medical products for patients who have a real clinical need.

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THE PSYCHOLOGICAL EFFECT ON EMPLOYEES OF THEIR INCREASING SURVEILLANCE AT WORK

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Abstract

Employers frequently exercise their right to monitor the activity of their subordinates in the workplace. However, with recent advances in surveillance technology it has become apparent that it is possible for employers to covertly monitor the activity of their workers. Today, employers have access to information which extends beyond relevance to the duties performed by the worker. As such, workplace surveillance now instils a clear power asymmetry which the employee must bear. Drawing on theory and research, this paper examined the different domains of workplace surveillance and the psychological experiences associated with it. Findings suggest that although surveillance may be intended for the use of productivity and performance purposes, quite often those under surveillance perceive it as an infringement of their privacy, and as demonstrative of a coercive use of the control and power afforded to those in leadership roles.

Introduction

Society was once predominated by agriculture and industry but following a slow and steady increase in electronic resources, today's society has progressed to a more technological landscape which is dependent on information and communication. Such well-established progressions have led to the proliferation of alternative and more advanced ways of monitoring behaviour in economic and personal spaces, one of which includes electronic surveillance. Gandy (1989) defines surveillance technology as "an integrated system of hardware and software that includes devices for sensing, measuring, storing, processing and exchanging information and intelligence about the environment" (p. 2).

Surveillance is emerging as a growing pervasive culture in the workplace that is likely to continue to expand as technologies advance. According to Botan and McCreadie (1990), the terms "monitoring" and "surveilling" may be distinguished. According to these theorists, monitoring makes reference to the collection of automated information ranging from the administration of bonuses to tracking inventory. Thus it is quite generic without a specific purpose. On the other hand, they define surveillance as the explicit relationship between figures of authority and a particular individual/group whose behaviour they wish to manipulate or control. Further, although aspects of monitoring are integrated into surveillance, rarely is surveillance incorporated into acts of monitoring. According to Introna (1997), privacy is a means of establishing social capital for relationships and for acquiring autonomy, and

transparency is a means of establishing control, ensuring the efficiency of services or resources, and for taking disciplinary precautions.

In light of the above, this paper seeks to make sense of the interaction between surveillance and work relationships in terms of context, motives, effects, and perceptions. This will be achieved by firstly assessing how traditional forms of surveillance have evolved, but how a clear power asymmetry and a motive to control still exists. This will be followed by an analysis of three studies which examine attitudes towards surveillance and the relevant correlates. This will set the groundwork in place for investigating employee performance in the workplace which will consider how surveillance may affect the quality and quantity of production. Lastly, the concept of social identity will be introduced as a possible explanation for why individuals hold different perceptions towards surveillance and the influence of identity on relationships in the workplace. It is the intention that this paper will provide an insight into a relatively new and neglected issue within organizational theories of psychology.

Panoptic Effects of Surveillance

Surveillance may be studied across and within an array of several contexts and Bentham's work on the concept of the panopticon and its technical modern-day equivalent, stands as an influential approach that is worth examining. Mack (1969) first described the panopticon as an entity comparable to that of a workhouse or prison which is composed of a circular building where all parts of the interior are separated by individual cells, and a single tower which is placed in the centre of this building. The tower is positioned in such a way that from its windows, one can see clearly into each cell but those occupying these cells cannot not see one another, are exposed to the towers constant observation, and are unable to discern when or if they are being observed. The relationship that derives from the panopticon, according to Foucault (1977) is based on a visible-invisible domain, such that the visibility of the cell occupants makes them vulnerable and this vulnerability is further enhanced by the fact that the observer is invisible. Drawing on Raven's (1993) theory on social psychological power, coercive (disciplinary threats) and reward (possibility of bonuses) exist as the two traditional forms of social power. This analysis is mirrored in Foucaults work on the panopticon such that coercive and reward power may function within the visible-invisible domain of surveillance whereby employees must consistently behave as if they are being surveilled whether or not they actually are.

Examining the social theory of panopticism, Boton and McCreadie (1990) asserted that information technology is transformed into surveillance technology when its purpose extends from serving solely as a work tool, to establishing a specific power relationship and panoptic effects. These effects may both be internal- which relates to the vulnerability that arises from the visible-invisible contrast- and behavioural, -which relates to the acts made in response to the realization of this vulnerability. Although specific to each situation, they suggest that panoptic effects in the workplace demonstrate interactions between the employee under surveillance and their perception of it, the potential of the surveillance in use, the policy management, and maturation. To illustrate this, an example would include a company where the phone calls made by the employees are under surveillance. In this situation, the employees have been informed by management that they are under surveillance. The potential of the surveillance technology is high but moderate, as although employees are aware that their phone activity is visible, they also retain a degree of control. For example being actively able to reduce the time spent on the phone. In terms of management policy, results obtained from phone activity will be examined to assess quality and for taking any necessary disciplinary actions. Finally, the surveillance

procedures are recognized as mature and are regarded as a legally incorporated element of the proceedings in that organisation (Boton, 1996).

In a situation as such, all four elements of the panoptic effect are at hand and although leaders may hope that generating a panoptic effect will help advance production and services provided, and assume that this is made possible because of surveillance, the consequences of the panoptic effect create a surveillance experience which is understood in a completely different way for employees. Boton (1996) investigated this phenomenon with an emphasis on examining employee's perceptions of being under surveillance. Administering a survey to information workers (n= 465) results from the study retained support for the alternate hypotheses predicting panoptic effects. Firstly, it was found that those who perceived themselves as being under a high level of surveillance felt that they had a lack of privacy in the workplace such that the visibility element of surveillance lead the employees to believe that they had no control over the invasions of their privacy and that any and all aspects of their work were constantly on display. Secondly, they felt uncertain about their place of employment such that (with reference to the invisible element of surveillance) they were unsure whether surveillance procedures were active or not, leading them to feel as though that their daily working lives was quite ambiguous. Thirdly, electronic surveilling was viewed by employees as suggestive that they were incompetent and distrusted in their role at work which in turn ignited a direct reduction in their self-esteem.

The study found that with an electric panopticon, the individuality of workers tasks meant that employees felt isolated from their co-workers as there was an insufficient amount of time designated to working alongside one another, for socialising or indeed for any form of communicative action. It should be noted here however, that some organizations have sought to and continue to accommodate team-work in the workplace by strategically planning work environments in such a way that they encourage employees to communicate with one another which in turn, helps increase their sense of self- control within the workplace (Tarricone, & Luca, 2002). For example, in a correlational study conducted by Lee, and Brand (2005) it was found that with the provision of an open-workspace, there was a higher sense of personal control given to the employees which led to higher job satisfaction and increased sense of group cohesiveness.

This theory and research demonstrates how employees who are electronically surveilled are likely to be subject to experiencing an array of panoptic effects. Further, if such effects are not the anticipated outcomes of those who are responsible for implementing it (rather it may have been assumed that it would increase turnover, commitment, and motivation) one might argue that if unintended consequences as mentioned above exist, then there might indeed be a number of other negative outcomes associated with surveillance and panoptic effects such as deteriorations in physical and mental health.

Correlates of Attitudes towards Surveillance

A correlational cross-sectional study carried out by Oz, *et al*., (1999) investigated attitudes towards electronic surveillance. The study which assessed 823 individuals who were in full time employment and were attending college part time, analysed and compared differences in attitudes between the employer and employee. As predicted, supervisors were more in favour of electric monitoring believing it would reduce theft. On the other hand, the subordinates expressed their disapproval of it, contending that it would create a negative and tense energy in the workplace and further asserted that employees should be made aware of when and what exactly they are being surveilled on. The study also found that overall, women held a higher regard for surveillance than men did. Interestingly, within the realm of gender differences it

should be noted that although anyone may be subject to surveillance, service workers (such as those employed in health insurance, as hotel and airline clerks, and those employed in revenue) have a higher chance of being surveilled and as it is predominantly women that are employed in this sector, surveillance has a disproportionate focus on females (Silberger, 1990).

Samaranayake, and Gamage carried out a more recent study in 2012 to assess the interaction between electric surveillance and job satisfaction. A 75-item questionnaire with a 5-point Likert scale was administered to 380 individuals employed at a computer software company in order to examine their job satisfaction, their perceived relevance of surveillance, their judgment of its effectiveness, and their regard for infringements to their privacy. The study found there to be a positive correlation between surveillance and job satisfaction for those who held a positive regard towards electric surveillance. By contrast, those who perceived it as an invasion of privacy felt less satisfied in their job and sensed that it made their work tasks more complex. Notably, when assessing subgroups it was found that those who had more or higher professional experience, were less concerned about being surveilled.

Furnham,and Swami (2015) also examined attitudes towards surveillance at work with a sample of 283 women and 342 men who were either in full or part-time employment in London. All participants held some sort of educational qualification and a total of 14.2% out of the entire sample were part of a union. Through the administration of surveys, the British sample fulfilled a series of measures designed to address satisfaction, autonomy, discrimination in the workplace and political orientation. Those with higher scores on the negative aspects of surveillance showed a significant reduction in job satisfaction and job autonomy. Further they did not hold a positive attitude towards those in authority and felt as if they were being discriminated against. Lastly, in terms of political preferences they showed a greater orientation towards left-wing. Opposite significant correlations were found to be evident for those who scored higher on the positive aspects of it, showing a greater orientation towards right-wing. No significant differences were found in terms of gender, educational status, or trade union membership in relation to positive and negative scores.

As it can be noted from the above three studies, findings on attitudes towards surveillance are mixed and quite likely based on a number of factors which are specific to particular working environments. However, when assessing attitudes towards surveillance and the contributing correlates, it is important that particular attention be paid to different personality types and how these may act as confounding factors. For example, those who held a more negative perception towards surveillance may fit the profile of an alienated employee who feels quite dissatisfied with their job in general. In turn, reporting a negative attitude towards surveillance may stem from having a pessimistic personality type. Concurringly, those who hold a more positive regard towards surveillance may have a more positive personality type (optimistic, sanguine) and so they may adopt a more trusting attitude towards it.

Productivity and Performance

Quite often it is the case that managers choose to monitor their employees so as that they can set goals, give objective feedback, and acknowledge the achievements of their employees (Smith, 1988). In turn, such managerial activity can have an influential effect on employee productivity. For example, a study carried out by Komaki (1986) found that managers that spent more time monitoring the activity of their workers were deemed as more effective because the employees were proven to show a higher performance in their tasks, than subordinates who were not monitored by their manager. Larson, and Calahan (1990), suggested that workers are given cues about the relevance of their work when they are monitored and so expend a greater effort as a

consequence. Computer-Based-Performance monitoring (CPM), allows the manager to ascertain how the employee spends their time at work, and measure the time they spend on productive and non-productive tasks.

Some research has suggested that CPM influences employee's quantity of production but not necessarily the quality of it. Grant, and Higgins (1989) found that when workers were aware that they were being monitored by CPM systems, they were inclined to sacrifice the quality of production in order to increase the quantity instead. An insurance claims company decided to monitor their employees by incorporating a CPM system which was designed to examine and measure how workers carried out a clerical task. The system was not designed to assess their standard of customer service. Irving, Higgins, and Safayeni (1986) administered a survey to 50 of the workers employed in this organisation and compared their responses to 94 workers who were also insurance claims processors but worked for an organization that did not have a CPM system installed. In comparison to those who were not monitored, the study found that those who worked for the company using CPM reported themselves as having a higher quantity of work production and that in general, they perceived their work ethic as more productive than the employees who were not monitored. However, it was also evident that the increased productivity lessened the quality of the activities which were not being monitored. These employees reported that they tended to neglect tasks such as customer service, and devote their effort to their clerical responsibilities which they knew they were being monitored on. Findings as such therefore suggest that employee's performance on tasks is determined by whether or not they are being monitored.

CPM and productivity has been addressed through a number of laboratory studies which have found that although CPM may influence productivity, this association is not always positive. For example, through the use of personalised computers in a laboratory, Aiello, and Klob (1995) randomly assigned participants to completing either a simple or difficult anagram solving task. One half of the participants were told that they would be electronically monitored by a supervisor and the other half was told that the supervisor would not be able to monitor their activity. Results were consistent and demonstrated that for the easy tasks, those who were monitored performed better and for the more difficult tasks, those who were not monitored performed better. The researchers concluded that CPM effects can be understood within the framework of social facilitation. According to this perspective, people perform mundane simple tasks effectively when they are surrounded by others and perform more difficult and unfamiliar tasks better when alone (Zajonc,2004). In turn, applying this to CPM, monitored- employees should perform better on simple tasks, but performance deteriorates when more difficult tasks are observed. As the majority of companies that have CPM installed require their employees to perform quite simple or repetitive tasks, it does not come as a surprise that field studies have found that it increases productivity (Irving, Higgins, and Safayeni ,1986). However, laboratory tests suggest otherwise, finding that performance of tasks is likely to have a negative effect on productivity when workers are electrically monitored on novel or difficult tasks.

It should be noted that on account of the protection afforded by the State, discrepancies exist between the privacy rights of those employed in the private sector and those employed in the public sector. In the United States, the state statutory protection of employees is dependent on the common law protections of that particular state. For example, if an employer in Connecticut discloses information about their employee's performance, and authorization was not permitted, then the employee has the right to refute this action. However, had this situation occurred in Alabama, the employer would not be at fault as there are no privacy protection statutes in place (Pincus, & Trotter, 1995). Therefore, with no privacy protection in place, the employer has the power to collect and access personal information that extends beyond relevance to the employees job. Taking this concept of privacy infringement, together with the recent advances in workplace surveillance, it may be the case that without interjections from

state or government bodies, surveillance is implemented, experienced, and perceived quite differently by those employed in the private sector, in turn contributing to their level of performance and productivity. In order to enrich the research on the differential effects of surveillance on various jobs, it is recommended that a large scale study begins by comparing the uses and effects of surveillance in these sectors.

Surveillance and Social Identity

Much of the literature has worked under the implicit assumption that those who encounter surveillance systematically adapt or change their behaviour in response to it such that the effect of it is homogenous in nature (Armitage, 2002). Additionally, some of the research has suggested that people tend to hold a negative perception of surveillance. Alternative work has reported that these perceptions are disparate in that some regard it as acceptable and other do not. However this research is rather *post hoc* as it rarely accounts for differences in opinion (Short, & Ditton, 1998).

The social identity model of deindividuation (the loss of self-awareness in groups) offers a theory-based approach to understanding the effects of surveillance. Applying this model within the context of CCTV surveillance, Levine (2000) argues that in order to progress the understanding of its effect, the relationship between the party under surveillance and the party imposing it must be taken account of as well as who it is that is instigating the surveillance. To be more specific, he notes that the identity of the individual imposing the surveillance is what affects the consequential behaviour of those being watched.

Drawing from this, more recent research has rejected the idea that perceptions of privacy infringement are a fated response to surveillance and instead, has advocated that such perceptions are influenced by social and contextual determinants and that there is a need to consider the interaction between surveillance, social identity and leadership (Dixon, Levine, & McAuley, 2003). Social identity theorists assert that a leader's influence is dependent on the extent to which they can identify with the people they are managing and the way in which their behaviour is in accordance with what is regarded as the best interests of the group (Reynolds, & Platow, 2003). Correspondingly, when there is a sense of shared identity, the leader may instigate a greater motivation to work and cooperate without resorting to overt forms of influence (Zdaniuk, & Levine, 2001).

In this way, within the framework of group processes and the power associated with leadership, social identity theorists have discriminated between "power through" which relates to a power realized through a shared identity, and "power over" which relates to a power based purely on the use of coercive procedures (Simon, & Oakes, 2006). Internal motivation stems from the "power through" approach, and external motivation stems from the "power over" approach whereby surveillance is more likely to be used as a means of increasing conformity. O'Donnell, Jetten, and Ryan (2010) proposed that the relationship between the opposing parties and the context, in which the followers are surveilled, is an important predictor in determining the willingness of the followers to work and the sacrifices they are prepared to take on behalf of the group and indeed the leader. Simon and Oakes (2006) asserted that within the workforce, there is an expectation that coercive tactics will be reserved for members of the out-group (do not have a shared identity) but when the leader is part of the in-group (shared identity), this is quite conflicting for the followers as surveillance (particularly a high level) is likely to affect their attitude, behaviours, and feelings about their leader and the relationship they thought they shared (Reynolds, & Platow, 2003).

Demonstrating this, through two studies O'Donnell et al (2010) examined how follower's reactions to their leaders with whom they may or may not share an identity with, may

be moderated by the implementation of surveillance. In the first study it was found that where levels of surveillance were high and identity was shared, perceptions of the team- membership of the leader were undermined. These findings were replicated in the second study where it was found that followers were more likely to cooperate and work for the group when levels of surveillance where low and identity was shared, and were less willing to work for the group when the surveillance was high. The researchers concluded that although identity-based influence has its benefits, when a leader has a genuine capacity to influence their workers behaviour but resorts to using high levels of surveillance in unnecessary contexts, the shared identity diminishes and the work ethic of the followers deteriorates. Research as such furthers extant literature on some of the more defining characteristics of surveillance and its implications within the social context.

Discussion

Privacy is a controversial subject. The latter half of the twentieth century played host to the social revolution of Marxism which brought with it the unionisation of labour, articulated conflicts about the appropriateness of surveillance, and an increasing demand that modern management defend such transparent procedures which were becoming less overt as surveillance technology intensified (Introna, 2000). However, despite advances in liberal democracies, as it currently stands, decisions to surveill are made at the discretion those in charge, the employer holds the legal right to carry out surveillance without being obliged to justify it or ensure it is fair, and in the US alone less than 20% of workplaces are unionised today (Furnham, & Swami, 2015)

This paper has demonstrated the different ways in which surveillance may be applied, understood, and responded to. It has explored how surveillance is associated with an imbalance of power, the effects it has on those being monitored, when and why some people may or may not perceive it as acceptable, and the extent to which it contributes to employee's performance and productivity in the workplace. Further, this paper advances research on social identity and examined how having a shared identity may affect the leaders influence over their followers. In a practical sense, a revolving issue in this paper is perceptions of the appropriateness of surveillance. It is expected that all individuals have ultimate control over their privacy, however, in the workplace it is expected that all of those employed in that organisation are exposed to scrutiny as it is in the interest of the organisation to have complete power over surveillance. Should the employee be given absolute control to exercise their privacy, they may take advantage of this right and defraud the organisation and if the organisation is given complete control over transparency, they may deny the employee of their autonomy and make selective unreliable judgements. Surveilling workers is a conscious choice made by those who are in a position to extend their control, thus it is evident therefore that there is a clear power asymmetry which the employee must bear. Consequentially defending existing power imbalances in work-related hierarchies, and justifying the demand for privacy has become and remains an unresolved contemporary issue of debate.

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TEAM COHESION AND COMMUNICATIONS IN SURGERY: RE-DESIGNING THE SURGICAL SAFETY CHECKLIST (SSC) TO SUPPORT TEAMWORK, PATIENT SAFETY AND SAFETY 11 PRACTICES

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Abstract

This paper presents a case for redesigning the existing surgical safety checklist (SSC), to better support team cohesion/communications and safety culture. In so doing, it proposes the following enhancements:

- The redesign of the SSC needs to take into account Safety 11 concepts
- Redesign activities need to link to broader hospital safety management concepts and practices
- The SSC should be located in the context of both formal and informal planning/briefing practices involving different members of the multi-disciplinary team prior to the 'sign in' stage and post 'sign-out'

Further, this paper argues that good teamwork will necessitate behaviour change on the part of all relevant actors in surgery. This behaviour change will be underpinned by wider organisational change. Critically, organisational change is necessary to address the socio-technical 'root causes' of non-compliance and specifically, cultural issues.

In support of this, this paper draws upon the findings of the first phase of a clinical audit pertaining to teamwork practice and the use of the SSC, at a Dublin hospital.

Overall, these enhancements - which go beyond existing guidelines (Health Service Executive and World Health Organisation), will better support team cohesion/communication and safety culture. This in turn will positively impact on patient safety.

Introduction

People often work alongside each other (i.e. operating as a group), but not in teams (Katzenbach and Smith, Cashman et al, 2004). Teams act as a cohesive unit, with a common positive purpose, with a collective competence and experience more than the individual, and with mutual accountability for results (Cashman et al, 2004). As highlighted by Hackman (1990), team effectiveness is not a given. Rather, teams develop their expertise over time. Successful team formation is essential to team performance. A defining characteristic of such team formation is 'team cohesion' (Moran, 2012). Further, team leadership has an impact on the quality of team performance and team effectiveness (West, 2012).

Patient safety depends upon open communication, trust, effective interdisciplinary teamwork and systems thinking (Francis, 2013; Madden, 2008; Department of Health and Children, 2001;

Kohn, Corrigan, Donaldson, 1999). The Madden Report (2008) highlights many challenges to effective teamwork in healthcare (i.e. hierarchical culture which impinges on teamwork, lack of trust, and a reluctance to seek help if a mistake is made). As highlighted by the Medical Council (2010), "Medical practitioners must co-operate with colleagues and work effectively with healthcare professionals from other disciplines and teams. He/she should ensure that there are clear lines of communication and systems of accountability in place among team members to protect patients".

Teamwork and communication is critical to safe surgery and the delivery of patient centred care. However, teamwork is not a given, and even 'experts' need help (Gawande, 2009). The WHO Surgical Safety Checklist (SSC) (2009) is a communication tool that supports teamwork and communication in Surgery. The World Health Organisation (WHO) SSC is structured in 3 stages: (1) before the induction of anaesthesia ("sign in"), (2) before the incision of the skin ("time out") and (3) before the patient leaves the operating room ("sign-out"). Teamwork checks are performed at each stage. Evaluations of the effects of the WHO SSC have been very positive (Haynes, Weiser, Berry, Lipsitz, Breizat, Dellinger, Herbosa, Joseph, Kibatala Lapitan, Merry, Moorthy, Reznick, Taylor, Gawande, 2009; Weiser, Haynes Dziekan, Berry, Lipsitz, Gawande, 2010). A recent study evaluating the attitudes of theatre staff towards a modified version of the WHO surgical checklist at an Irish hospital, identified a need for the involvement of all theatre team members in the checklist process, and for 'demonstrated support' for checklist practice from senior personnel (O'Connor, Reddin, O'Sullivan, O'Duffy & Keogh , 2013). Safe surgery is an important priority for the Health Service Executive (HSE). In this regard, the HSE have issued Safe Surgery Implementation Guidelines (HSE, 2013, 2015).

Performance shaping factors include both internal and external factors. The behaviour/performance of theatre staff in surgery needs to be conceptualized from a socio-technical perspective. That is, it needs to take into account relationship between people, processes, procedures, technology/tools, environment, culture and training. In this regard, Salas (2011) argues that we must create and sustain an organisational system that supports teamwork.

Safety (Safety-I) has traditionally focussed on the avoidance of bad events. That is, a reactive approach responding to what is going wrong and/or identified risks. Hollnagel and others argue that safety requires a proactive approach (Hollnagel, 2014, Hollnagel *et al*, 2015). 'Focusing on what goes right, rather than on what goes wrong, changes the definition of safety from 'avoiding that something goes wrong' to 'ensuring that everything goes right' (Hollnagel, 2014). This is termed 'Safety-II'. Importantly, 'Safety 11' is underpinned by open communication (briefings and debriefing), routine reporting and a just culture (Hollnagel, 2014, Hollnagel *et al*, 2015).

Research Context, Objectives and Method

Research Context

The Adelaide and Meath Hospital Incorporating the Children's Hospital (AMNCH) provides child-health, adult, psychiatric and age-related healthcare services. There has been a strong history of engagement with the SSC at AMNCH. The first local implementation of the SSC occurred in 2009, in advance of the HSE Safe Surgery guidelines. A further version was implemented in 2011. In 2013, the third (and current version) was introduced. In August 2013, the Theatre Department issued a policy document relating to Patient Identification Verification for Surgical/Invasive Procedures through the 'Surgical Safety Checklist', in the Operating Theatre of the Tallaght Hospital (Tobin, 2013). This has since been updated and makes reference to relevant SSC procedures (Tobin, 2015).Currently, the AMNCH SSC checklist is printed on the induction room and theatre walls. Theatre personnel refer to checklist items from memory. An electronic system (the Patient Information Management System - PIMS), is used in

parallel to the SSC, to record compliance with the SSC. This is in line with HSE guidelines (i.e. recording of checklist stage, team members involved and times completed).

Objectives

A locally initiated clinical audit of teamwork practice in relation to the use of the SSC is currently being undertaken at AMNCH. The overall objective of this audit is to redesign the existing checklist following evidence based human factors research concerning existing teamwork/SSC practice. The research is structured in term of two phases. Phase 1 involves an initial indicative audit of teamwork practice in relation to the use of the hospital's SSC (comprising interviews and observations, research analysis and provisional recommendations for an improved checklist). Phase 2 examines change recommendations in more detail – involving (1) stakeholder based co-design workshops to identify changes and an implementation plan, (2) piloting a new checklist/practice and measuring performance/impact and (3) an awareness campaign linked to this. Overall, this research can be characterized as qualitative action based research, following a 'stakeholder involvement/evaluation' methodology (i.e. AMNCH staff act as co-designers of an improved SSC). This links to the existing Plan, Do, Study, Act (PDSA) quality improvement methodologies adopted by the hospital.

Overview of Phase 1 Research

First, relevant SSC standards including WHO (2008), HSE (2013, 2015) and publically available hospital SCC templates/examples were reviewed. A detailed interview was conducted with a Nurse Manager, to understand the background to the implementation of the SSC at the hospital and current human factors issues. Also, the researcher reviewed the PIMS system and associated reporting outputs.

The researcher briefed nursing personnel in advance of the theatre observations and interviews. Further, posters were positioned in hospital social areas and in theatre, to communicate the purpose of the clinical audit to staff. Ten observations spanning different theatres/surgery types (Orthopaedics, Urology, Paediatrics, Trauma and Vascular) were undertaken. Also, the researcher conducted twenty three interviews with theatre staff. This included Clinical Nurse Managers, theatre nurses [scrub and circulating}, Surgeons and the Anaesthesia team. Some of these interviews were opportunistic (in theatre and/or post-surgery). Structured interviews were conducted with three nurses (Theatre manager, Theatre Nurse and Admissions Nurse), one Anaesthetist and two Surgeons. The Researcher obtained an ethics waiver from the hospital for this research. For a detailed breakdown of research steps/activity, please see Appendix 1: Research Stages & Steps.

Key Findings

The following is a summary of the key findings of theater observations and interviews:

- Nursing personnel are a key co-ordinating interface between all roles
- Much of the functional logic of theatre work depends on informal communications/information sharing between nursing personnel and the other members of the team (i.e. informal social process)
- Team members understand each other roles/function
- In general, team members exhibit appropriate behaviours (i.e. assertiveness, respect, communication, co-ordination, clinical leadership)
- The SSC is familiar to all and the importance of complying with the SSC in relation to communications/safety culture and patient safety is well understood
- The SSC (i.e. AMNCH Implementation) is well integrated with work activity

- Mostly, staff reflect a positive attitude towards using the SSC
- Theatre personnel engage with the SSC at different levels (mostly nurse led)
- Staff are using the SSC – but not always appropriately and/or accurately
- Not all steps are happening formally (this issue spans all three phases)
- There are some key concern in relation to briefing and debriefing around patient risk (risks to be addressed in surgery, and post-operative concerns)
- The performance of the checklist follows from (and links to) various prior briefings (both formal and informal) undertaken by some similar and different roles, both earlier in the process (from admissions to team briefings at the start of the day etc) and later in the process (recovery)
- Time pressure has an impact on SSC compliance – particular in relation to patient handover (sign-out phase)
- Surgeons need to show leadership re compliance with SSC and safety culture
- The physical design of the workspace (social rooms, induction rooms) impedes teamwork
- There are some gaps in relation to the existing implementation of the SSC and recent HSE SSC guidelines

It was also noted that staff do not obtain teamwork training (i.e. training in non-technical skills). Further, it was observed that any SSC redesign activity needs to take into account the lessons learned from past redesign activities. Specifically, this concerns the need for management buy-in and the importance of adopting a 'stakeholder evaluation' approach.

Discussion

Non Compliance & Root Causes

The SSC is intended as a formal checklist and not a guide. As such, non-compliance issues must be addressed. Team performance must be understood from a socio-technical perspective. Preliminary root-cause analysis suggests broader issues linking to teamwork/communications values/culture (i.e. teamwork culture, safety culture/attitudes, perception of different roles, professional latitude), mind-set re policy and policy change, training, process design issues (time and resourcing issues) and the design of staff work contracts. Evidently, the system must be designed to facilitate and promote teamwork (i.e. time in process, training delivery, clarity/fairness re work contracts, attention to culture etc). For the SSC to work, these other elements must be in place. In this regard, there is a relationship between behaviour change (change in behaviour for theatre staff) and organisational change (changes to existing hospital processes, culture and so forth) to enable staff behaviour change.

Teamwork States

Observations indicate that processes/checks related to briefing and debriefing require improvement. Potentially, there is a lack of clarity across team members (1) in relation to the teamwork/communication states to be achieved (both individually and collectively) to support patient safety, and (2) how this is enabled by the SSC. The 'states' can be defined in relation to two aspects of team cohesion (1) task cohesion and (2) social cohesion. For example, at the time-out stage, team states might include:

- The procedure and associated risk is understood by everybody in the team
- Open verbal communications between all staff (irrespective of rank/level of expertise)
- Senior team members supporting training of Junior team members

These states will need to be agreed with stakeholders and used as a basis for setting the 'communication/teamwork' goals for each stage of the SSC. For more information on teamwork states and the SSC, please see Appendix 3.

Vision for the Improved SCC

Compliance with the SSC is not the only teamwork/communication indicator. Moreover, compliance with the SSC is not the only indicator of patient safety. The SSC needs to be considered as one element of an overall safety management approach/system delivering patient safety. Other elements include open disclosure, the development of reporting systems (mandatory, confidential), the promotion of safety culture, routine monitoring of risk (predictive and reactive), the specification of communication/information sharing processes/procedures, the practice of briefing/debriefing and teamwork training. Such practices are typical of other safety critical systems (e.g. aviation and energy management).

The SSC should not simply be a tick-box exercise to demonstrate a 'minimal' level of teamwork. It should be used to promote a strong safety culture, characterized by open communications and disclosure, healthy disagreement, attention to patient risk and staff of all levels feeling free to speak up. One way of promoting this culture is to develop a corresponding step for this type of communication in the SSC (i.e. embed culture in checklist). For example, at the Time out stage, team members might be invited to 'speak up' (check item). At the 'Sign Out' stage, staff might confirm whether a report is required.

Critically, the redesign of the AMNCH SCC must be considered in the light of Safety 11 concepts. Safety 2 is not just about learning from adverse events, but also about learning from what was done well. Importantly, both the existing AMNCH SSC and the existing HSE standard (2015) do not sufficiently address Safety 11 concepts. Such concepts might be easily embedded in the SSS. For example, at the 'Sign Out' stage, a new check might be introduced to confirm that theatre staff have briefed about what went well and what might be improved.

SSC and Broader Hospital Information Flow Processes

Although redesign activities are necessarily focussed on delivering appropriate teamwork states in theatre (scope of SCC), they must take into account relevant team states and activities associated with wider processes and staff information sharing activities. The performance of the checklist follows from (and links to) various prior briefings (both formal and informal) undertaken by some similar and different roles, both earlier in the process (from admissions, to the start of the day/list team briefings) and later in the process (i.e. briefing in recovery). If something is skipped/not covered in detail, then these briefings provide a level of redundancy/resilience. Currently, the relationships between communication activities as part of the SSC and these wider briefing pathways/processes (both formal and informal) are not clear. This is particularly important in relation to the first (sign in) and last stage (sign out) of the checklist. Overall, the checklist redesign needs to be situated in the context of existing patient centred information flows from admissions to recovery. Potentially, the existing process design and level of technology support does not afford this. This warrants further research. Ideally, there might be a formal requirement for a start of day/list briefing for all team members involved in theatre activity.

Initial Redesign Recommendations (high level)

The following is a list of provisional redesign recommendations, which will be validated by relevant stakeholders in a future co-design workshop.

- Overall, the focus of the checklist should be on the teamwork dimensions which underpin patient safety (communication, speaking up/out, briefing, debriefing and reporting)
- The SSC should be designed (and used) from a verification perspective (i.e. confirming what has been done) as opposed to functioning as a guide
- Each stage/phase starts with a 'formal' check that team members are ready to commence (taking into account issues around courtesy and workload)
- Each stage/phase of the checklist is initiated by a designated person (leadership role for verification)
- Given resources issues (feasibility of all team members being in the room at the same time) – consider splitting certain phases into two stages (not everybody present for all)
- Surgeon (or representative from team) involved in the 'sign-in' stage
- All members debrief properly at the 'sign-out' stage (i.e. safety patient handover)
- Consider simplifying the level of reporting in relation to the use of the SSC in PIMS
- The SSS should be integrated with the Safety 2 approach (debriefing in sign-out stage)
- The SSC should be integrated with other staff information sharing processes from admissions to recovery
- There should be a formal requirement for a start of day/list briefing for all team members involved in theatre activity
- Some standardization is required in relation to HSE guidelines

Conclusions

Good teamwork/communication protects both staff and patients alike. A well-designed check list can improve team cohesion/communication and patient outcomes. However, to be effective, the checklist has to work from a functional perspective (i.e. deliver the right teamwork states in relation to task and social cohesion), it must be acceptable to staff (i.e. easy to use and not hamper work activity), staff must use it correctly (i.e. formal check not guide), staff must value it (i.e. safety culture/not just a 'tick-box' exercise) and it must be supported at an organisational level. Further, the checklist must comply with the agreed hospital policy and national/international standards. The root causes of non-compliance must be addressed. This will necessitate examining the broader organisational issues pertaining to current teamwork and SSC practices (process, training, culture). Behaviour change for theatre staff is dependent on broader organisational change. It is likely that this will involve a piece of research around policy specification and implementation, mind-set around policy, the design of work contracts, the provision of training and culture/attitudes. Further, compliance with the SSC is not the only teamwork/communication indicator. Also, compliance with the SSC is not the only indicator of patient safety. The SSC needs to be considered as one element of an overall patient safety approach. As such, redesign activities need to address necessary linkages between the SSC and wider safety management practices. This research indicates that Safety 11 concepts might be embedded in a future redesign of the SSC (specifically, in relation to debriefing). The SSC should be located in the context of both formal and informal planning/briefing practices involving different members of the multi-disciplinary team prior to the 'Sign in' stage and post 'sign-out' (i.e. recovery). Also, the SSC might focus more strongly on team briefing practices concerning patient risk factors at the sign in stage, and in the time out stage. One member of the Surgery team should be present at the 'Sign-in'. Moreover, briefing in relation to the post-operative plan/safe handover might be improved.

This was an initial indicative audit (small number of interviews and observations). Additional audit activities might be undertaken. Further, all proposed redesign recommendations must be validated with key surgery functions (phase 2 research). As noted previously, future research needs to investigate what key states are required at each stage of the checklist, and how these might be enabled by the SSC. A future co-design workshop will focus on this. Also, a redesigned SSC has been advanced (including some new checks). The proposed checks for each stage of the checklist will need to be reviewed and validated by relevant surgery functions. It is anticipated that this will enhance the quality of the checklist design, along with addressing issues around staff buy-in and attitude to change.

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Appendices

Appendix 1: Research Stages & Steps

Table 1 Research Stages and Steps

#	Stage	Step
1	Research planning and ethics	Initial research review – telephone and in person interviews Preliminary interview/observations to understand practice and issues Submit pro forma Submit TCD, School of Psychology Ethics Submit TCD, School of Medicine Ethics Submit AMNCH, Ethics
2	Literature review	Review WHO literature and best practice Review HSE literature Review of 10 SSC (publically available information) – including WHO and HSE guidelines Comparison of existing hospital checklist with above
3	Field research and initial analysis (phase 1)	Review of SSC implementation history and PIMS walk-through with Clinical Nurse Manager (Claire Dardis) Theatre observations (10 - involving theatres 1, 3, 4, 5, 9 and 11) Interviews with theatre staff (23 – comprising different functions: Clinical Nurse Managers, theatre nurses [scrub and circulating}, Surgeons and Anaesthesia team)
4	Initial analysis and report	Initial analysis of findings (conformance with SOP and recommendations for redesign) Redesign proposal: proposed checklist example Production of phase 1 intimal report Review of report with stakeholders
5	Report Review	Review with team
6	Further analysis	Comparison of findings with HSE guidelines (in reference to HSE audit instrument) SSC gap analysis (HSE, WHO and AMNCH) – at level of information units
7	Final Report (Phase 1)	Integration of review feedback Production of phase 1, version 2 report

Appendix 2: SSC and Process/Information Flows

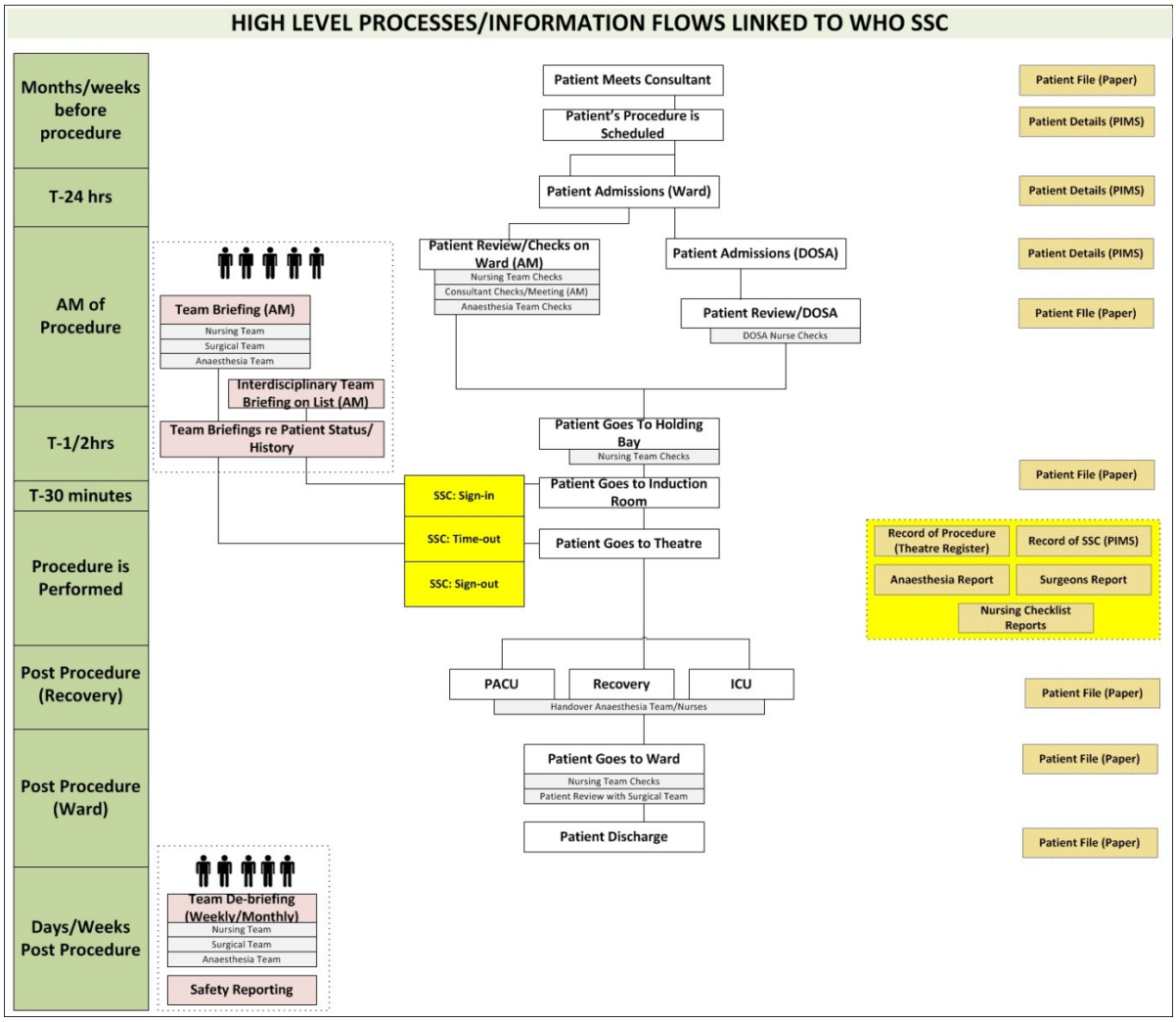

Figure 1: Information flows linked to SSC

Appendix 3: Teamwork states and SSC

Table 2: Teamwork states and SSC

#	SSC Phase	Teamwork States
1	Sign-in	Successful team formation (i.e. the group becomes a team) Patient at ease and understands procedure Relevant team members briefed re patient status, procedure and associated risks (Consultant Anaesthetist, Anaesthetist Dr Jr, Anaesthetist Nurse, Member of Surgery team etc) Surgeon has discussed procedure with patient - if required
2	Time-out	Successful team formation (i.e. the group becomes a team) The team understand their goals and how they will achieve this as a team Team members understand all members roles and functions The team acts as a cohesive unit (i.e. a team and not a group) The team have a common positive purpose (patient safety, teamwork) The procedure and associated risk is understood by everybody in the team All team members are briefed re procedure Team based situation assessment Predictive risk management Open verbal communications between all staff (irrespective of rank/level of expertise) Potential for healthy disagreement Understanding/agreement that reporting/speaking up is valued Professional latitude for all staff Senior team members supporting training of Junior team members Junior staff comfortable requesting support of senior staff if needed (particularly in situations when senior staff are not in theatre)
3	Sign-out	Surgery completed All team members have a clear risk picture re status of patient All team members are briefed re procedure performed and any issues arising Open verbal communications between all staff (irrespective of rank/level of expertise) Safe patient handover Team learn lessons – what went well, what might be improved Safety events reported

IF MACHINES COULD SET GOALS, COULD THEY REPLACE PEOPLE AT WORK?

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Abstract

This paper investigates the importance of goal-setting in the workplace and the difference between people orientated goal-setting and machine and robotic goal-setting. This paper will focus on the association among conscious performance goals and the stage of the task performance and how if machines could do the same thing would they soon replace the need for people in the workplace. This paper found that the human presence is not something that can ever truly be replaced by any form of machine or robotics. While the vast developments in technology and artificial intelligence are improving the workplace to no end, they cannot fully replace the role and position of a person. They can however work alongside each other together to help the continuous enhancements in the workplace. Machines and robotics still remain embedded in the human world, owing to its preservation of human goals.

Introduction

The theory of goal-setting falls inside the large field of cognitive psychology (Meichenbaum, 1977). The goal-setting theory was developed primarily on the foundation of empirical research that was centred on Ryan's (1970) principle (actions are affected by conscious goals). A goal is the aim or the purpose of an action, what an individual is striving to achieve (Locke, 1969). For example, to achieve a certain standard of expertise typically inside a set time period. Other commonly used terms that are comparable in consequence to goals are; task (a portion of work to be achieved), budget (a limit or goal on expenses), performance standard (an evaluating rod for measuring and rating performance), work norm (a level of suitable behaviour that is identified and set by a work group), deadline (a set period for finishing a task), quota (the least sum of production or effort), and objective (the end desired goal of an endeavour) (Locke and Latham, 2002). The main focus and point of interest for industrial-organisational psychologists is to predict, justify, persuade and shape performance in all work and organisational related tasks. This paper will focus on the association among conscious performance goals and the stage of the task performance and also if machines could do the same thing would they soon replace the need for people in the workplace.

There are four main mechanisms through which goals influence performance. Firstly, goals act as a form of directive role as they point attention and effort toward actions that are goal relevant and away from actions that are irrelevant to the goal at hand. This happens cognitively and behaviourally. Rothkopf and Billington (1979) discovered that students who

have explicit learning goals were more likely to be more attentive to and learn prose passages that are specifically goal relevant better than passages that are goal irrelevant. Locke and Bryan (1969) also found that individuals performance improved on an auto-driving task on the aspects for which they had goals, when they were provided with feedback relating to numerous aspects of their performance.

Secondly, goals have an exhilarating role. The greater the goal, the larger the effort put in will be. This is displayed when tasks; (a) contain dimensions of subjective effort, (b) specifically involve physical effort, (c) involve physiological gauges of effort, and (d) involve replicated and recurring performances of basic cognitive tasks (e.g. addition) (Bryan and Locke, 1967a; Bandura and Cervone, 1983; Sales, 1970).

Thirdly, persistence and perseverance can be affected by goals. If a participant is permitted to manage the time they employ on a task, hard goals delay and lengthen the effort given (LaPorte and Nath, 1976). Nevertheless, in work there is frequently a trade-off seen among intensity of effort and time. It is feasible to work quicker and more intensely for a brief time space when met with a complex goal, opposed to working less intensely and gradually for a lengthened time space. A more swift work rate can be seen when an individual is presented with strict deadlines and targets (Bryan and Locke, 1967b).

Finally, goals can ultimately influence action by directing to the discovery, arousal, and the use of task-relevant information and tactics (Wood and Locke, 1990). It is seen as a fundamental saying that all actions are the outcome of motivation and cognition. However, these factors can work together in complex ways (Locke and Latham, 2002).

Goal difficulty

One of the most important aspects to consider when discussing goal-setting is the difficulty of the goal set. Atkinson (1958) found that the difficulty of a given task, when evaluated as the possibility of task success, is directly associated to performance in a curvilinear inverse function. The greatest amount of effect is achieved when the task given is relatively difficult. Inversely, the least amount of effort occurs when the task given is either too easy or too hard. Locke and Latham (1990) found that there is a positive, linear association between goal difficulty and the amount of effort and performance delivered. Meta-analyses on the effect sizes of goal difficulty ranged from $d = 0.52$ to $d = 0.82$, which is a moderate to strong effect size. Performance is seen to decrease and level off when the limits of capability are reached or when there is a slip in dedication to a goal with high difficulty (Erez and Zidon, 1984).

Locke and Latham (1990) also evaluated the different effects between difficult goals and the ‘to do one’s best’ motto that is frequently used in organisational settings. They found that goals that are more specific and with a higher difficulty level attached to them, resulted in a greater performance outcome by an employee than simply insisting they do their best. The meta-analyses effect sizes of this ranged from $d = .42$ to $d = .80$, which again is also a moderate to strong effect size. According to Locke, and Latham (2002) people do not always do their best when they are merely requested to do so. The reason for this is because these 'do your best' goals do not have any form of external significance or reward and therefore are deemed idiosyncratically. This form of motivation and goal-setting permits an extensive variety of acceptable levels of performance as opposed to when a goal level is precisely stated. Goal idiosyncrasy alone does not essentially lead to peak performance as explicit goals differ in complexity. Nevertheless, taking into account that performance is entirely controllable; goal idiosyncrasy does decrease disparity in performance by decreasing the uncertainty surrounding what exactly is to be achieved (Locke, Chah, Harrison, and Lustgarten, 1989).

Expectancy and social-cognitive theories

The theory of goal-setting emerges in conflict with and challenges Vroom's (1964) valence instrumentality expectancy theory. His theory declares that the power to perform is a multiplicative amalgamation of valence (expected fulfilment and pleasure), instrumentality (the assumption that rewards will be attained from a performance), and expectancy (the assumption that effort will direct towards the performance that is required to achieve the rewards). Expectancy is thought to be positively associated with performance, assuming other aspects remain equal. However, as complex goals are more difficult to achieve than simple ones, the expectancy of goal accomplishment would seemly be adversely associated to performance (Locke and Latham, 2002).

The evident conflict amid both theories can be settled by differentiating between expectancy within and expectance between goal circumstances. Research conducted by Locke et al. (1986) discovered that when the level of a goal is kept consistent, which is essentially expected in valence-instrumentality-expectancy theory, the greater the expectancies the greater the degree of performance. Lower expectancies, related to greater goal levels are linked to greater performance across goal levels.

The differentiation between expectancy within and expectancy between is not conflicting with the social-cognitive theory (Bandura, 1986, 1997). The notion of self-efficacy is significant in the goal-setting theory for numerous reasons. Self-efficacy is determined by gathering efficacy rankings across an entire scale of likely performance consequences, opposed to from an individual consequence (Locke et al., 1986). When a goal is set by an individual themselves, those with greater self-efficacy are seen to set higher goals, opposed to those individuals with poorer self-efficacy. Individuals with greater self-efficacy are also more dedicated to their allocated goals, discover and employ superior task tactics to achieve their goals, and they react more positively to constructive criticism and feedback than those individuals with poor self-efficacy (Locke and Latham, 1990; Seijts and Latham, 2001).

Positive communication with employees

Employee contribution

What happens more often than not in the workplace is that employers are the only ones to set goals and targets without any input or communication from the rest of the company and employees, who will inevitably be the ones carrying out the tasks. There is a need for goal-setting strategies in companies to change the way they are currently going about setting goals, as much research highlights the importance and benefits of allowing an employee to have some form of involvement in setting the goals on tasks they are required to work on. According to Locke (1991b) the 'motivation hub' embodies personal goals, comprising of self-efficacy and goal commitment. These factors are frequently, but not always, the most instant, direct and conscious motivational elements of action and can arbitrate the effects of external enticements. For instance, allocated goal effects are arbitrated by personal or self-set goals which an individual selects in response to the present assignment or task, along with self-efficacy. Allocating an employee a difficult and complex goal has been shown to increase self-efficacy as it is an implied indication of confidence and belief from the task or project manager that the employee can achieve the goal. The correlation concerning self-efficacy and self-set goals is greater when there is no goal allocated.

The rewards of contributing in the decision making process are mainly cognitive opposed to motivational. However, research conducted by Latham, and Yukl (1976) and Latham et al. (1978) discovered that when employees are permitted to contribute in the setting of their work

goals, they set larger goals and perform better in their work performance, opposed to those employees who are merely allocated goals by their managers and have no say in the set goal. The greater the set goals are, the greater the performance execution will be. Kirkpatrick and Locke (1996) also discovered that goals and self-efficacy arbitrated the outcome of idealistic management on employee performance.

Need for feedback

Not only is it important to allow the employee to have some sort of contribution to the setting of the goals and tasks that they are required to do, they should also continuously work with a supervisor or manager who will constantly give them feedback on how they are getting on with their task. Furthermore, in order for goals to be successful and valuable, employees require summary feedback that uncovers and shows their development in the goals they are trying to achieve. If an employee is not aware of how they are getting on, it is hard or even unfeasible for them to alter the effort or course of their work, or even to change their performance tactics to meet the needs of the goal better. For example, if an employee is given a goal of selling 15 pieces of property on a given day, that employee has no way of knowing if they are on target with their sales unless they know how many pieces of property they have sold. When an employee discovers they are beneath a target, they usually enhance their efforts or seek a new performance strategy (Matsui et al., 1983). Feedback is a mediator for goal outcomes in the sense that the amalgamation of feedback, along with goal-setting, is more successful than having a goal on its own (Bandura and Cervone, 1983; Becker, 1978; Erez, 1977; Strang, Lawrence, and Fowler, 1978).

Machines in the workplace

Control theory

The control theory also stresses the significance of combining goal-setting with constant feedback in order to achieve maximum motivation (Carver and Scheier, 1981). However, the basic beliefs of the control theory are questionable (Locke, 1991a, 1994; Locke and Latham, 1990). The theory is centred on a machine model that is taken from cybernetic engineering (Powers, 1978). The basis of motivation is emphasised to be a negative feedback loop that removes goal-performance incongruities. The instinctive status of the organism, by conclusion, is one of rest or interlude.

The control theory is a mechanistic interpretation of Hull's drive reduction theory (Mowrer, and Solomon, 1954). However, machines cannot acquire internal motivational elements and they do not have the ability to have and create their own goals (not yet anyways!). The goals, so to speak, that a machine holds are the goals of the machine's designers and developers. In addition, incongruity reduction is a consequence oppose to a source of goal-directed behaviour. As noted by Bandura (1989), goal-setting is primarily a discrepancy-creating procedure. Along with feedback, motivation needs feed-forward control. When an employee has achieved the goal that they have been seeking, they will then set an even greater goal for themselves in their next task. This implementation of increasing ones goals generates, opposed to decreases, motivation discrepancies to be perfected. “Self motivation thus involves a dual cyclic process of disequilibratory discrepancy production followed by equilibratory reduction” (Bandura, 1989, p. 38).

Machines and goal-setting

With the developments in technology and the vastly growing world of artificial intelligence people are beginning to wonder and test if machines or robotic can carry out the same tasks and

achieve the same goals as people. There have been many different developments into this area including work by Schmidhuber (2006) and Goertzel (2014). In theory, Schmidhuber's Godel Machine (Schmidhuber, 2006) is an architecture that is capable of taking an arbitrary goal function and generating a way to accomplish it in a manner that is evidently advantageous, given its present abilities and knowledge. This also involves discovering how to adjust itself in order to better accomplish the goal in the future, after the adjustments have taken place (Goertzel, 2014). Following on from this, Goertzel (2014) developed the goal-oriented learning meta-architecture (GOLEM), which is a high-level artificial general intelligence (AGI). Goertzel (2014) believes that the GOLEM is capable of maintaining its original goals, whilst fundamentally enhancing its familiar intelligence.

Both of these models can be seen to be trying to replace the role of people in the workplace. However, these machines are not perfect and come with their own errors. Machines can make mistakes and can break down due to technological problems. Machines constantly need the current knowledge and capabilities from a person in order to be programmed. They also need to be initially hard-wired and they often still need continuous input and checks from the developer or programmer. Machines are incapable of self-modification. Inefficient algorithms can also be provided to summarise the intended goals which can cause errors and machine malfunction and shut down. For example, the Godel Machine (Schmidhuber, 2006) could in fact be unintentionally performing flawed and incorrect features due to analysis short-cuts it is required to do so that actions get created inside a realistic time frame in relation to its restricted resources.

Another issue that can be seen in Goertzel (2014) GOLEM model is how to insure that the machine employs the required goal material? How can it be guaranteed that the machine is constantly updated with the new information being obtained from the world, as it is constantly changing and evolving? A machine cannot do this in a way that conserves the spirit of the initial goals. A machine cannot do this on its own as it only knows what it has been programmed to know and to do. It will continuously need the assistance of a person. While technology and artificial intelligence has greatly enhanced the workplace and the world we live in, there is no replacement to the actual human presence and abilities. It can be argued that the GOLEM for example can expand and develop far past humans in regards intelligence, understanding and capabilities. However, it still remains embedded in the human world, owing to its preservation of human goals. Machines are also incapable of achieving the four main mechanisms through which goals influence performance; cognitively and behaviourally, human effort, persistence and perseverance, and motivation and cognition. Furthermore, machines are unable to justify and persuade performance in all work and organisational related tasks like people can.

Conclusion

The main focal point of the goal-setting theory is on the centre assets of an effective and successful goal. These properties include; the appropriate application of learning versus performance goals, the function of goals as mediators of alternative enticements, specificity and complexity means, mediators of goal outcomes, the outcome of goal origin (allocated goals versus self set goals), arbitrators of goal outcomes, and goal outcomes at an individual, group and organisational level.

One of the main focuses in goal-setting theory is motivation in work surroundings. The research of main influence in social-cognitive theory are mainly centred on self-efficacy, its reasons, its measurement, and its effects at the individual, group and societal stages in various fields of performance. The goal-setting theory and the social-cognitive theory both link and agree on what is believed to be of most significance in performance motivation (Locke, 1997).

The results of goal-setting are especially dependable and consistent. Failure to duplicate and repeat these results are typically due to mistakes and blunders. Some errors that can cause failures are; failing to incorporate an adequate array of goal complexity stages, failing to match the goal to the required performance measure, failing to communicate task information, failing to give performance feedback, failing to achieve goal commitment, and failing to assess an individual's self-set (personal) goals (Locke and Latham, 1990).

To conclude, goal-setting theory has shown that definite complex goals are likely to increase an employee's performance. Meta-analyses have shown this on over 100 diverse tasks concerning over 40,000 participants in a minimum of eight countries and carried out in field, simulation and laboratory surroundings. Some of the dependent variables in these studies have incorporated quality, costs, quantity, behaviour measures, and time spend. The time periods have also varied from one minute to 25 years. The outcomes are also relevant to groups (O'Leary-Kelly, Martocchio, and Frink, 1994), organisational units (Rogers and Hunter, 1991), and entire organizations (Baum et al., 2001), as well as individuals. All of these effects have been discovered through employing experimental, quasi-experimental and correlation designs. The research has also examined the different effects of goals when they are allocated or self-set personal goals.

The main findings from all of these studies are that there is a positive, linear association between goal difficulty and the amount of effort and performance delivered. The difficulty of a given task, when evaluated as the possibility of task success, is directly associated to performance in a curvilinear inverse function (Atkinson, 1958). The greatest amount of effect is achieved when the task given is relatively difficult. Inversely, the least amount of effort occurs when the task given is either too easy or too hard. When a goal is set by an individual themselves, those with greater self-efficacy are seen to set higher goals, opposed to those individuals with poorer self-efficacy. Individuals with greater self-efficacy are also more dedicated to their allocated goals, discover and employ superior task tactics to achieve their goals, and they react more positively to constructive criticism and feedback than those individuals with poor self-efficacy (Locke and Latham, 1990; Seijts and Latham, 2001). Allowing an employee to contribute to the goal-setting of a task they are required to work on has a huge impact on their performance. When employees were permitted to contribute in the setting of their work goals, they set greater goals and perform better in their work performance (Latham and Yukl, 1976; Latham et al., 1978). One of the final attributes that is important in goal-setting and employee performance is ensuring that the employee continuously gets feedback on their work. Feedback is a mediator for goal outcomes in the sense that the amalgamation of feedback, along with goal-setting, is more successful than having a goal on its own (Bandura and Cervone, 1983; Becker, 1978; Erez, 1977; Strang, Lawrence, and Fowler, 1978). Briefly put, goal-setting theory is in the midst of the most applicable and practical theories in the field of employee motivation in organisational psychology (Lee and Earley, 1992; Miner, 1984; Pinder, 1998).

Furthermore, all of the aspects spoken about in this paper are what make goal-setting possible and so unique and distinct to people. It is not something that can ever truly be replaced by any form of machine or robotics. While the vast developments in technology and artificial intelligence are improving the workplace to no end, they cannot fully replace the role and position of people. They can however work alongside each other together to help the continuous enhancements in the workplace. Machines and robotics still remain embedded in the human world, owing to its preservation of human goals.

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RECENT DEVELOPMENTS IN THE LAW OF EMPLOYERS LIABILITY

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Extended Abstract

Through a series of cases commencing with the decision of Ms Justice Irvine in *Barry v Dunnes Stores*, *Smith v HSE* and more recently *Bowell v Dunnes Stores* it is now well established that not only does an employer have an obligation to provide a safe place of work for their employees but by virtue of Section 13 of the Safety Health and Welfare at Work Act 2005 places an obligation upon an employee to take reasonable care to protect his or her safety. This is more commonly referred to as Statutory Contributory Negligence. Prior to the cases referred to above Statutory Contributory Negligence was given very little weight. In the Barry case the employee was found 30% contributory negligent. In the Smith case the employee was found 25% contributory negligent. In the Bowell case the employee was found 30% contributory negligent. The onus of proof is on the party alleging the contributory negligence and he or she must offer positive evidence of same.

The employer has also an obligation to prove that an employee was properly trained. Mr Justice Barr in December 2014 in the case of *Meus v Dunnes Stores* in dealing with the adequacy of the training provided to the employee in light of the employer's obligations under Section 10 of the Safety Health and Welfare at Work Act 2005 along with the relevant Regulations was not satisfied that the demonstration given to the employee as to how to lift a box of A4 paper was inadequate and not remotely comparable to the lifting exercise which the employee had to do in the course of her duties in the workplace. There was a further difficulty insofar as no attempt was made to enquire whether the employee actually understood the content of the instruction given to the employee in relation to the manual handling. In the particular case the employee was a Polish national.

More recently in the decision handed down by the Court of Appeal in the case of *Martin v Dunnes Stores* the Defendants appeal was allowed and accordingly the claim promoted by the plaintiff for Personal Injuries arising from a partial tear to the biceps muscle of the Plaintiff's right arm which resulted when she was replacing a 10 KG pack of potatoes for a customer failed. In the lower court the trial judge was satisfied that

" … the accident was caused by a dangerous lift and an absence of adequate training the proper lifting of objects such as this and the failure of the defendant's system for providing assistance on the day in question …"

There was no dispute that the Defendant had a system in place whereby members of the checkout staff could access assistance from other members of staff to the required. It is accepted that the Plaintiff was trained in manual handling techniques on a regular basis. The Court of Appeal was satisfied that the defendant fulfiled their obligation to identify potential hazards likely to affect the safety and health of the Plaintiff. In this case the Court of Appeal felt there was very little potential hazard or risk faced by an employee working at a checkout in the store and in order to meet the expectation of the customer they had available to them a system whereby they were instructed to seek assistance and not undertake any unwarranted tasks. The Court of Appeal touched off the issue as to whether training by using an empty cardboard box in demonstrating lifting techniques was adequate and whether the defendant should have in place a manual handling training system which included practical training for employees concerning the various products. Ms Justice Irvine in the Court of Appeal was of the view that such a system

"would be neither reasonable nor practicable for any employer particularly one such as the Defendant, who presumably has an ever-changing range of products from groceries to furniture to household goods which employees have to handle on a regular basis."

The Court was satisfied that the employer had reasonably discharged its obligations to the plaintiff by training her on a regular basis as to the principles of safe manual handling which was then up to her to deploy when faced with any given task.

In *Thompson v Dublin Bus* the Supreme Court in dealing with an appeal from a decision of De Valera J in the High Court changed the landscape involving claims against an employer for injury arising secondary to an inherent defect in machinery. Prior to this decision proof of the fact of an injury caused by defective machinery was sufficient to justify imposing liability on an employer. The issue was whether the employer was liable for the consequences arising from the defective suspension in the bus which caused the plaintiff's injury. The Supreme Court found that the Defendant had exercised all reasonable care in and about the sourcing of the boss in question, allowed the appeal dismissed the Plaintiff's case.

Quite often in RSI cases the issue of the date of knowledge\injury\cause of action receives particular attention. The Statute of Limitations is often pleaded. Helpful guidance is available on the back of the decision of the Court of Appeal in the case of *Liam Brandley and WJB Developments Limited v Hubert Deane t/a Hubert Deane & Associates and John Logan t/a John Logan Ground Works Contractor*s. The Plaintiff's claim was for damages as a result of defects in the foundations of a house. The issue before the court was when the Plaintiff's cause of action accrued. Three relevant dates were considered. The foundations were completed in March 2004. On 4 September 2004 the Certificate of Compliance issued. In December 2005 the cracks appeared in the houses. The Court of Appeal overturned the decision to dismiss the plaintiffs case stated that

" … negligence by itself without the accompaniment of damage or loss is not actionable. The plaintiffs did not suffer damage at the time when the defective foundations were installed. When the defective foundation was put in, the only complaints that the plaintiffs could have had was that the foundation was

defective. They had not suffered any damage at that point-there was merely a defective foundation-but that is not damage of a kind that is actionable in tort."
We have, of course, the benefit of the Statute of Limitations (Amendment) Act 1991 as amended by Civil Liability and Courts Act 2004,s 7 which provides that the period of limitation if a plaintiff claims damages for personal injuries is two years from the date of accrual or the date of knowledge if later than the date of accrual and it is arguable that the decision of the Court of Appeal does nothing to alter the statutory position.

ENGINEERING AND ERGONOMICS CONSIDERATIONS IN RSI LEGAL CASES

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Extended Abstract

Legal cases cost, both to take and to defend. No one initiates legal proceedings for a wrong doing against them unless they have some hope or belief that they have a chance of recompense. However, once a case is initiated – on-line with the Injuries Board, it sets in motion a chain of events – which can involve solicitors, barristers, physicians, consultants (medical and subject matter experts), engineers, insurers, loss adjusters, liability adjusters, the claimant and the defence (Figure 1).

When cases are "straight forward" e.g. a person has sustained a cut when using a knife, the specific contribution the knife made to the injury can be ascertained, the size of the scar, the depth of the cut and long term sequelae are easier to quantify. The variables will only include such issues as contributory negligence and legal compliance.

However, when it comes to cases involving claims of RSI, things become less straight forward – partially due to the on-going research relating to the prevalence of RSI, particularly, carpel tunnel syndrome in the general population – indicated to be as high as 4% [1]. In such cases, the variables can be more influential.

Successful civil litigation depends on a number of factors, including but not limited to how evidence is presented, the understanding of the decision makers (solicitors, barristers and judges) on the exact circumstances of a claim, and in turn how that interpretation may influence the application of the burden of proof – which for civil cases is "balance of probabilities", as well as compliance with legal statutory requirements. However, even what at first might appear as a simple interpretation of statutory requirements in itself can be open to interpretation – producing yet another variable into the chances of winning or losing a civil action.

Claimants take cases on the basis that the balance of probabilities will fall in their favour, and defence teams prepare their defence of any claim on the balance of probabilities falling in their favour – suggesting that the more variables in the mix the better the chances of winning or losing a case. To this end, taking or defending a claim can be a risky business.

Looking at CTS specifically, although CTS remains an idiopathic syndrome, there are certain risk factors that have been associated with this condition. The most significant of these are environmental risk factors. Prolonged postures in extremes of wrist flexion or extension, repetitive use of the flexor muscles, and exposure to vibration are the primary exposures that have been reported [2], but despite this, there are still quite a number of variables which can be brought into the mix by either party, so parties prefer, whenever possible to include specific statutory duties and failures in respect of same to introduce some element of certainty into

cases. It is easier to establish with a degree of certainty if an employer has in their possession a written risk assessment or has conducted an assessment of a VDU workstation (in accordance with Chapter 5 of Part 2 (Regulations 70 to 73) and the related Schedule 4 to the Safety, Health and Welfare at Work (General Application) Regulations 2007 (S.I. No. 299 of 2007), than it is to ascertain with a great deal of certainty that work which was carried out constituted a risk in respect of repetition or application of force.

Of course, there are significant guidance documents in respect of what is considered to be repetitive of highly repetitive, but no one agreed global definition – according to the ILO a task is highly repetitive if involves similar movements repeated more than 20 times per minute – but even with this definition, the term similar hand movements is open to interpretation. One individual might determine that a cycle is a combination of 3 tasks, whilst another might interpret each task as constituting a cycle.

So, when carrying out an engineering report for civil cases involving RSI, it is essential that the ergonomist consider all of the aforementioned risk factors, extremes of flexion or extension of the wrist, repetitive motion and exposure to vibration and applies their professional judgement in respect of same.

However, it is in the specific interpretation and application of statutory requirements which will provide the greatest strength towards a successful civil case.

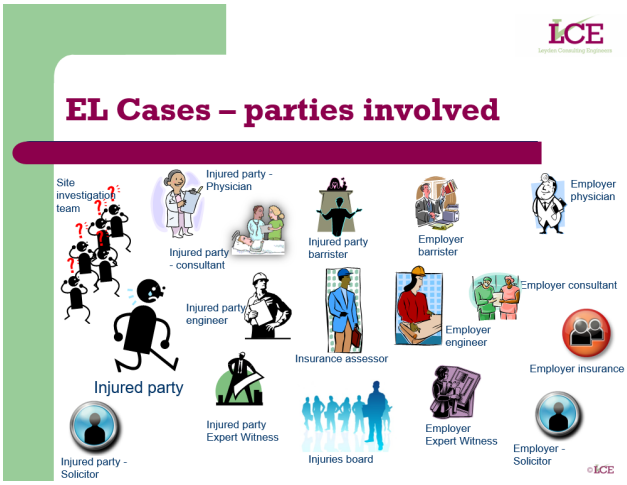

Figure 1

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