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Leonard W. O'Sullivan and Thomas Waldmann

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CIVIL AVIATION SECURITY: IMPROVING THE EFFICACY OF PASSENGER HANDLING THROUGH AIRPORT SECURITY

Eugene E. Skelton BA MIDI MIES

1 Clonmore Road,
North Strand,
Dublin 3,
Ireland.

Abstract

Lengthy queues in airports have become the norm and they are widely accepted by air travellers as a necessary but annoying inconvenience but can anything be done to improve this? Some air travellers are completely oblivious to the requirements which the civil aviation security regulations demand of them and so present themselves to security staff completely unprepared!

A short Ethnographic Research and Design Development Programme was conducted with selected airports on the island of Ireland to identify the issues and produce plausible solutions which would improve the efficacy of the security staff and their regulated procedures. In doing so saving the airports thousands of euro per annum and also increasing passenger throughput and improving their personal experience.

Currently the architects who design the spaces for security screening are only interested in the footprint required by the scanning lane assemblies. Those who design the scanning equipment are only interested in how to process passengers' belongings through their 'isolated' system. Neither of these groups is focusing on the Human Factors requirements of the passengers or the security staff, the result is a system which is poorly considered, inefficient and costly.

Introduction

A clear understanding of the security needs of end-user organisations (airport security) was paramount and this necessitated bringing together a group of these from all over Ireland, these included representatives from three airports on the island of Ireland covering international and domestic flights and different jurisdictions. These organisations have responsibility for security functions which are delivered directly or through third party subcontractors. Key personnel with roles in the various security organisations were identified and they became our first point of contact and the key stakeholders for the subsequent programme.

Approach

A team travelled to all three airports to meet with the key personnel and begin the interviewing and information retrieval process. At this stage the research team were following a very broad spectrum of investigation to identify problem areas, what was of value to the key stakeholders, who are the users (passengers' demographic) and to record all of the above and make observations. A sound understanding was gained of the airport security organisations' main needs and also the day to day requirements that the regulations place on their staff.

This was followed by a 'passenger journey' informal information gathering process which included recording methods such as photography, staff interviews and impromptu team discussions. This led to a subsequent team discussion, brainstorm and preliminary realisation of a long list of observations which were linked to the key beneficiaries. This list of observations (over 60 in total) were presented back to the key personnel identified earlier and the list was evaluated and consolidated based on their feedback and key criteria which delivered most value for them, the finalists were refined further with their input. Sixteen refined observations emerged from this process and following this an Ethnographic Research team led by an Industrial Designer were fully briefed on their details.

At this stage, one airport was chosen for the 'transformation process' of turning these observations into insights. The first stage of this process was for the Ethnographic Research team to meet with a key stakeholder and present back the sixteen refined observations and try to focus in on a smaller number which the research team could concentrate on effectively using the one onsite day allocated within the programme. Three observations were discussed and agreed on as they fell within the remit of the Ethnographic Research and Industrial Design processes which were commissioned. These three observations centred around two areas of concern, which were, the physical management of the trays used for the X-Ray scanning procedure, and the physical management of the pulsing of passengers which occurs more readily now due to online check in.

Research Assessment

The research commenced with an analysis of all the stages in the passenger journey through the airport where queues form either artificially or systematically in consideration of the chosen observations. After several hours spent on both landside and airside it was concluded that the actual security scanning zone had the most significant queues which was having a serious detrimental knock on effect before and after the process. This is where we needed to investigate further and with more focus and therefore the three person team was set up in the security scanning zone concentrating on the entire security scanning procedure from beginning to end. Several hours of video were shot, staff interviews were conducted and copious amounts of note taking and sketching was the order of the rest of the day. It was then back to the office where all the interviews, video recordings and notes were assessed by the team in detail during several days.

In much of the footage viewed, the team continually identified that there appeared to be a 'bottle neck' occurring at the current 'undress' position on the entrance rollers feeding the trays into the scanning machine. Also on exit, the same appears to be happening in reverse in that passengers begin to queue again before they are enabled to retrieve their trays and belongings as this compact area is inappropriately but mostly used for 'redress'.

The research team understands that there will inevitably be a restriction to the speed of passenger throughput in these locations regardless, as the security staff does require a certain amount of time to process each passenger and their belongings adequately to meet the regulation demands. However, the research team believed that there are steps which could be taken to alleviate these 'bottle necks' and that the result will be an environment in which there will be less demands placed on the security staff in relation to passenger/belongings/tray handling and therefore result in a more security biased system where the staff can concentrate on their primary role, to identify suspect passengers and illegally concealed items.

The main goal with this particular 'snapshot' ethnographic research programme was to identify, in a relatively short period of time, plausible* solutions which will enable the passenger screening security environment to function more efficiently and result in a more thorough screening process. We want to empower the staff to concentrate on the security issues and not be continually misappropriated with passenger/belonging/tray handling issues.

*The research team is fully aware of the financial constraints faced by many airports that have already recently invested in new scanning technology, security personnel training and cabin baggage handling equipment. Therefore, our main goal throughout this development programme is to advocate solutions which can not only be cost effective and relatively easy to install but will also be adaptable in other locations with a myriad of space and equipment configurations.

Concept Definition

As highlighted earlier there were three observations which related to two areas of concern, the physical management of the trays used for the X-Ray scanning procedure and the physical management of the pulsing of passengers which occurs more readily now due to online check in. Based on their ethnographic research findings the industrial design team now needed consolidate these observations into a single insight as they believed they were all intrinsically linked. This would result in a more efficient design thinking application to the problems identified but ultimately whatever insight was proposed would have to be vetted and cleared by the key stake holders. This sign off was achieved with the following considered statement;

Our Insight Statement

"The 'Undress/Redress' procedure and positioning is protracted and awkward which continually results in the inappropriate misuse of security staff resources."

Concept Direction Explanation

Once passengers are placed into a queue they are in a linear format with one behind the other and so on. Therefore, if one passenger is slower/less efficient (for any reason) than those behind them they will invariably 'hold up' the queue's progression and therefore its speed.

Firstly a system whereby the various passenger undressing/redressing speeds could be accommodated in a non linear and self regulating scenario. Then the queue would function at maximum efficiency and a pace could be set and maintained by the security staff and their requirements.

Secondly a system whereby the passengers do not queue and wait to undress but they actually undress while they queue. In effect the queuing procedure would then be dual functional. This would have a similar effect to concept one in that people arrive at the scanning equipment completely ready for the scanning procedure.

Concept One – Undress Self Regulated

At the heart of this concept is a designated undress and redress area and the intention here is to remove the 'bottle neck' from the scanning equipment both before and after and continuous need for security staff verbal prompts. We envisage the undress area being situated just as you pass through the first boarding pass security check, the passenger will walk directly into a segregated and glazed area. The glazed walls will enable staff to monitor all that is happening within and also inform passengers that they are now in 'preparation zone'. The redress area will be a series of coloured coded waist high benches separated from the scanning lanes where people will be instructed to remove their baskets to (See Figure 1); this will enable the throughput speed to be maintained by the scanner personnel.

The glazed room will have a rack of baskets on either side of its entrance clearly signed, the passengers will remove the basket they require and place it on a peripheral waist high bench which will run around the glazed wall of the area (See Figure 2). They will then undress as per usual and then in their own time (speed) make their way to the exit where a member of the security staff will ensure that they have correctly populated their basket before they are allowed to join a designated queue for the scanning procedure. The intent here is to create an area which will be seen as a 'preparation area' before entering the 'security area'; this should have a positive effect on their impression of the efficacy of the security procedures.

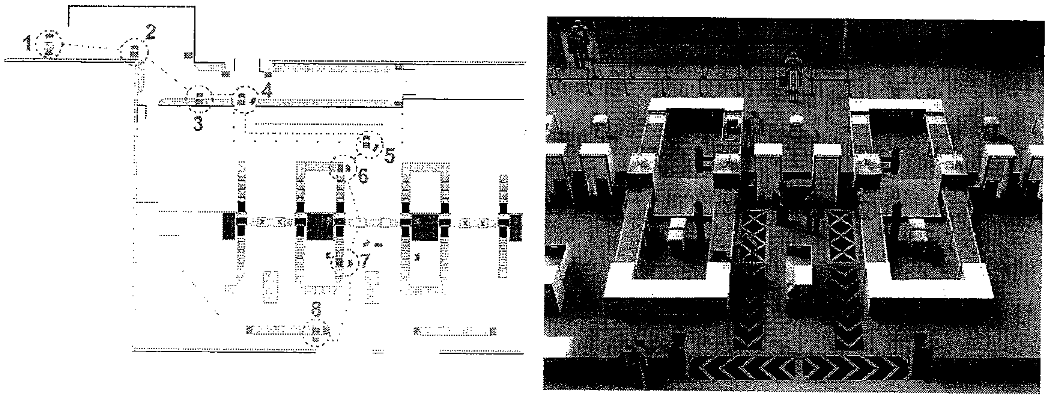


Figure 1. The 2D floor plan diagram & 3D view of security environment.

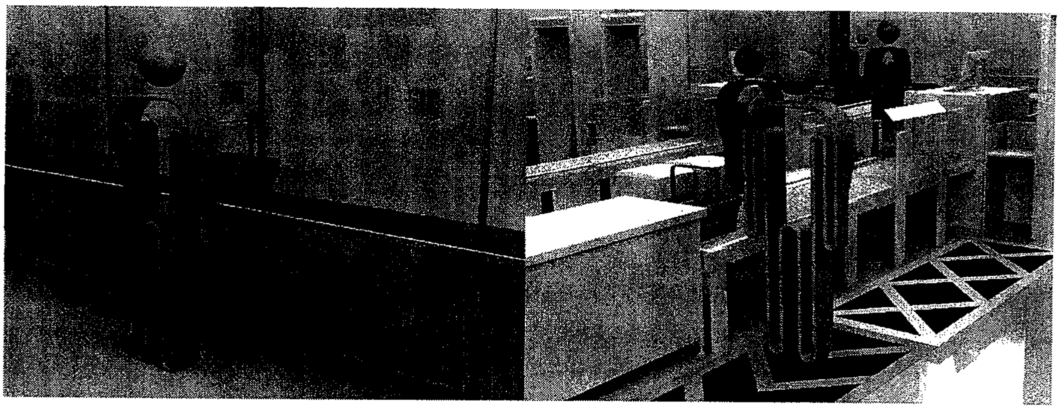


Figure 2. Passenger in undress area & exiting the scanning procedure.

Concept Two – Undress While You Queue

At the heart of this concept is a dual function queue/undress area and the intention here is to remove the 'bottle neck' from the scanning equipment both before and after and to alleviate the pressures and demands on staff to prepare passengers for scanning. We envisage this queue/undress area being situated just as you pass through the first boarding pass security check, the passenger will walk directly into a 'U' shaped glazed channel around which they can place their trays (See Image 4). This scenario is reminiscent of a self service style cafeteria where your trays can be pushed around the bench channel as you progress down the queue and while doing this the undressing procedure can be completed. The intent here is that all passengers being in a system where they are directed (simply by being in this new environment) to begin the undressing procedure before they reach the scanning equipment.

The redress area will simply consist of a series of colour coded islands (See Image 4) whereby more passengers can be accommodated as the trays and belongings can be withdrawn away from the scanner. The trays will also have a designated return rack system which will be clearly indicated. The intention here is that this too is completed by the passenger.

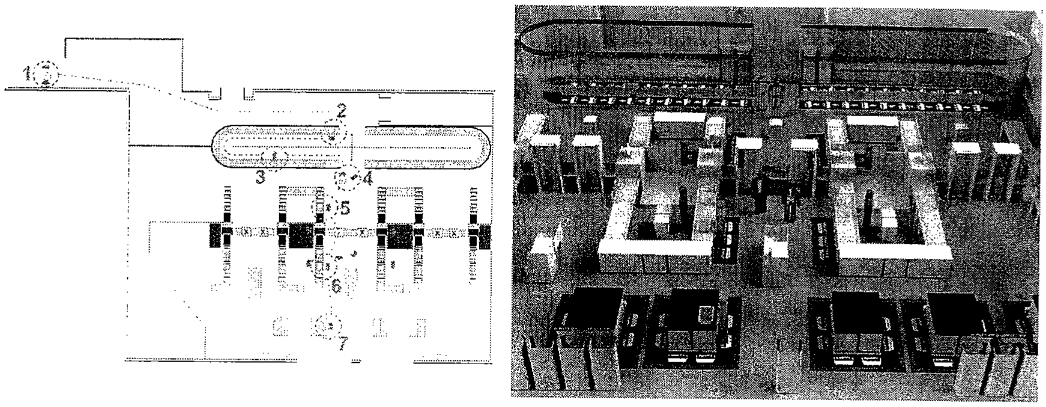


Figure 3. The 2D floor plan diagram & 3D view of security environment.

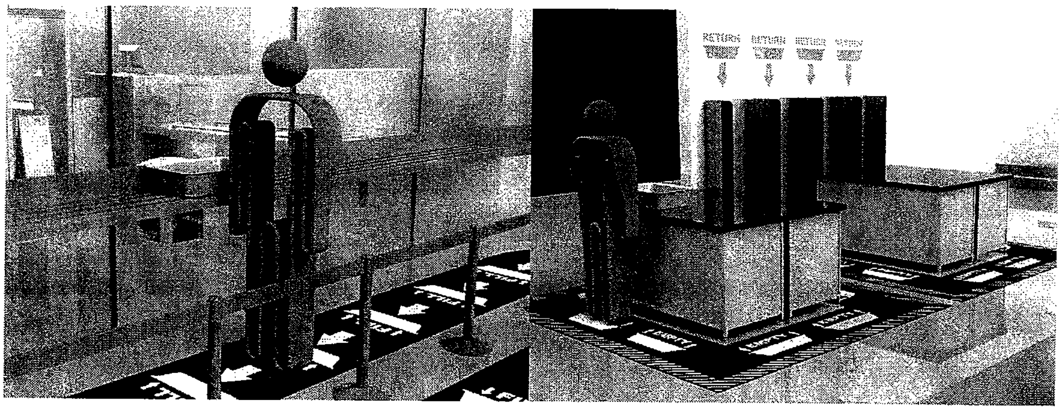


Figure 4. Passenger in 'undress while you queue' area & at the redress area.

Conclusion

Overall, the key stakeholders identified value in the enhanced security activities resulting from both concept directions and in particular the short term goal of making the proposals commercially viable for retro-fitting to existing scanning technology and security environments. All accepted that a direct result would be that their staff would be more focused on their primary role and that this would keep them more motivated and focused. Removing the manhandling of the trays away from the staff was seen as a definite plus but passenger education would need to be addressed in this regard. There was much support for the use of colour coding to help with the passenger flow and also tray/basket management, they prefer the concept of the passenger being responsible for their tray/basket. Directional mats and LED mats to guide the passenger were seen as a major benefit when combined with the designated and strongly identified redress areas. At the heart of each concept is a different tray and basket design and the internal laptop tray in Concept 1 combined with the shopping basket concept was acknowledged as clever but cost would have to be addressed (Image not included). Concept 2 had a simpler tray which had symbols on the bottom internal surface and these were likened to a checklist of sorts for the passenger and seen as a positive (Image not included).

Incorporating technology cultures from other sectors such as supermarkets and cafeterias was applauded as it is a 'known' methodology and therefore more easily understood by the passengers with less education required in situ. They all understand the core of the thinking behind each concept in that the design team wanted to remove the 'bottle neck' from directly before and after the scanner (as uncovered during the Ethnographic Research).

It is the design teams' belief that the designers/manufacturers of the scanning equipment have been solely focused on the tray handling issues and not those concerning the human beings using their systems whether they are operators or passengers. Therefore, they simply do not understand why or are aware of the 'bottle necks' which are forming prior to and after the scanning procedure. Also, there are architects and planners of airports who are not focusing on these issues because they simply do not know they exist or if they do it simply does not fall within their remit. Therefore, between both groups (those who design the spaces for security screening and those who design the scanning equipment which is situated in these spaces), no one is focussing on the Human Factor. As a result, the quality of the passenger's journey and the efficacy of the security staff will continue to suffer.

Preliminary Cost Savings Identified

The key stake holder in each of the locations have indicated that on paper the concept systems would appear to identify cost savings which could be achieved. However, it was recognised by all that pilot runs would need to be conducted to scientifically measure the effect which both systems would have, both on the passengers and the security staff.

The first major saving which was identified was that a member of staff (the loader) could be omitted from each of the scanning lanes as they would no longer be required to aid the passenger populate their trays. The substantial savings here could be used more effectively in other supporting security applications.

The second major saving which was identified but which could only be confirmed after the pilot run was that one lane could possibly be closed down. It was estimated that this could happen for four hours per day, four days per week during predicted slow periods and the estimated savings would be substantial (cannot be made public).

The third major saving was that they believe systems like these would prompt and remind passengers more effectively to present liquids in the correct manner and therefore they predicted a 50% reduction in the amount which they have to dispose of.

Finally Airport Operations (control the retail sector) have stated that they believe those passengers who exit the security scanning zone in an emotionally stressed condition purchase less or nothing at all in the retail sector before boarding their plane.

Acknowledgements

I would like to thank my team for this short but intensive work programme; Martin Bruggemann a senior Industrial Designer and Claire Shanahan a Researcher.

AN ERGONOMICS PRODUCTIVITY IMPROVEMENT TOOL FOR SHORT CYCLE REPETITIVE WORK

A. Finneran and L. O'Sullivan

Ergonomics Research Centre,
Department of Manufacturing and Operations Engineering,
University of Limerick,
Limerick

Abstract

MusculoSkeletal Disorders (MSDs) especially those of the upper limb are a common concern in modern industry. Physical risk factors such as force, posture and grip type are associated with the causation of MSDs. Limiting the effects of physical risk factors through ergonomic redesign have positive implications for operator discomfort, cost benefits, end product quality and improved productivity. The benefits of productivity are difficult to capture. Risk assessment methods and international standards contain no metric to capture productivity. Productivity is not easily captured in cost-benefit models, where productivity effects are often estimated through lost work days instead of on-site productivity limitations, meaning that actual productivity effects are often under-estimated. Qualitative metrics of on-site productivity loss are still in their infancy and do not offer a standardised metric of productivity loss. There is a need for a quantitative on-site productivity model to assess the benefits associated with ergonomic intervention. Quantitative models have several benefits including acting as a Key Performance Indicator (KPI), highlighting positive connotations of ergonomic interventions and providing a standardised metric of productivity.

1. Introduction

1.1 MusculoSkeletal Disorders (MSDs) and benefits of intervention

MusculoSkeletal Disorders (MSDs) are a prominent work-related health concern for modern industrialised nations (Waters, 2004). Across Europe and most of the industrialised world the most prevalent of all MSDs are those of the upper limb (Colombini and Occhipinti, 2006). It is generally accepted that physical risk factors force, posture, repetition, duration of exertion and grip type are associated with the causation of MSDs (Moore and Garg, 1995). Putz-Anderson (1988) highlighted that where physical risk factors are present in jobs, such as assembly and manual activity there is a risk of MSDs. A 1997 NIOSH report found evidence relating physical risk factors to the causation of MSDs, particularly where risk factors were reported in combination. Evidence from the literature highlights how ergonomic interventions have positive implications not only for operator well being and discomfort, but for end product quality improvements (Eklund, 1995); cost benefits (Oxenburgh et al, 2004) and productivity improvements (Hendrick, 2008). Productivity is an important indicator of both economic growth and social health. Productivity plays an important role in defining business opportunities in society and may also be used as an indicator of how healthy or unhealthy a population is. Productivity in relation to health may be defined in terms of absenteeism and presenteeism. Absenteeism reflects productivity losses for the worker physically not being present. On the other hand, presenteeism occurs where operators are present at work despite having symptoms that would warrant their absence (Meerding et al., 2005). In research there is generally a focus on absenteeism as productivity losses as lost days are easily quantifiable. However, it is estimated that 0.93% of all working hours are lost due to presenteeism.

1.2 Ergonomics cost benefit analysis

Estimating positive effects of a planned intervention could be helpful data in persuading management to initiate ergonomics programmes. As the benefits of ergonomic interventions are generally over and above initial cost savings it is felt that general economic and accounting tools are unable to capture the true benefits of ergonomic interventions. Various cost-benefit ergonomic tools have been developed to highlight the benefits of ergonomic interventions. For example the most well know of these models is Oxenburgh's productivity assessment tool (Oxenburgh et al., 2004). In a review of current cost-benefit models a worrying trend was noted in the way that productivity is captured, if at all. Goggings et al. (2008) highlighted that as productivity is a commonly reported benefit of ergonomic interventions it should be included as a metric in even the most basic of models. However, the authors also reported a wide range in productivity numbers, which appears to indicate that different organisations have different views on how productivity is reported. The problem appears to be that the models are at best estimates of the financial benefits an intervention would bring about and the difficulty lies in assigning cost to an operator's physical health and wellbeing (Mossink, 2002). Problems associated with estimation problems are often based solely on lost work days, however, Brouwer et al (2002) highlight that estimations based solely on absence may seriously under estimate productivity costs. Stewart et al. (2003) estimated that presenteeism accounted for 71% of the $226 billion worth of lost productive time per year. If there is a situation where there is difficulty estimating the costs associated with not implementing an intervention then there are in turn serious under-estimates of benefits gained from implementation.

Productivity is extremely difficult to estimate due to the lack of standardised metrics (Sennett, 2002). This is especially true for presenteeism where appropriate measurement tools are still in their infancy (Koopman et al., 2002). Brouwer et al. (2002) noted that there are a number of qualitative metrics and scales which have been used by various authors and organisations in an attempt to capture presenteeism and absenteeism health effects. Such metrics are essential to measure economic business competiveness. However, their estimates offer substantially different estimates of productivity effects and costs. Moreover, the scales are qualitative thereby limiting strength of predictions.. No quantitative metrics or scales capable of estimating the effects of presenteeism were found within the literature. One area where such a model would be highly beneficial is in assembly work where MSDs are a repercussion of badly designed tasks.

2. Model Development

2.1 Selection of Model Risk Factors

It is generally accepted that physical risk factors and their interactions are important factors in the causation of MSDs. Moreover, case studies have highlighted that work space and task design improvements which limit the effects of physical risk factors also improve productivity. It was clear that there was a link between physical risk factors, discomfort and operator productivity. At this stage, it appeared feasible that this relationship could be used as a basis for model development. The next stage of development was to decide which risk factors should be represented in the model. Several risk assessment methods are available in the literature and an overview of the risk factors assessed by a selection of these are summarised in Table 1.

The most commonly occurring risk factors in the methods investigated were intensity of exertion, posture and duration of exertion and on this basis it was decided that these risk factors would be included in the model development. Grip type did not occur as frequently as the other risk factors. However, it was noted in the literature review as an important risk factor in the causation of musculoskeletal disorders. Moreover, the interaction of grip type and posture during forceful exertions has further implications for the causation of MSDs. Wikstrom et al. (1991) highlighted a force-precision trade off between different grip types which implied that it may be difficult to alternate between grip types in a job and task design. It was also unclear whether different grip types would have different effects on the profile of operator performance. For these reasons it was decided that grip type would be included as a factor in the model. Repetition and rest/recovery time are also important in the causation of MSDs and are represented in several of the injury models investigated. However, they are temporal aspects which by their very nature are inter-related to industrial productivity and performance metrics. These factors could not be easily investigated in a productivity model. Instead, it was decided to make allowances for these factors in model development. It was decided that the model should deal specifically with the effects of repetitive tasks, thus allowing for repetition. Additionally, as identified in the literature review the model should use Duty Cycle Time (DCT) as a metric for output. Using DCT as a metric the model will focus on the non-rest part of work which would in turn benefit the overall cycle and operator discomfort and performance.

In conclusion, the following risk factors were included in model development:

1) Force (Duration and intensity of exertion).
2) Posture.
3) Grip type.
4)

Table 1 Risk factors evaluated in ergonomic risk assessment methods

	Risk factors					
Method	Duration of Exertion	Intensity of Exertion	Posture	Grip Type	Rest/Reco very	Repetition
RULA		√	√			
HAMA			√	√		
PLIBEL			√			
QEC	√	√	√			
Armstrong et al. (1982/6)		√		√		
PEO			√			
Strain Index	√	√	√		√	√
OCRA	√	√	√		√	√
ART	√	√	√		√	√
HAL		√				√
OWAS		√	√			
HandPak	√	√	√	√		√

2.2 Model structure

Four risk factors were found to be the most important in model development. At this stage it was decided to focus on the OCRA, Strain Index and QEC methods to assess further convention and risk assessment approaches. These task assessment methods are extensive and cover the majority of risk factors in the proposed model. Moreover, these methods have been extensively validated and have a high level of usability and sensitivity (Stanton et al., 2004). Focusing on the criteria and advantages of these methods, the following set of criteria were noted for the proposed model:

1) The method should be simple, quick and easy to use (QEC).
2) The method should be applicable to a variety of different work conditions (QEC).
3) Consider a wide variety of risk factors and their combinations (QEC, OCRA, SI).
4) Linked To motion study and time analysis (SI, OCRA).
5) Compare different work contexts (OCRA, SI).
6) Allow for pre and post intervention analysis (OCRA, SI).
7) The outcome should allow for risk scoring of a particular situation resulting in an outcome score (OCRA, SI).
8) The method has to be both valid and reliable (OCRA, SI, QEC).

The next step was to decide on model format and flow. The formation of the Strain Index offers a context for model development. The method allows the analyst to rate each risk factor separately and then to calculate a final risk score. On this basis it was decided that the model would have tables to allow for final risk scoring. However, as the method was to be based on technical actions and linked to motion study (see point 4 above) it was decided that an initial table was required to allow the analyst to evaluate a task and separate it into its fundamental movements. In addition, it was decided that the method would provide the information and data tables for model use. Prior to experimentation a series of industrial studies were completed prior to experimentation in order to establish typical risk factor levels and durations and to identify common grip types. This allowed the identification of risk factor levels to be catered for in experimentation.

3. Experimentation

In order to populate the model with data a series of psychophysical experiments were conducted investigating the relationship between physical risk factors, discomfort and productivity.

3.1 Experiment 1: The effects of force and posture on discomfort and productivity

Experiment one was completed to investigate the relationship between posture, force, discomfort and productivity. The analysis highlighted that both wrist posture and force have a significant effect on discomfort and productivity. In addition, similar trends across risk factors were illustrated for both discomfort and productivity Increasing levels of force and more deviated postures result in longer Self Paced Cycle Times (SPCT) i.e. lower levels of productivity. In a study investigating the effects of posture, duration and force on Maximum Acceptable Frequency (MAF), Klein and Fernandez (1997) also found that participants decreased their rate of work if their posture was more deviated as force increased.

It was concluded that Average SPCT values be calculated for the force and posture combinations across each of the three levels of initial repetition. These were converted to DCT percentages, a more accurate metric of productivity, and plotted against average discomfort at 10 minutes across each of the respective treatments. The data revealed a significant negative correlation ($r^2 = 0.77$, $p<0.05$).

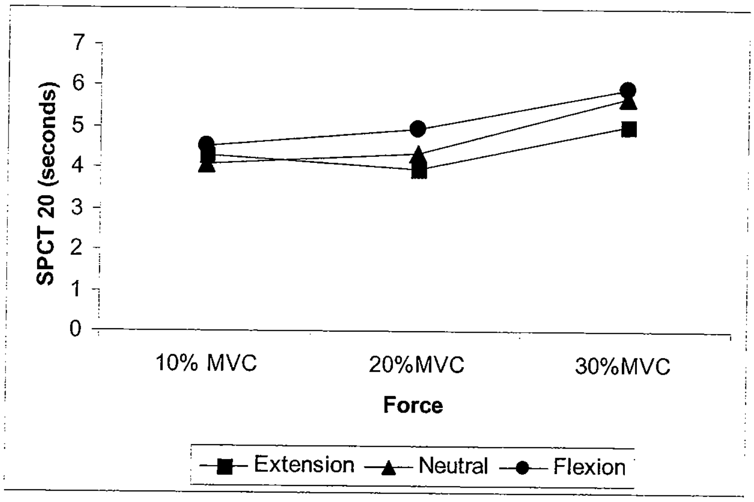


Figure 1 RAW SPCT at 20 minutes for force versus posture : Experiment 1

3.2 Experiment 2: The effects of force and exertion duration on discomfort and productivity

From this experiment onwards the dependent variable was Duty Cycle Time (DCT). For the subsequent modelling exercises it became apparnatn that DCT would be a better measure than SPCT as in Experiment 1.

Experiment 2 investigated the effects of force and duration of exertion on duty cycle time, where increasing levels of force and exertion period increased both discomfort and DCT. There was a decrease in active working time (DCT) as the level of force and exertion duration increased, as illustrated in Figure 2. Abu-Ali et al. (1996) conducted a psychophysical experiment to investigate work cycle parameters and assess safe exposure limits. Using the equation developed for DCT in the Abu-Ali study a profile of DCT over a set of force and exertion duration values was derived (Figure 3).

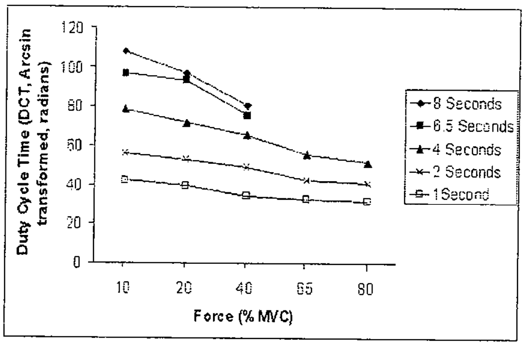


Figure 2 Average Transformed DCT data for Force versus Exertion Duration

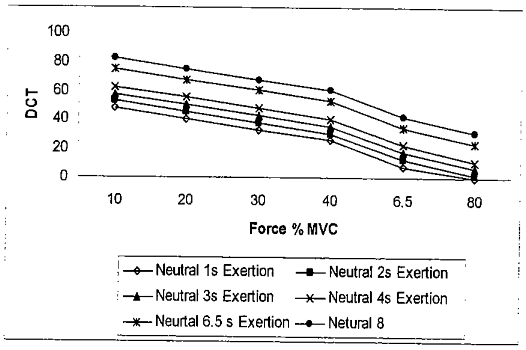


Figure 3 Study of work cycle parameters, Abu-Ali et al. (1996)

3.3 Experiment 4

A preceding short experiment (no 3 not reported here) highlighted the need to gather further data on the profile of DCT for precision grips as well as power grips. Experiment four was conducted to gather data and generate profiles of DCT for three separate grip types. In line with experiment one a decrease in DCT was found with a more deviated posture and higher levels of force (Figure 4 and Figure 5). The study also illustrated that more precise grip types had lower levels of DCT than power grip (Figure 4 and Figure 5). Potvin et al. (2006) investigated maximum acceptable forces for manual insertions using pulp pinch, oblique grasp and finger press. The study found that maximum acceptable force decreased at higher frequencies and with more precise grips (Figure 6).

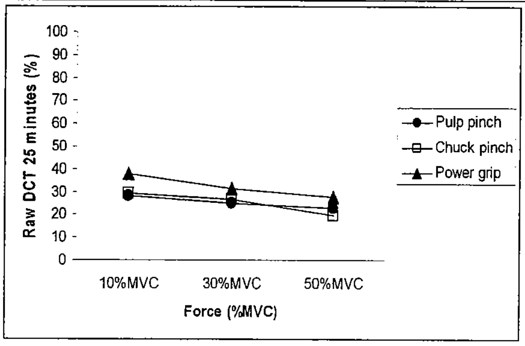


Figure 4 Raw DCT values at 25 minutes for force versus grip type

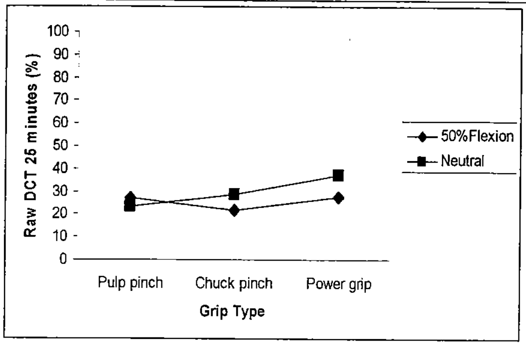


Figure 5 Raw DCT values at 25 minutes for grip type versus wrist posture

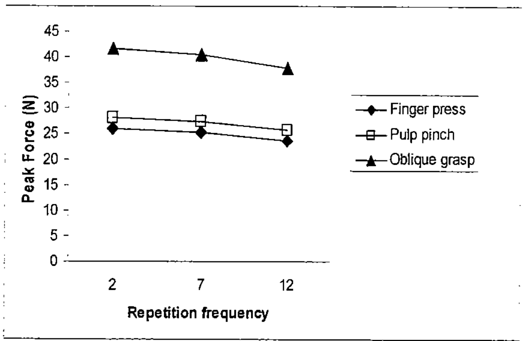


Figure 6 Potvin et al. (2006)

4. Statistical modelling and model population

4.1 Step one: Power Grip, Force and Exertion duration

All experimental productivity data were converted into DCT % for further statistical analysis. Raw DCT data from experiment one for neutral posture combinations and raw DCT data from experiment two were used to construct a linear regression model (Table 2) to predict DCT for power grip for force and exertion duration with a neutral posture. Findings from experiment two highlighted that force had a log linear relationship with DCT and that there was an interaction effect of force and exertion. Several attempts at modelling the data also highlighted that the squared transformation of the exertion period data was better. These interactions and transformations were included in the model development. The resultant regression model was used to populate the model section for power grip indicated in Figure 7.

Table 2 Equations used for model population

Grip type	Equation
Power Grip	22.84 - 5.48(LNForce) + 0.37(EXERTION^2) -0.228(LNFORCE(EXERTION^2)
Chuck Pinch	18.42 - 1.81(LNForce) + 0.39(EXERTION^2) -0.213(LNFORCE(EXERTION^2)
Pulp Pinch	14.52 - 1.46(LNForce) + 0.309(EXERTION^2) -0.213(LNFORCE(EXERTION^2)

*Force: % MVC
*Exertion: Seconds

4.2 Step two: Force, Exertion Duration, Chuck Pinch and Pulp Pinch

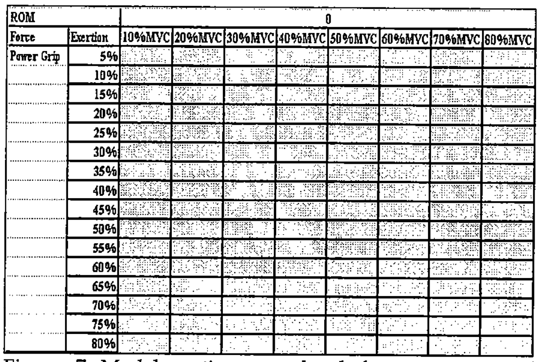
The next step was to populate the pulp and chuck pinch sections of the model using raw data from experiment 4. Using raw data from experiment 4 the profile of DCT over the three grip types for force at 2 seconds duration of exertion was investigated. While increasing levels of force had a similar effect across all grip types the magnitudes of the effects was not the same (Figure 8). Raw values of DCT were averaged and compared across the three levels of force and grip type examined in experiment 4 in order to effectively scale down the force multiplier for the chuck and pulp pinch regression equations.

4.3 Step three: Populate across model for posture

The next step was to populate across the model for each of the wrist posture deviations. Based on experiments one and four it was clear that deviated postures had an effect on DCT i.e. as wrist postures deviate there is a greater reduction in DCT because of increased discomfort. However, data gathered from experimentation was not sufficient to estimate performance changes due to deviated postures. Data from Fernandez et al. (1995) and experiment four (Table 3) were used to develop a regression equation (Figure 9) to estimate a series of multipliers which could be applied to existing values in the table to estimate percentage reduction in performance as postured became more deviated. Values used to develop the equation were transformed into DCT, where only repetition and duration of exertion were cited and the value at 0% ROM was taken as optimal for both data sets. Multipliers derived form the regression equation are shown in Table 4. Based on these multipliers it can be seen that if an operator were to deviate their wrist to 66% ROM they would only be 78% as productive in the alternative neutral combination. At this stage all of the cells in the model were populated.

4.4 Step four: Equate DCT values to performance decrements

At this stage the model was populated with percentage DCT values based on regression equations modelled on data from this work. However, the purpose of the model was not to give actual DCT values as these values are not easily generalised across different work situations. Instead the purpose of the model was to highlight performance decrements when tasks and work stations are designed away from optimal parameters. Based on results from the literature review and experimentation it was clear that lower levels of force, shorter exertion duration and more neutral postures gave optimal work conditions. As such the cell containing the DCT value for the 10% MVC, 5% Exertion Duration and 0% ROM was used as a reference for optimal productivity across grip types. The value in this cell was taken as 0 (no more design improvements could be made) and subsequent cell values were calculated based on decrements from this value.



ROM		0							
Force	Exertion	10%MVC	20%MVC	30%MVC	40%MVC	50%MVC	60%MVC	70%MVC	80%MVC
Power Grip	5%								
	10%								
	15%								
	20%								
	25%								
	30%								
	35%								
	40%								
	45%								
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	65%								
	70%								
	75%								
	80%								

Figure 7 Model section completed from step one of statistical modelling

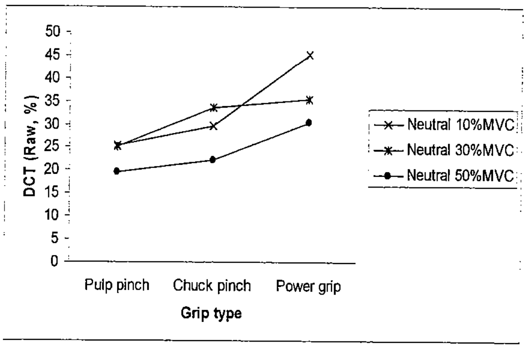

Figure 8 DCT profile of grip types for force and neutral posture: Experiment 4

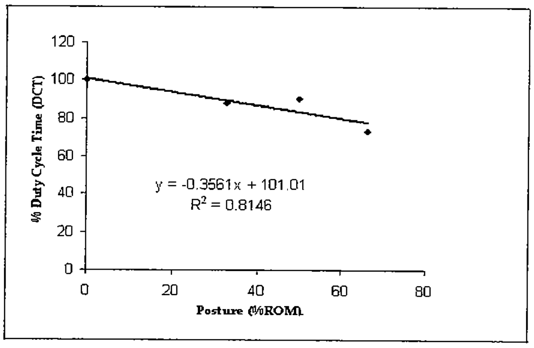

Figure 9 Scatter plot and regression model for postural multiplers

Table 3 Table of data used for regression model: postural multipliers

ROM	0%	33%	50%	66%			
Finneran	100	88	90	73			
ROM	0%	11%	22%	27%	33%	44%	55%
Fernandez	100	85	77	75	64.45	54.13	66.34

Table 4 Postural multipliers

%ROM	Multiplier
10	0.98
20	0.94
30	0.91
40	0.87
50	0.84
60	0.8
66	0.78

5. Discussion

As highlighted previously the prevalence of MSDs especially those of the upper limb is a common concern for modern, industrialised nations. The frequency of these disorders has implications not only for operator discomfort, but for several other factors such as, cost, end product quality and industrial productivity. Ergonomic interventions play an important role in limiting the effects of MSDs. In order to adequately capture the benefits of ergonomic interventions several cost-benefit models are presented in the literature. However, one major concern is the way in which these models capture productivity. Due to difficulty of capturing productivity, results may be generalised or focus on elements such as absenteeism. In general, there is a lack of coherence among these models as to how productivity is captured. Moreover, there is paucity in the data in relation to on-site productivity (presenteeism). The effects of presenteeism in relation to productivity are more prominent, but measures to capture presenteeism are still in their infancy and a quantitative model is not yet present.

A quantitative model to assess the presenteeism effects associated with MSDs has several benefits as illustrated below:

- Research in this area will augment data available in current literature.
- A quantitative model will emphasise positive conations of ergonomic interventions, by highlighting possible productivity improvements.
- A quantitative model is crucial in alleviating some of the problems associated with qualitative models such as generalisation of results.
- A quantitative model will aid analysts in the presentation of cost-benefits of ergonomic interventions where productivity benefits may be more comprehensively recognised and aptly estimated.
- Key Performance Indicator (KPI): Once an organisation has decided on its mission, identified stakeholders and defined its goals, there should be a way to measure these goals. KPIs are a way of measuring organisational goals. A trailing performance indicator may only be evaluated after an even has occurred, for example measuring health effects through lost work days. However, a leading indicator can be thought of as a predictor of future trends. A quantitative model may be used to estimate the benefits of one work station design over another predict productivity benefits.

Acknowledgement

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HUMAN FACTORS METHODS IN MANUVAR: A CONTRIBUTION TO GO BEYOND LEAND AND AGILE APPROACHES

M.C. Leva[1], P. M. Liston[1], A. M. Kay[1], S. Cromie[1], B. Krassi[2], S. Aromaa[2]
[1]*Trinity College, University of Dublin, Ireland*
[2]*VTT Technical Research Centre of Finland, Tekniikankatu 1, FIN-33101 Tampere, Finland*

Abstract

The ManuVAR project, funded under the European Union 7th Framework Programme, is a response to changes in the European manual-labour market. High-value, high-knowledge manual work is essential to European competitiveness – the assembly of satellites, maintenance of locomotives, operation of nuclear power plants, and testing of work-station design all require, and benefit from, manual work. Automation is neither a feasible nor an appropriate alternative to this type of manual work and in a bid to drive costs down there has been a movement towards outsourcing these activities to developing-nations where labour costs are lower but where reliability, quality and efficiency are more difficult to guarantee.

The ManuVAR project will use Virtual Reality (VR) and Augmented Reality (AR) to make high-value, high-knowledge manual work profitable and efficient in Europe by harnessing the potential of VR and AR to improve communication between people and systems; precluding the need to outsource. The ManuVAR project has four main stages: (i) identify industrial problems - targeting real issues for real organisations, (ii) develop innovative VR and AR solutions to these issues, (iii) demonstrate value for European industry, and (iv) produce a commercial tool to assist more European industries fight outsourcing.

The experience, intelligence and adaptability of the manual worker in many organisations provide the flexibility necessary to navigate a productive path through the competing forces of quality and efficiency. However, productivity and costs both need to be optimally managed for manual work to be a sustainable part of the European manufacturing industry. Over the past fifteen years or so, lean and agile principles and practices have underpinned operational improvement initiatives in many industrial sectors. The literature recently has been pointing out some of the limitations of Lean and Agile principles and applications some of which strictly relate to Human and Organizational factors. This paper aims to describe how HF methods in ManuVAR can contribute to support a product lifecycle beyond lean and agile approaches. The positive change on ergonomics, safety, work-assistance and training achieved as a result of using VR and AR to enable a two-way flow of knowledge it's aimed at having an effect throughout the product lifecycle of the manufacturing and service industry partners involved in the project. To do so Human Factors (HF) methods needs to be applied more systematically throughout the lifecycle widening their scope from design phase to cover the whole lifecycle. .

1 ManuVAR Overview

The ManuVAR project is an ongoing European Union 7th Framework project that is aimed at improving the reliability and efficiency of high-value manual work in Europe. Manufacturing industries in today's volatile commercial climate are frantically searching for ways to make substantial cost savings to maintain profitable businesses in an economic downturn. Labour costs are often one of the most expensive costs to a business and automation is one option to make cost savings. However sometimes it is not possible or appropriate to replace a human worker with a machine or a mechanised process, especially in Europe where manual work is not just a synonym for unskilled work. In Europe manual work is often high-skill and high-knowledge and automation would pose particular challenges. How can you develop or program a machine to remotely troubleshoot a maintenance issue on a locomotive? How can you build a machine which has to build unique and singularly delicate satellites? Would a machine be able to substitute the hand of a well-trained surgeon?

Outsourcing and/or off-shoring can offer companies that can't - or choose not to - automate their manual work the chance to make cost savings. For companies facing rising labour costs off-shoring and outsourcing to less industrially developed nations can seem like a panacea but these options are not without their disadvantages. While labour costs are undoubtedly lower in developing nations oftentimes so too are the reliability, quality and efficiency of the services provided or the products produced. Off-shoring and global outsourcing also bring with them problems and concerns such as increased lead-times and transportation costs, weaker management, and slower learning and adaptation.

The general objective of ManuVAR is to develop a technology platform and methodological framework for supporting high-value, high-knowledge manual work that cannot be automated or off-shored throughout the product lifecycle by enabling the bi-directional flow of knowledge, models and data and their reuse on the basis of Product Data Management and Product Lifecycle Management (PDM/PLM) and employing Virtual Reality and Augmented Reality (VR/AR) technology. The ManuVAR project, thus, can be seen as a proactive step towards exploring how to exploit VR/AR technology to improve the efficiency and reliability of high-value manual work in Europe.

1.2 High-value, High-knowledge work

The ManuVAR project can help to demonstrate how the high-value, high-knowledge manual work that characterizes the European manufacturing sector can be a strength and an opportunity to improve the competitiveness of European industries. The assembly of satellites, remote maintenance of locomotives, operation of nuclear power plants, and testing of work-station design all require, and benefit from, manual work. This type of manual work is high-value and high-knowledge – the outputs of the manual activities are critical to the overall operation of the company, produce value and require considerable skill, knowledge and experience to be produced. The experience, intelligence and adaptability of the manual worker in these organisations provide the flexibility necessary to navigate a productive path through the competing forces of quality and efficiency. However, productivity and costs both need to be optimally managed for manual work to be a sustainable part of the European manufacturing industry.

1.3 The clusters & Life-cycle focus

To this end the applied focus of the project is centred on five clusters, each of them located in a geographic area and developing a specific industrial case. The five case studies are in five different and diverse industrial areas but all will be based on the general ManuVAR platform and methodology thereby demonstrating the utility of the ManuVAR solutions in different industrial settings (ManuVAR Project website 2010). The five clusters are:

1. Terrestrial satellite assembly
2. Assembly line design
3. Remote maintenance of trains
4. Personnel training for maintenance of nuclear reactors
5. Large machine assembly process

The 5 cluster case-studies are also spread across the system lifecycle, in line with the project goal of optimizing the overall leanness and agility of the system as a whole – not just in manufacturing, but also design, operations, maintenance and recycling. System design, incorporating ergonomics, safety, usability, maintainability are all issues that impact on the productivity and capabilities of the person performing manual work, and as such must be borne in mind. Given that these activities occur at times and locations remote from manufacturing the ManuVAR project has chosen clusters that also represent the spectrum of the system lifecycle (Aromaa et al 2010).

Table 1 plots the five clusters along the system lifecycle and demonstrates the aspects of manual work supported by the cluster. The clusters are designed to collectively cover the system lifecycle and provide a complete representation of all manual work categories.

Table 1: Clusters represented according to manual-work support offered and system-lifecycle stage represented

		Lifecycle				
		Design	**Assembly / Manufacturing**	**Maintenance / Service**	**End of life**	**Customer relations / Sales**
Manual work support	**Work planning**	*Cluster 4* *Cluster 1* *Cluster 5*	*Cluster 1* *Cluster 5*	*Cluster 4*		*Cluster 2*
	Work testing	*Cluster 1* *Cluster5*	*Cluster 1* *Cluster 5*	*Cluster 5*		*Cluster 2*
	Training	*Cluster 2*	*Cluster 1*	*Cluster 4* *Cluster 3*		
	Work support	*Cluster 2*	*Cluster 1* *Cluster 5*	*Cluster 5*	*Cluster 3*	

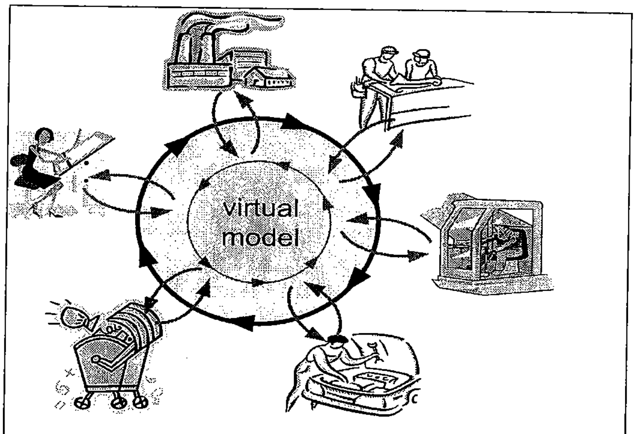

Fig.1. ManuVAR bi-directional knowledge flow concept (Manuvar 2008)

In addition to the life-cycle focus the project has a bi-directional knowledge flow, whereby the Virtual Model (VM) can be fed with essential knowledge that is produced during the lifecycle stages without it having to be propagated throughout the lifecycle on a unidirectional basis, thereby linking all actors along the lifecycle to the VM (see Fig.1).

2 Requirements and needs in industrial lifecycle. How can Human Factors help?

2.1 Lean and Agile methods in industrial lifecycle

Over the past fifteen years or so, lean principles and practices have underpinned operational improvement initiatives in many industrial sectors (Womack and Jones, 1996; Liker, 1997). The term "lean" was first used to describe the application of Japanese manufacturing techniques in the automotive sector (Womack et al 1990). In essence, lean manufacturing aims to enhance customer value and improve quality while reducing time to market, lead times, inventory levels and, ultimately, total life-cycle costs.
Similarly the problem of how organisations can successfully deal with unpredictable, dynamic, and constantly changing environments has also lead, in the beginning of the 1990s, to a new emerging concept: agility.
The difference between Lean and agile can be best described by Sanchez and Nagi (2001) when they state that "lean manufacturing is a collection of operational techniques focused on productive use of resources, whereas agility is an overall strategy".
The authors of "agility" concept at the Iacocca Institute, of Lehigh University (USA) defined it as: "A manufacturing system with capabilities (hard and soft technologies, human resources, educated management, information) to meet the rapidly changing needs of the marketplace (speed, flexibility, customers, competitors, suppliers, infrastructure, responsiveness) " (Yusuf et al., 1999).
The literature recently has been pointing out some of the limitations of Lean and Agile principles and applications some of which strictly relate to Human and Organizational factors. As early as 1992 Consumano pointed out that:

"One of the brilliant contributions of Toyota managers such as Ohno Taiichi, inventor of the kanban system and director of manufacturing operations at Toyota during the formative years of its system from the 1950s the rough the 1970s, was to view automation with scepticism. Automation, unless it was flexible in a physical or programmable sense, introduced rigidity into production processes and was not suitable for labour-intensive assembly operations. As a result, Toyota introduced transfer machinery cautiously and introduced robots in large numbers only in the 1980s, after they had become programmable and reliable. Instead, Toyota relied on relatively well-trained workers and gave them relatively broad responsibilities, including the task of doing much of their own inspection, preventive maintenance, and janitorial work."

However the labour shortage and the high cost made it necessary for Toyota to adopt a change in strategy and tactics, but as pointed out by Coffey and Thornley (2006) "Toyota's most thorough-going experiment with automation in the late 1980s proved disappointing. The "technically sophisticated" line at Toyota, struggled to achieve the production volumes needed to justify this capital expenditure".

Further the great Japanese assembler experienced difficulties in recruiting assembly line operatives sufficiently motivated to work in its factories. Since then the focus has been placed on "segmentation of the assembly line from the viewpoint of better managing the manual component, with in-process buffers absorbing the temporary effects of stoppages on any single segment without stopping the entire process". (Coffey and Thornley 2006).

Some other limitations of Lean are that it uses simple problem solving tools which may not be suitable for chronic problems and that embedding the Lean way of working into the culture can take several years and requires constant support and guidance from management. Therefore the need to support a culture of change and change management which is an issue Human and Organizational factors approach have often confronted in the past.

On the other hand Agile Manufacturing frameworks make an attempt to present a more integrated and holistic model, but they still presents a view mostly focused on production and the technological aspects of enterprise. Moreover, most agility-related publications are focused on the theoretical descriptions of agility and agility frameworks. Only few of those metrics and frameworks were investigated in empirical research. (Sherehiy et al 2007)

As pointed out by Sherehiy et al (2007) a range of attributes that are believed to be associated with workforce agility has been identified. However, there is a lack of studies that empirically investigate and determine the attributes of the workforce. The agility research has mainly considered the agile workforce from the operations and work shop floor perspective. At present the literature on workforce agility is rather limited (Sherehiy et al 2007).

Furthermore, the drive to integrate operations management with safety management, and in particular aligning lean operations or agile strategies with human factors management, is an innovative vision for many industrial sectors (aviation, process industry etc.). In the past, operations and safety requirements have often been viewed as a trade-off, i.e. reduced costs will lead to increased safety risks. However, in the current environment, it is essential that both operational and safety improvements can be achieved simultaneously, the common ground of management of change, or better techniques for training and information sharing for skilful workers required for both agile and lean interventions, together with the evaluation of suitable metrics to support the analysis and the empirical research, is an example of an area where human and organisational factors approaches can provide a fruitful contribution.

2.2 Practical needs highlighted in ManuVAR to go beyond Lean and Agile methods.

In the Manuvar Cluster examples it is possible to find some of the limitations already mentioned in the literature for both Lean and Agile manufacturing methods, and those limitations often

constitute the needs for ManuVAR Interventions. In the case study about train maintenance for instance the need to have an agile approach for remote train maintenance starts from the need to have an integrated and skilful team to deal with maintenance intervention, but this is very difficult when the issue relates to one of the Agile propositions: "Team self-organization" if the tasks the team have to deal with can be across 5 sites maybe in different countries.
Another Lean problem is presented in Cluster 4, where a lean structure is kept for the main people dealing with a highly skilled maintenance intervention (i.e. a Metallographic replica). However during peak requests there is the need to effectively and efficiently train more people for the job in a very short time. This is not easy since the task requires a certain amount of experience to be efficiently carried out.
Furthermore, in identifying the needs connected with Cluster 2- assembly line design - in terms of sustained productivity and flexibility (product and volume flexibility), it was highlighted that assembly companies may well profit from the design of flexible and ergonomic work stations and intelligent operator support systems. Until now however, the practical application of this technology lags behind. The reasons might be that:

- the financial and other benefits of application (e.g. productivity, less fatigue, worker satisfaction) are largely unknown,
- the design (VR and AR) tools to be used for assembly workstation design are unknown, not complete or too complex/expensive for SME,
- there is no data exchange between operational use of workstations and simulation/ design stage of workstations and vice versa.

Given that knowledge is essential for operations management & safety management, the integration of these activities requires sophisticated and effective knowledge management mechanisms. The knowledge management literature stresses the importance of both codification and personalisation strategies for managing knowledge (Maier and Remus, 2003; Schonstrom, 2005). Technology-based systems are suitable for the codification of knowledge, i.e. the capture of explicit knowledge. However, technology-based systems alone are not adequate for effective knowledge management, with technology-oriented approaches often failing (Lam and Chua, 2005). While information technology (IT) systems are useful for data and information capture, and knowledge sharing to some extent, tacit knowledge is very difficult to transfer by means of a technological solution (Swan et al, 1999). Personalisation strategies for knowledge management involve creating an environment for social interactions to complement an IT-based system (Maier and Remus, 2003). Networks and the correct ethnographic setting of those IT solutions are, therefore, critical for knowledge management and innovation (Swan et al, 1999; Buchel and Raub, 2002; Schonstrom, 2005).

3 The ManuVAR HF Methodological Framework

The ManuVAR project has four main stages where HF approaches needs to be used to realize the actual potential of technology applications (VR/AR) to go beyond current conception of lean and agile in assisting product Lifecycle. Those four stages are: (i) identify industrial problems - targeting real issues for real organisations, (ii) develop innovative VR and AR solutions to these issues, (iii) demonstrate value for European industry, and (iv) produce a commercial tool to assist more European industries fight outsourcing.
To assist those four stages an array of selected HF methods and tools for applying the ManuVAR system (PLM model, Application Tools, Virtual Model) has been identified. There are different kind of requirements and needs to be considered when integrating and choosing HF

methods for the ManuVAR PLM model. The process starts by collecting those requirements from the end users and also the state-of-the-art research.

As a result from the requirements of ManuVAR goals, gaps, cluster cases, technology applications and impact levels, the array of HF methods and tools were organized into four thematic areas (Figure 2):

1. Manage requirements (ISO 13407)
2. Support workplace/task design (plant)
3. Evaluate actual situation and get feedback (actual output of a planned or a working system)
4. Support training and sharing of information (feedback loop).

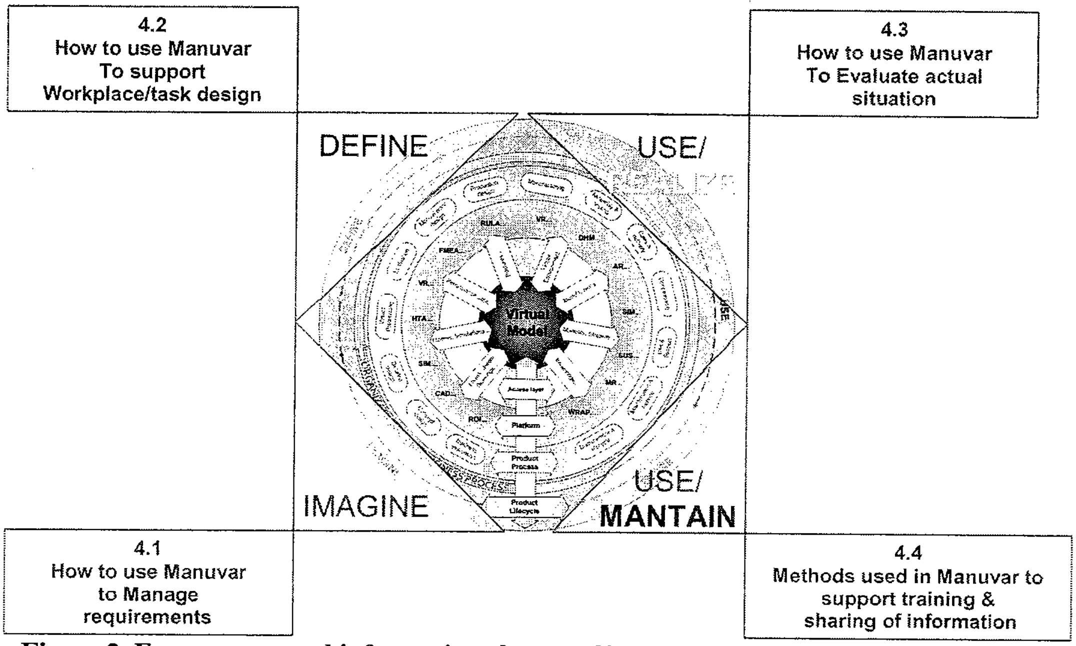

Figure 2. Four groups and information change of human factors methods in ManuVAR product lifecycle management model (Leva 2010).

The first group, manage requirements, includes methods that establish requirements coming from human (e.g. physical, mental), tasks, tools, environment, organisation, business and legislation and also from the product (e.g. from previous generations). It is good to remember that all requirements discussed here are human related and other requirements e.g. technical are not included here. The second group concentrates on design support and includes methods that correspond to workplace design, task design and production design needs. The third group highlights the importance of getting evaluation and feedback from the real users and actors across the whole lifecycle. It focuses on actual situations either in the real world or in Virtual Environment (VE). The fourth group supports training and sharing of information and means methods that deliver work instructions, support motivation and provide training (off-line). The four groups together cover the system lifecycle and also the sharing of information, but they are not in a certain order or time-line of use (Aroma et al 2010).

From the cluster cases it is possible to highlight a few examples of how integration of HF method in ManuVAR could affect an industrial lifecycle at different levels:

- At the individual and organizational level ManuVAR should support training for knowledge and skill acquisition that is normally acquired on the job and after many years of experience, speeding up the process. A ManuVAR tool could also provide solutions for task support that may improve the performance at individual and organisational level (easy accessibility of required documentation in a paper free and user friendly format and remote assistance).
- At a sectoral level ManuVAR technology can be used to support the design stage of a process or of an assembly line, further it can also be used to support the planning stage of safety critical tasks across multiple organizations
- At the organisational level some of the possible benefits can also be transferred then to a wider audience of complex operations industry (Wider impact). The solutions to be developed for supporting a meaningful way of storing knowledge can have a high level of transferability to other similar contexts. For example the availability of a 3D model for a plant accessed on repeated occasions could support a clever way of storing information about places where interventions have been previously realised that can be marked in the VR simulation and documented. The operator could use this to see where tests have previously been performed, and if there are any comments and/or results. Or in some case ManuVAR is currently studying a system to store knowledge about successful troubleshooting performed on non-routine tasks, to be made available for further consultation by the workforce whenever needed. Both approaches could easily be transferred to industrial contexts different to those that they have been generated for.

The ManuVAR HF Framework is intended to support also the phases needed to develop an application able to respond to the problem statement(s) identified (Krassi 2010), those phases start from capturing the problem (industrial case) and cover all the subsequent necessary steps such as:

(1) Manage requirements (e.g.: crucial point: identification of improvements areas and definition of the scope of it: What is to be actively modelled in terms of plant, process, task, etc.).

(2) Support design (e.g. definition of desired level of detail (granularity), for goals HMI and communication interactions)

(3) Evaluate actual situation and get feedback (e.g. preparation of a reusable template for testing and evaluation of VR/AR solution: Measurement of established goal such as: is the production, training time improved? Accuracy? etc).

(4) Support training and sharing of information. This procedure needs to be structured in such a way to make the experiment repeatable for end users and facilitate the processes of transfer of knowledge.

The framework stems also from the consideration that manufacturing does not just deliver technology for sale, but has to provide a system (or, more accurately, part of an operational system) and this has to deliver operability (it has to work better, in all its system functions, than its competitor's system). New systems and new technologies do not just change the jobs that people do – they can modify the whole process (McDonald 2009). It is this process transformation which delivers the step change in operability. Therefore the manufacturer has not only to engage with the Human-Machine-Interface, but also with how the technology fits into and facilitates the whole operational system. In this sense particular emphasis in ManuVAR is placed also on training. ManuVAR gives the training developers the chance to influence and guide the requirements gathering process such that subtle training issues can be explored and investigated. In specifying the case studies that will be modelled in the VE, the use of ethnographic methods further serves to strengthen the chances of successful implementation of the ManuVAR training solution in end-user organisations by ensuring the content and face validity of the training programs (Liston et al 2009).

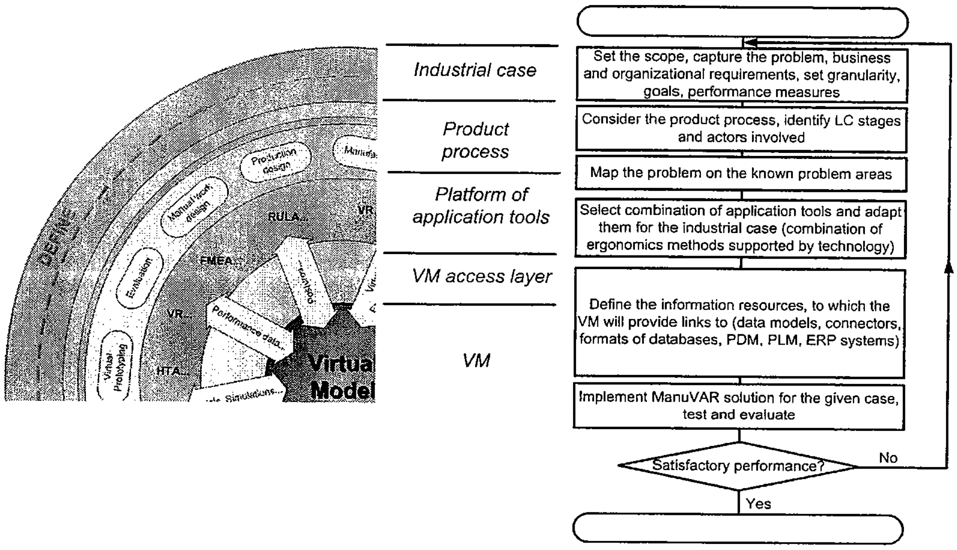

FIGURE 3. ManuVAR methodology (the flowchart) as a "vertical" projection of the PLM model (Krassi et al. 2010)

4 Conclusions

There are wide-ranging practical and theoretical implications for research being conducted in such a diverse innovation network with close collaboration between industrial and research partners. The activities of the Manuvar network have the potential to radically transform the way manual work is supported in the future. This has significant implications at a variety of levels:

- Individual employee level – improved working practices, procedures and conditions; enhanced usability of and accessibility to products for operations and maintenance
- Organisational level – reduced costs; better knowledge and risk management; increased levels of innovation; reduced numbers of safety-related incidents; better process orientation; improved operational performance
- Sectoral level – improved safety; lower life-cycle costs; improved productivity and competitiveness; faster system-wide diffusion of innovation
- Wider impact – applicability of approach to other complex, safety-critical industrial environments.

However, this will require overcoming practical challenges including the development of a common vision across all stakeholders within the network, and across disciplines in the research team, and the implementation of effective knowledge sharing mechanisms at both organisational and sectoral level.

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THE ENVISIONMENT AND DESIGN OF AN ELECTRONIC BRIEFING TOOL

Joan Cahill, Nick Mc Donald and Gabriel Losa

Aerospace Psychology Research Group,
School of Psychology,
Trinity College Dublin
Dublin

Abstract

This paper reports on research conducted as part of the Human Integration into the Lifecycle of Airline Systems (HILAS) project, related to the design of a new electronic briefing tool, assisting Flight Crew performance of the pre-flight, flight planning and briefing task. Specifically, this paper focuses on the methodological approach adopted in this research. The overall purpose of this paper is to illustrate the requirement to extend formal Human Computer Interaction (HCI) design methods, for the purpose of new tool envisionment, design and evaluation.

Introduction

This paper focuses on the application of a range of design methods, to support the envisionment, design and evaluation of a new electronic briefing tool, embedded in the Flight Operations process. The overall purpose is to demonstrate the requirement to integrate several different methods, for the purpose of new task and tool envisionment. Three phases of research were undertaken, spanning six related studies. Collectively, these studies focussed on understanding the nature of the Flight Crew task (both generally and in relation to the specific pre flight, flight briefing and planning task), for the purpose of identifying the requirements for improved pre-flight, briefing tools. Methods include process modelling, task analysis, collaborative prototyping and evaluation of new tool concepts and underlying process redesign requirements, and implementation workshops. This research was conducted as part of work requirements of HILAS project, sponsored by the European Commission.

First a background to the briefing task and Human Computer Interaction (HCI) methods is provided. Following this, the specific methodological approach is presented. A summary overview of the emerging HCI design solution is then provided. Research methods are then discussed. Lastly, some preliminary conclusions are outlined.

Background

Briefing task and design requirement

A safe flight starts with effective performance of the pre-flight flight planning and briefing task. However, several problems related to the execution of this task can be identified. Despite the importance of this task, and the existence of specific task problems, there seems little attention on this task. In general, the literature provides minimal information about this task and Flight Crew usage of the flight plan. Although Flight Operations manuals provide a normative description of this task, these descriptions are quite high level. The Crew Resource Management (CRM) literature confers sense on the role of briefing in terms of fostering teamwork and situation awareness, along with supporting workload management (Cooper, White and Lauber, 1980). However, it does not provide concrete information about the nature of the pre-flight, flight planning and briefing task. Further, specific problems related to the execution of this task are not discussed. Many new tools have been introduced into commercial cockpits. Nonetheless, to date new tool development has not focussed on ameliorating the task problems outlined earlier, and/or making improvements to the existing flight plan. Potentially, the introduction of an electronic flight plan provides an opportunity to improve the quality and availability of information provided to Flight Crew, thereby enhancing the quality of crew briefings. Overall, this will impact positively on the operational and safety outcome of the flight.

Socio-technical systems theory

Hutchins 'distributed cognition' theory, investigates certain aspects of the man machine relationship in socio-technical contexts (1995a). Hutchins contends that cognitive activity is constructed from both internal (e.g. cognitive acts) and external resources (e.g. social interaction with others, artefacts/tools, structure of the environment and so forth) (Hutchins, 1995a, 1995b). As such, operator performance must be understood in relation to the situated social context in which the activity occurs. To this end, Hutchins proposes the use of participant observation.

Mc Donald (2005, 2006) distinguishes two related aspects of the operational process: the functional process and the social process. In Mc Donald's analysis (2005, 2006), the functional process refers to the transformation of inputs into outputs. The social process refers to the relationship between different system operators. This includes communication and co-ordination mechanisms, informal workarounds and so forth. It is argued that the quality of social relations has an impact on the overall operational outcome and specifically, contributes to the stability of the system (Mc Donald, 1999, Mc Donald, 2006, Morrison, 2007). Therefore, to be successful, new process and tool design must optimise these underlying 'social process' mechanisms (Mc Donald, 1999, 2005, Mc Donald, 2006, Morrison, 2007).

Task performance is often constrained by process design (Mc Donald, 1999, 2006). Therefore, to understand human performance, and how it can be improved, we must start with model of the existing process. Specifically, this model should elucidate the relationship between task and process, and in particular, the collaborative work requirements of the process (including social process dimensions). From a methodological perspective, this creates a requirement for process modelling. As outlined by Morrison, such approaches have been successfully utilized to identify the role of technology in improved operational processes (2007, 2009).

Human Computer Interaction Design Methods

According to HCI theorists, the design of human friendly technology involves adopting a 'user centered design' methodology (Preece, Rogers and Sharp, 2002, Constantine and Lockwood, 1999, Hackos and Reddish, 1998). The HCI literature defines a range of formal and informal methods for this. The specific approaches adopted reflect underlying theoretical assumptions about design practice. In particular, they represent diverse views concerning the role of end users, the specific process for envisioning new technology requirements, and the relationships between design and evaluation.

Typically, formal methods start with analysing the existing task (Preece et al, 2002). To this end, a task analysis is first undertaken, involving the participation of end users. Structured or semi-structured interviews are used to understand and evaluate current work practices and supporting technology requirements (Hackos and Redish, 1998). Several analysis steps are then undertaken without the participation of end users. Analysis outputs include lists of end users, user and task matrices and task workflow diagrams. This is followed by different design activities such as storyboarding and prototyping. Once the prototype is developed, users are involved in different evaluation activities. In this way, design and evaluation are conceived as separate steps.

Formal HCI methods have been the subject of much debate in the HCI literature. Specific challenges have come from the fields of Ethnography and Participatory Design. Ethnographers argue that classical HCI methods do not take work practice seriously; failing to address the social aspects of work (Hutchins 1995, Vicente 1999). Participatory design theorists have questioned the separation between design and evaluation in formal methods (Bødker and Buur, 2002). Specifically, they have challenged the instructiveness of traditional user and task analysis outputs for design guidance.

Central to Participatory Design theory is the idea that Usability Engineers design 'with' end users, as opposed to 'for' them. Accordingly, users are active participants in the design process (Bannon and Bødker, 1991, Bødker and Grønbæk, 1996). Several techniques are outlined in the literature. This includes concept generation, envisionment exercises, scenario role playing, story collecting and story telling (through text, photography and drama), and the co-creation and evaluation of prototypes. According to participatory theorists, new tools cannot be designed on the basis of existing task and information models alone. Rather, we must also consider the opportunity afforded by new technology to change/improve existing processes and task practices (Bødker, S. & Burr, J. 2002; Carroll, 1995, 2000; Muller 1991, 1993, 2003). Further, it is argued that users need to have the experience of being in the future use situation, or an approximation of it, in order to be able to comment on the advantages and disadvantages of the proposed system. Thus, some form of mock-up or prototype needs to be built in order to let users know what the future use situation might be (Bannon, 1991, Bannon and Bødker, 1991). Accordingly, in this approach, requirements gathering/task analysis, design and evaluation linked.

Research Objectives & Methodology

Research Objectives and Methodological Approach

The research objectives include:

- To understand the current task, existing tool usage and task facilitators and blockers
- To envision a new way of performing this task and associated new tool requirements
- To model and evaluate a user interface and workflow for the proposed new tool concept
- To identify the underlying process re-design requirements necessary to the implementation of the new tool at the airline, and to identify any potential implementation barriers

Overall, a user centred design approach was adopted. The methodology integrates formal HCI methods (e.g. user interviews), Ethnographic methods (e.g. user observation), Participatory Design methods (e.g. envisionment of new task practices/tool requirements, and collaborative prototyping and evaluation), and methods used in Organisational Ergonomics field (e.g. process mapping). High level field research was conducted with five partner airlines, while more detailed research was conducted with two airlines – hereafter referred to as airline two and five. This involved three phases of research, spanning six related studies. These studies were conducted over a four year period, from May 2005 to September 2009. A task analysis was first undertaken. This research comprises studies One, Two, Three and the first part of Study Four. This set the stage for the participatory design of the new electronic briefing tool (e.g. collaborative prototyping and evaluation activities), which formed the second phase of research.

This involved three sequential stages of research encompassing the second half of Study Four, Study Five and the first part of Study Six. The third phase of research focused on specifying the underlying operational and organisational processes necessary to the implementation of the new electronic briefing tool at airline five, and potential implementation barriers. This research was undertaken in Study Six.

Overview of Studies

The first study involved a high level examination of the Flight Crew task, in the context of the Active Flight Operations process. As part of this, this study focused on the development of a high level model of the overall Flight Crew task, along with a specific model of the briefing task. Other processes that impinge on Flight Crew task performance were also examined, albeit at a high level. This study also involved a preliminary examination of existing airline performance monitoring/safety management methods and tools. First the researcher reviewed relevant Flight Operations documents. Following this, process mapping workshops were conducted with five partner airlines. Overall, this involved forty two participants - sixteen Pilots, six Maintenance Engineers, three Ground Operations representatives, one Flight Operations representative, three Dispatchers and seven personnel involved in airline safety management activities.

The second study focused on the flight planning process. The objective was to produce a high level map of the flight planning process and specifically, to map the pre flight, flight planning and briefing task, in the context of this process. Seven participants, reflecting a spread of relevant functions (e.g. Flight Planning, Dispatch, Flight Operations Control), were interviewed. Further, four observations were undertaken, including both Dispatch and Flight Operations Control functions. Also, the Researcher conducted additional observations/interviews with three Flight Operations Control representatives. This research was conducted with airlines two and five.

The third study follows up on certain of the issues raised in the first study, concerning the relationship between the Flight Crew task and the broader Safety/Quality/Improvement process. Specifically, it examined the broader safety management process, of which performance monitoring activities and CRM training activities form a part. This included: (1) a high level study of airline performance management methods and tools, conducted with airlines two, three and five, (2) follow up research conducted with Airline two, in relation to the airline's Line Operations Safety Audit (LOSA) evaluation and an analysis of a specific flight scenario, and (3) follow up research conducted with Airline five, in relation to the airlines CRM training programme, and new tools developed by the airline. As part of this, the researcher analysed relevant process descriptions, safety material, CRM training material and specific safety reports. User interviews were conducted with twenty five participants – reflecting a spread of functions including, Safety, Risk Management, Fleet Captains/Training, Documents/Procedures Design and CRM Training. Further, the researcher observed a CRM session.

The fourth study entailed a more detailed analysis of Flight Crew task performance. Overall, this comprises two phases of research. In the first phase, the researcher endeavoured to validate the findings of the first study in relation to the emerging Flight Crew task models. Also, a more detailed investigation of briefing task was undertaken. As part of this, the Researcher conducted a walkthrough of the briefing task, observed two pre flight briefing sessions, conducted two interviews with Flight Operations participants and rode jump-seat on seven flights, with crew from airlines two and five. The second phase of the task analysis involved a more detailed analysis of the pre flight, flight planning and briefing task. In so doing, the Researcher conducted six semi-structured interviews with Flight Crew participants from airline five. Participants were asked questions related to task roles and co-ordination, task workflow and adherence to procedures, task information requirements, information gaps, information sources, information classification and priority, specific use of tools and information resources, task facilitators and blockers, and task errors. Further, the Researcher questioned Flight Crew participants about tool problems and requirements. Following this, the Researcher conducted a preliminary envisionment exercise. Participants were invited to consider how the existing briefing task might change given introduction of new tools. Participants were then invited to draw high level concepts for improved tool user interfaces, using a pencil and paper. The researcher also drew certain concepts using a pencil and paper, to assist problem solving and communicate/share design ideas with participants.

The fifth study involved the participatory modelling of the new briefing tool – termed the Intelligent Flight Plan (IFP). Three phases of research were undertaken. In the first phase, the researcher analysed and specified the emerging tool requirements. These requirements were translated into a series of future task scenarios. High level prototypes were then developed. Following this, these prototypes were further specified and evaluated, using collaborative prototyping and evaluation techniques. This was structured in terms of two phases of participatory research, involving fifteen Pilots from airline five. The research design involved the integration of technology envisionment and collaborative prototyping approaches defined by Muller (1991) and Bodker (1985, 2002), with the future use scenario based design approach proposed by Carroll (1995, 2000). Prototype screens were used as a basis from which to establish more detailed requirements concerning task workflows, information requirements and information structure and presentation.

The sixth study followed from the fifth study, further examining the requirements for an IFP, for the current flight only. Overall, this involved two phases of research. First, two participatory sessions were conducted with one Pilot from airline five. The objective of these sessions was to further advance the intelligent flight plan concept, and to specify the underlying flight operations and safety management processes. In this session, the Researcher and the Pilot jointly reviewed the proposed IFP user interface screens, for the current flight only. In so doing, the Researcher and the Pilot analysed and agreed on improvements to the existing HCI concept, and further specified certain functions which were previously undefined and/or only partially defined. Following this, the researcher and the Pilot commenced the initial high level specification of the underlying operational and organisational processes supporting the implementation of the IFP concept at airline five. This included a specification of the specific processes and functions involved, task workflows, and high level information sharing requirements. In the second part of the study, an implementation workshop was conducted with ten participants from airline five. Overall the participants spanned different airline functions including Flight Crew, Dispatch, Safety Management, Flight Operations and Technical Services. The objective of this workshop was to further review and evaluate the proposed HCI design concept, and to further map and validate the underlying process specifications. Overall, the workshop methodology was inspired by participatory methods – involving a scenario based design and evaluation approach. First, the Researcher outlined the project background and objectives. The Researcher then explained the background to the IFP concept. Following this, the Researcher presented a mid fidelity HCI prototype for the proposed IFP. As part of this, the Researcher reviewed the high level IFP concept and the allied user interface screens/workflows. Participants were then invited to assess the usability of the proposed HCI and to suggest re-design requirements. The Researcher then jointly reviewed the underlying process scenarios with the participants. In so doing, the Researcher read out the individual process scenarios, which were detailed in a workbook provided to participants. In parallel, the Researcher referred to the IFP prototype, to demonstrate the link between the different user interface functions and the underlying process/task requirements. Participants were then invited to comment on the process/task specifications, and in particular, to further specify the workflow requirement from their perspective. The Researcher then led a discussion about the underlying information technology requirements. This involved a discussion of issues related to the integration of Flight Crew/Dispatch tools with other airline systems, and the requirements for new systems to support certain new information sharing functions between Flight crew and other roles.

Summary Overview of Proposed Design Solution

The overall objective is to improve the quality of Flight Crew pre flight, flight planning and briefing activities, and in particular, to solve existing problems identified in relation to this task. To this end, an electronic version of the flight plan is advanced which (1) provides all necessary task support information, (2) facilitates information sharing across the different operational agents involved in the flight operation, and (3) exploits the outputs of airline safety analysis.

As defined, the proposed intelligent flight plan is embedded in the flight operations process, integrating information flow across relevant operational agents, and exploiting the outputs of airline safety/risk analysis. Three versions of the proposed flight plan are provided (e.g. current flight, next flight and future flights). This supports Flight Crew briefing in different contexts. These are accessible on the different application concepts. This includes the Personal application (e.g. briefing for next flight and future flights), the Dispatch application (e.g. briefing for current flight) and the Electronic Flight Bag (EFB) application (e.g. briefing for current flight and next flight).

The flight plan for the current flight is available on the Dispatch and EFB applications only.

In relation to the IFP for the current flight only, a number of core tools features have been identified. These include:

- The flight plan provides electronic access to all relevant task information – both from the cockpit (e.g. EFB application) and from the dispatch room (e.g. Dispatch application)
- The flight plan provides crew with the latest information pertaining to their flight
- Information is pushed to Flight Crew
- The flight plan assists Flight Crew information sharing with other operational agents
- The flight plan exploits the output of airline Safety Management System (SMS) analyses
- The flight plan facilitates an at a glance analysis of the flight situation
- The flight plan allows crew to actively partake in flight planning and briefing tasks
- The flight plan actively supports crew application of Crew Resource Management (CRM) and Threat and Error Management (TEM) concepts
- The flight plan allows crew to perform a number of high involvement tasks on an optional basis

Discussion

Task Modelling

In keeping with standard HCI approaches, it is argued that new tool development should be premised on a model of task practice. However, in opposition to normative HCI approaches which focus on modelling the current task, it is argued that the task model should reflect both an understanding of the current task, along with an understanding of how the future task might be performed, given the power of new technologies to change the way the task is performed for the better. In this way, the task analysis approach reflects an integration of normative HCI approaches (e.g. focus on current task) with PD approaches (e.g. envisionment of improved task practices).

Perhaps with other systems it is sufficient to focus on core task for tool development. However, the same is not true for cockpit systems. As part of the briefing task, crew brief on all aspects of the flight from start to end. In this way, to understand the briefing task, we need to elucidate the overall Flight Crew task. Thus, the identification of new tool requirements necessitates the advancement of a task model on two levels. First, a high level model of the Flight Crew task, in the context of the broader operational and organisational system is required. Secondly, a more detailed model of the pre-flight, flight planning and briefing task is required. Overall, a level of expediency in relation to task modelling is required. The high level task model need not provide detailed information about specific task dimensions. Given the requirement for concrete outputs (e.g. prototypes), detailed task modelling is directed at those aspects of task performance, most relevant to the advancement of tool concepts. In this respect, the pre-flight planning and briefing task was modelled at a sufficient level of detail, such that overall HCI requirements could be established. Key task and information dimensions pertaining to the execution of the pre flight briefing task were further defined as the Researcher engaged in collaborative prototyping and evaluation activities.

Critically, in advancing a task model, it is necessary to attend to the socio-technical dimensions of the task. This necessitates modelling the relationship between task and process – thereby creating a requirement for process mapping. Process mapping of the Active Flight Operation process (e.g. Study One) and the study of the relationship between the Flight Planning process and the FC task (e.g. Study Two), facilitated an understanding of Flight Crew tool requirements, in terms of the wider operational perspective. In addition, the study of the performance management/safety management process (e.g. Study Three) allowed for an understanding of the organisational context for Flight Crew task performance. Such an approach is not typically used in the HCI field. Typically, HCI methods evaluate user task workflows and technology/tool interactions in isolation from the broader operational and organisational processes and related information flow. Crucially, this reflects a shift in perspective. That is, a conceptualization of Flight Crew tool requirements in relation to the broader system (e.g. broader operational and organisational processes) and associated 'system information flow' requirements.

The data analysis approach directly linked into design activities. As such, there was less of a focus on the production of formal user and task analysis outputs such as role/task matrices and workflow diagrams. Rather, the outputs included a high level task model, high level tool requirements, future task/use scenarios and provisional prototypes. Overall, this reflects an attempt to link into the design process and support tool envisionment activities.

Usefulness of PD Methods

In keeping with Bannon's argument (1991a, 1991 b, 1993), research demonstrates the utility of using a prototype to support future task/future tool envisionment activities. Prototypes were used as a basis for exploring, evaluating and communicating future task and future tool design ideas. Critically, having first undertaken an analysis of the existing task, the Researcher was in a position to interpret and weight participant opinions related to the proposed future task and associated HCI design solution. It is difficult for participants to fully envisage and evaluate HCI design ideas, without the development of such prototypes. Essentially, these techniques allowed both users and the Researcher to experiment with different visual/interactive affordances (e.g. menu structures, icons, presentation of form fields) until a design consensus was reached. In this way, research does not stop short of providing concrete HCI design instruction. Moreover, the researcher was able to elicit feedback concerning the usability of future technology concepts, thereby circumventing the task artefact lifecycle.

Situating HCI in Operational and Organisational System

The introduction of new technologies cannot simply be evaluated from the perspective of end users alone (e.g. end user feedback about the usability of the system and suitability of new task practices). We must also consider how new technologies fit from a broader operational and organisational perspective. That is, the proposed HCI concept must be situated within the wider operational and organisational context in which it will be used. The introduction of new tools will result in changes at both process and task level. These new processes and task requirements must be specified. This also involves examining the implicit requirements pertaining to the introduction of new technologies for use by other operational agents, to support new information sharing practices identified in the core tool. Further, the introduction of new work processes may not be possible. Development costs may be too high. Proposed solutions may raise complex technical issues. Trade offs may be required. As such, the feasibility of the proposed concepts must be assessed (e.g. whether the organisation has the capacity to support the new tool concept in terms of underlying work effort, training requirements and so forth). Therefore, methods must facilitate the mapping of underlying process requirements supporting the implementation of the tool concept, and the evaluation of the feasibility of the proposed tool concept, in terms of organisational capacity, IT requirements and process design. The HCI literature does not provide guidance for these activities. In many ways, this falls out of the scope of HCI, as currently conceived. As such, participatory approaches were adopted for this purpose.

Conclusions

The introduction of an intelligent flight plan provides the opportunity to change the way the task is performed for the better. In this way, methods must focus the envisionment new task practices predicated on the introduction of new task transforming tools. In this respect, Participatory Design methods are useful. However, as a stand-alone methodology, participatory methods are insufficient. To design tools that improve upon current practice, we must start from current practice. Participatory research must be directed and evaluated from the perspective of 'real life' practice. As such, the development of a model of current task practice is a necessary precursor to participatory research. Further, research does not end at the envisionment and evaluation of future tool prototypes. The proposed new tools must be considered from the perspective of the broader socio-technical system. In particular, future tools must be evaluated in the context of existing operational and organisational processes and potential process re-design requirements. Accordingly, methods must support the specification of underlying process requirements, necessary to the implementation of the proposed tool. Moreover, methods must facilitate the identification and evaluation of implementation barriers.

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IS ANALYTICAL THINKING USEFUL TO TECHNOLOGY TEACHING?

Raymy Kate O'Flynn and Dr. Thomas Waldmann

Faculty of Science and Engineering,
Manufacturing and Operations Department,
University of Limerick,
Limerick, Ireland

Abstract

The Iowa Gambling Task is a famous and frequently-used neuropsychological task that is designed to simulate real-world decision-making. In a study conducted by Evans, Kemish and Turnbull (2004) results reported a significant difference in the performance of educated and less well educated participants in the Iowa Gambling Task. This study looks at the effects of a student's course choice and the effect it has on their everyday decision-making. 97 students took part in a computerised version of Bechara, Damasio A. R., Anderson, Damasio H. (1994) and Maia and McClelland's Iowa gambling Task (2004).
Keywords: Iowa Gambling Task, Decision- making, Somatic Marker, Education.

Introduction

From the subjects we study in Second Level education to the choices we make about the courses to take at Third Level education, we each try to choose the path that suits us best. The current study was undertaken to investigate if the type of education we receive has an effect on our decision-making. A computerised version of The Iowa Gambling Task (IGT) Bechara et al. (1994), (Demareea, Burns and DeDonnoa; 2009) and Maia et al. (2004) Somatic Marker Questionnaire (SMQ) was then used to determine the decision-making skills and knowledge of participants in different college courses.

Decisions vary in the degree to which they rely on intuitive and analytical processes Hammond, Hamm, Grassia, Pearson (1987). The IGT looks explicitly at how real world decisions are achieved, following research conducted by Demareea et al.(2009), it was found that IQ is a significant predictor of IGT performance suggesting that the IGT is a cognitively based task, the same has been suggested by Maia et al. (2004). Research conducted by Hammond et al. (1987) pointed out that recognitional decisions are more common in everyday decision-making than an analytical style of decision-making. Recognitional decision-making was found to occur more frequently when the decision maker was more experienced, environmental conditions were less stable and pressure or time constraints were greater. With colleges offering work experience, co-operative work placements and internships, this would suggest the more interactive courses that allow for these placements and encourage projects facilitating decision-making and use of intuition may benefit students decision-making in the work place. The more placement experience students gain or projects simulating job style situations may prepare them for their chosen area aiding their decision-making when they reach employment.

Advantageous decision-making is necessary in order to perform under time uncertainty and pressure constraints. Deciding advantageously suggests that participants select options that lead to a positive outcome.

The idea that education can have a defining effect on decision-making was a theory tested by Evans et al. (2004). They demonstrated that education has a contradictory effect on the IGT. Less-well-educated people adopt a more advantageous strategy in the task than their university educated counterparts. Mulderig (1995) gives an explanation for such findings, Mulderig suggested that tertiary level establishments encourage students to rely solely on documented evidence when forming arguments. The idea that people's level of education can have an effect on decision-making requires further investigation as Evans et al. (2004) tested only 30 participants all of which were Female. However, the type of course we choose may have a similar effect on our decision-making. Turnbull, Evans, Bunce, Carzolio, and O'Connor (2005) found that performing the IGT did in fact meet many of the criteria for intuitive operations. As reported by Brand (2008) a strategic approach to decision-making in the IGT may be impossible within the first few trials as participants must explore and figure out contingences. When these have been discovered cognitive strategies or a more analytical approach may be favoured. The IGT is constructed in such a way that participants can freely pick from four decks of cards, during the 100 trials participants will experience wins and losses in all of the decks. Two decks are considered to be good, and two considered to be bad. The "bad decks" have high gains and high losses associated with them resulting in an over all net loss when choosing only from these decks, while the good decks have smaller rewards participants will ultimately make a net gain on these decks. The IGT is thought to simulate real world decision-making with participants undergoing periods of reward, punishment and uncertainty. (Bechara, Damasio and Damasio 2000) Thus a successful completion of the IGT is said to be a predictor of advantageous decision-making. The IGT displays participants Advantageous Behaviour, while the SMQ is a display of participants Knowledge of Advantageous strategy. A participant displays Advantageous Behaviour when s/he selects from one of the two best decks (C or D). Participants' advantageous behaviour is assessed on the selections made through out the game, a participant is said to be behaving advantageously if there Net Advantageous Score is 0 or above. Calculation of Net Advantageous Score was carried out as per Bechara et al.(1994): ((C+D) - (A+B)) (Where A= -1,B= -1,C= 1,D= 1). Participants Knowledge of Advantageous strategies was assessed as per Maia et al. (2004) where;

Level 1: refers to a participant displaying a preference for on of the two advantageous decks.

Level 2: refers to a participant displaying Level 1 knowledge plus conscious knowledge of outcomes of the decks.

Level 2 calculated: refers to a participant displaying Level 2 knowledge and they can also provide quantitive knowledge of the value of the decks leading to advanced knowledge of the advantageous strategy.

Method

Participants

97 participants took part in a computerized version of the IGT. 88 Male, and 9 Female participants were tested. Participants ranged in age from 17- 42 with an average age of 19.35(STDev: 3.37). All participants were in attendance on one of five courses within the Manufacturing and Operations Engineering department; Materials and Architectural Technology (MAT), Materials and Engineering Technology (MET), Digital Media and Design

(DMD), Product Design and Technology (PDT), and Engineering (ENG). Participants were asked to provide personal information such as their age, course taken at college, level of education attained so far, and relevant information pertaining to work experience, or extra education availed of by the participants during their education.

Iowa Gambling Task

A computerised version of the IGT (Bechara et al.,1994) and a computerised version of Maia et al. (2004) SMQ were used. Participants did not receive any monetary reward for taking part or any "Hint" as to how the task should be carried out or contingencies within the task. Fernie and Tunney (2006) showed differences in performance based on a "Hint" versus no "Hint" schedule and differences based on real versus facsimile reinforcers. Facsimile rather than real money was used for this IGT. Bechara et al. (2000) also found that IGT results are unaffected by the use of manual versus computerised testing systems. Participants were allowed to select cards, in any order, from any of the four decks (A. B. C. and D.) as in Bechara et al. (1994) Decks A and B were disadvantageous decks and decks C and D were advantageous. As per instructions in Bechara et al. (1994) Losses were more frequent on selection of decks A and B, and the task was terminated after 100 selections. Knowledge level's on the task was assessed as per Maia et al. (2004) outlines.

Results

Participants were tested on their Advantageous Behaviour (selecting from more advantageous decks C and D on average during a trial) and on their Advantageous Knowledge; Level 1, Level 2 and Level 2 Calculated Knowledge based on Maia et al. (2004) definitions. As in Bechara et al. (1994) the 100 card selections were sub-divided into five blocks in each block the Net Advantageous Score was calculated. A net score of above zero implied that the participants were behaving advantageously, and if participants scored a net of below zero it was considered disadvantageous behaviour.

Table 1- Round Numbers and corresponding Blocks

Round	Block
1	1
2+3	2
4+5	3
6+7	4
8+9	5

In the study of student's Advantageous Behaviour in the IGT a difference was seen between PDT students and MAT students across blocks 3, 4 and 5. With PDT students making fewer advantageous decisions than MAT students. Block 3 N=45 p=0.015. Block 4 N=46 p=0.049. Block 5 N=50 p=0.060.
A difference was also found between PDT students and MET students in Block 3. Block 3 N= 41 p=0.031. See Figure 1 for Net Advantageous Scores of all 5 courses.

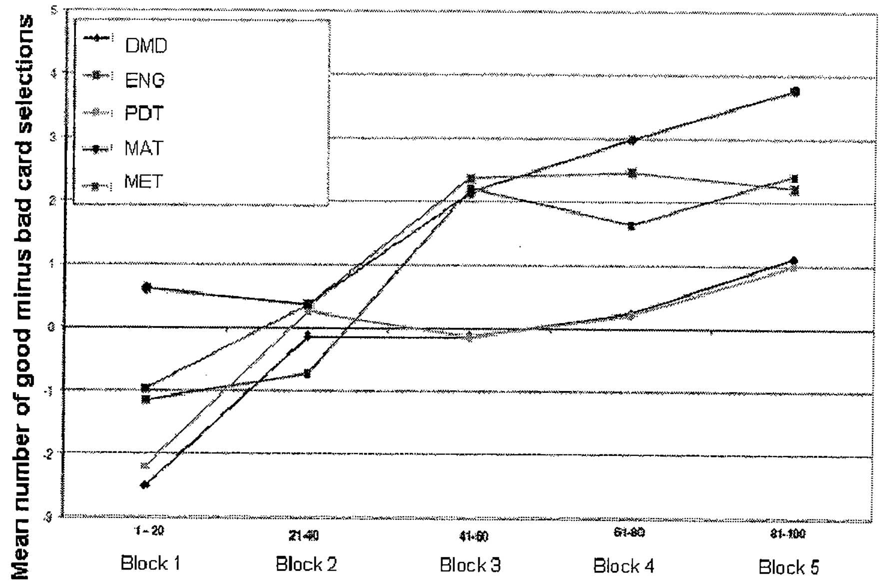

Figure 1. Net Advantageous Score of participants from all 5 courses

In the study of student's Knowledge of Advantageous Strategy in the IGT and the SMQ no significant difference was seen between participants for the time at which they stated Level 1 Knowledge of Advantageous Strategy.

A more significant effect was seen when looking at participants Knowledge of Advantageous Strategy for Level 2. See Figure 2 for a stem and leaf plot of the differences seen between students of DMD and PDT in Level 2 knowledge. (Mann-Whitney U=34.5, p=0.008)
A significant difference was also noted between students of DMD and
MAT (Mann- Whitney U= 100.5, p= 0.037)

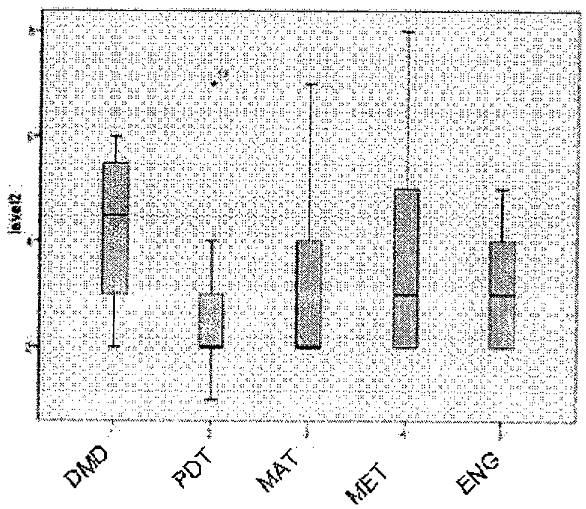

Figure 2. Level 2 Knowledge of Advantageous Strategy by Course

When looking at Level 2 calculated Knowledge of Advantageous Strategy students' of PDT performed significantly better than DMD students (Mann- Whitney U =29, p= 0.028). MET students also performed better than DMD students (Mann- Whitney U=29, p=0.036) See Figure 3 for a stem and leaf plot of Level 2 Calculated knowledge by course.

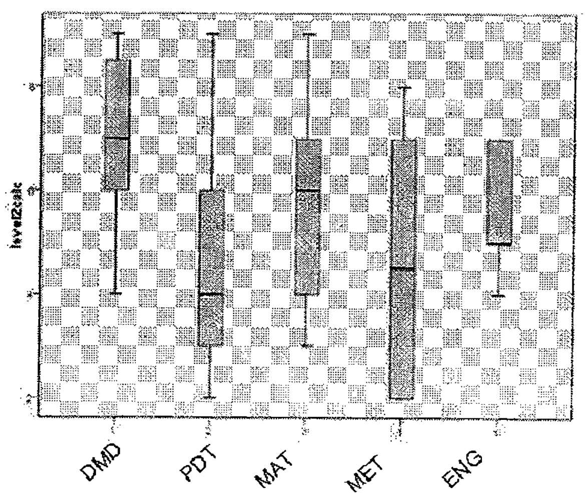

Figure 3- Level 2 Calculated Knowledge of Advantageous Strategy by Course

Discussion

Findings for Advantageous Behaviour

PDT students did not show a high level of advantageous behaviour across Blocks 3, 4 and 5 where Level 2 and Level 2 calculated knowledge were previously reported. PDT students reached only a mean score of 1 in their Net Advantageous Scores by Block 5, although positive Net Advantageous Scores reflect advantageous performance. However, PDT student's mean score is below that of other students. This suggests that even though PDT students could report Knowledge of Advantageous Strategy early they failed to act on such knowledge. DMD students reported a Net Advantageous Score that only improved to a mean score of 1, similar to PDT students.

MAT, Eng and MET students all reported Level 2 and Level 2 calculated Knowledge of Advantageous Strategy at roughly the same time. Reporting Level 2 Knowledge of Advantageous Strategy between Round 2 -3 (Block 2) and Level 2 calculated Knowledge of Advantageous Strategy early in Rounds 5- 6 (Block 3- 4). Reporting on such knowledge and acting on it occurred simultaneously for all three courses. As per findings on previous experiments the biggest differenced between groups can usually be found in Block 3 of the task. (Bechara et al. 2000; Hooper, Lucina, Conklin and Yarger, 2004)

Findings for Knowledge of Advantageous Strategy

PDT students showed a high Level 2 understanding and Level 2 Calculated understanding with most students reaching both levels ahead of other courses, PDT students on average reporting both understandings between round 2 and 4 respectively (see Table 1 for related Blocks). See Figure 2 and 3. DMD students reported Level 2 and Level 2 calculated knowledge later than other courses, reaching Level 2 knowledge at round 5 (Block 3) and reported Level 2 Calculated knowledge at round 7 (Block 4) . See Figure 2 and 3.

Findings Discussed

This investigation replicates many findings of the previous literature (Bechara et al. 1994; Bechara et al. 2000) with regular systematic progress and improvement in performance across the five blocks of the IGT. This effect was shown in the five courses tested. The rate of improvement in all courses falls within the range of performance previously reported (Bechara and Damasio 2002) Steady learning is seen across the blocks in all courses. See Figure1. In the IGT average success (Advantageous Behaviour) in Blocks 3-5 is lower than that of previous studies conducted by Bechara et al. (1994,2000,2002), and Maia et al. (2004). This may be due to the analytical nature of cognition taught in engineering courses. Using a Cognitive Styles Index (CSI) (Allinson and Hayes 1996) Cosgrave (2004) reported that the CSI score of Engineering students was 44 (scores above 38 on the CSI are considered to be "analytical learners"). A score of 38 or lower in the CSI is considered to be a more "intuitive learner". Engineers tested therefore had a tendency towards analytical learning and thinking allowing more logical, compliant thought and more structured systematic approaches to problems and decisions. This type of cognitive style may reduce IGT net score as participants from engineering backgrounds make-decision with a more analytical approach rather than the explorative style necessary at the start of the task. The current experiment replicates findings by Fernie and Tunney (2005). This task used facsimile money and no hint as to whether the some decks are more advantageous than others. The results of advantageous behaviour in this investigation are comparable to those reported by Fernie et al. (2005) for groups that receive no hint and use facsimile money.

Future Work

Further research into why PDT students could verbalise the Advantageous strategy but fail to act on it is necessary. One possible suggestion for this could be Stanovich and Richard's (1993) theory of "Disrationalia" where seemingly clever people make irrational choices.

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TECHNOLOGIES TO MONITOR AND PROVIDE FEEDBACK ON SPINAL POSTURE IN LOW BACK PAIN: A REVIEW

K O'Sullivan[1], L O'Sullivan[1], W Dankaerts[2,3], P O'Sullivan[4]

[1]*University of Limerick, Limerick, Ireland*
[2]*Catholic University, Leuven, Belgium*
[3]*University College Limburg, Hasselt, Belgium*
[4]*Curtin University of Technology, Perth, Australia*

Abstract

Low Back Pain (LBP) is a very common and costly musculoskeletal disorder. It is acknowledged that lumbo-pelvic posture and movement patterns may be related to the high incidence and severity of occupational LBP. Recently, several novel methods of monitoring and providing feedback on lumbo-pelvic posture have been developed. However, it is unclear how feasible, valid and effective many of these devices are. This review focussed on examining the minimally invasive technologies which are currently available, and could be used to monitor, or provide feedback on, dynamic spinal posture in the workplace. The results suggest that numerous devices are now available for the assessment, and potentially management, of occupational LBP. However, most require further development. A major issue is a lack of rigorous validation of the devices, and also a lack of controlled clinical intervention studies for those devices that can provide postural feedback. As a result, there is currently insufficient evidence that these technologies can significantly improve LBP outcomes. Recommendations for the further development of such devices are made.

Introduction

Low Back Pain (LBP) is a very common and costly disorder, which is often associated with prolonged absence from employment (Maniadakis and Gray, 2000; Hansson, Ihlebæk et al., 2006). It is commonly considered within a biopsychosocial framework, taking into account the contribution of multiple domains to the overall disability associated with LBP (O'Sullivan, 2005; Linton, Boersma et al., 2007). Despite advances in medical imaging techniques, most LBP lacks a specific radiological diagnosis, and has been termed non-specific chronic low back pain (NSCLBP) (Borkan, Van Tulder et al., 2002). It is increasingly recognised that within this broad NSCLBP population, specific subgroups exist which require management addressing the specific mechanism underlying their NSCLBP (Boersma and Linton, 2002; Borkan, Van Tulder et al., 2002; McCarthy, Arnall et al., 2004; Dunn and Croft, 2005; O'Sullivan, 2005; Kent, Keating et al., 2009). It appears that there are subgroups of patients with NSCLBP for whom significant psychosocial barriers (e.g. psychological distress, anxiety, depression, poor social support) may represent the primary barrier to rehabilitation (O'Sullivan, 2005). However, there is likely to also be a large subgroup of NSCLBP subjects for whom the adoption of altered patterns of spinal posture and movement represents a primary mechanism for their ongoing NSCLBP disorder (O'Sullivan, 2005). It has been proposed that these LBP patients that present with maladaptive spinal postures and movement patterns expose their spines to increased loads and increased tissue strain, which are factors in the development and maintenance of LBP (Van Dillen, Sahrmann et al., 2003; O'Sullivan, 2005; Poitras, Blais et al., 2005; Dankaerts, O'Sullivan et al., 2006; Womersley and May, 2006; Van Wyk, Weir et al., 2009). A number of studies now support the existence of these altered spinal postures in subjects with NSCLBP when examined in a laboratory environment (Burnett, Cornelius et al., 2004; Dankaerts, O' Sullivan et al., 2006; Dankaerts, O'Sullivan et al., 2006; Womersley and May, 2006; Smith, O'Sullivan et al., 2008; Dankaerts, O'Sullivan et al., 2009), and modification of posture has been associated with improved clinical outcomes in some clinical trials (Van Dillen, Sahrmann et al., 2003; Dankaerts, O'Sullivan et al., 2007; Horton and Abbott, 2008).

However, while lumbo-pelvic posture and movement patterns are very relevant to the management of NSCLBP, their analysis has traditionally been performed in laboratories using sophisticated motion analysis systems (Dankaerts, O'Sullivan et al., 2006). Considering the risks associated with ionising radiation from X-rays, and the costs associated with technology such as MRI, these laboratory-based systems are now very commonly used to analyse spinal posture and movement. While there will always be some error due to skin movement, these surface marker based systems are generally accepted as providing an accurate and detailed representation of the underlying spinal structure (Pearcy and Hindle, 1989; Gracovetsky, Newman et al., 1995). Most of them can analyse in three dimensions (3D), and can analyse not just static postures, but also dynamic movements. The use of these devices has facilitated a greater understanding of the role of lumbo-pelvic posture and movement patterns in CLBP (Dankaerts, O'Sullivan et al., 2006; Dankaerts, O'Sullivan et al., 2009). Unfortunately, these devices are costly and time-consuming. Furthermore, their cumbersome size, lack of portability, and the need for visibility of skin markers, means they are not a suitable means of analysing posture outside the laboratory, e.g. in most occupational settings. Therefore, the vast majority of research examining spinal posture and movement patterns in LBP has been confined to the laboratory, rather than taking place in the field in occupational settings (Dankaerts, O'Sullivan et al., 2006; Claus, Hides et al., 2009). To perform research on lumbo-pelvic posture and movement patterns in "real-world" settings, other less invasive technologies are needed. Recently, some smaller, more portable devices have been developed that can analyse static spinal posture very quickly and simply (Mannion and Troke, 1999; Norton, Hensler et al., 2002; Mannion, Knecht et al., 2004; Ripani, Di Cesare et al., 2008; McAlpine, Bettany-Saltikov et al., 2009; Sheeran, Sparkes et al., 2010). The reliability of some of these devices for measurement of sitting, standing, or other postures has been established (Sheeran, Sparkes et al., 2010). While some (e.g. spinal mouse) have been validated against X-ray (Kiss, 2008), many others have not yet been validated (McAlpine, Bettany-Saltikov et al., 2009; Sheeran, Sparkes et al., 2010), or indeed have been shown to be very poor indicators of underlying spinal posture (Cowherd, Gringmuth et al., 1992; Walsh and Breen, 1995). Furthermore, many of these devices only provide an estimate of static spinal posture, and so cannot quantify dynamic spinal posture and movement patterns. Finally, similar to most laboratory-based systems, many cannot provide subjects with real-time feedback to facilitate postural re-education.

Therefore, it is clear that any technology used to analyse lumbo-pelvic posture and movement in occupational settings must be able to address these limitations. This review aims to ascertain the options for occupational posture monitoring and feedback for the lumbo-pelvic region. The focus will be on the technologies currently available to analyse dynamic lumbo-pelvic posture and movement patterns in occupational, and other, settings outside the laboratory. Therefore, measurement systems which are limited to the laboratory, or can only determine static postures will not be considered. The key advantages and disadvantages of each approach will be discussed.

Methods

The following databases were searched during February-May 2010; Medline, Cinahl, Science Direct, AMED, and SPORTDiscus. These were searched using combinations of the following search terms; back pain / low back pain / lumbar spine / posture / low back posture / spinal posture / movement / real-world / occupation / goniometer / accelerometer / inclinometer / gyroscope / strain gauge / feedback / biofeedback / rehabilitation / motor control. In addition, reference lists of the selected articles were examined. Finally, researchers were contacted directly (via email) to determine if any of the devices had been further studied. Data considered suitable for inclusion included journal articles, book chapters, conference presentations and thesis submissions.

Technologies were included if they were able to monitor *or* provide feedback on lumbo-pelvic posture, *and* if their small size allowed measurements to be easily obtained during routine activities of daily living (e.g. sitting, standing and walking). Finally, only devices which had been used specifically for lumbar spine analysis were considered. Technologies were excluded if their measurements were limited to laboratory settings or to static postures, and if articles were not available in English. In addition, they were excluded if their size does not allow free movement or assuming common occupational tasks (e.g. sitting, standing, bending) in a normal manner (Marras, Fathallah et al., 1992; Donatell, Meister et al., 2005; Troke, Schuit et al., 2007).

Scoring

Four headings were selected in scoring the usefulness of the current technologies available. These were the (1) device feasibility, (2) parameters it is possible to measure, (3) evidence of methodological rigour, and (4) evidence of clinical utility. The feasibility of the device was assessed by considering the interference of the device with normal activities, and its ease of application. The measurement parameters scored included the number of planes the devices could monitor, measurement of lumbo-pelvic posture (as opposed to simple trunk inclination), if posture is expressed in angular output, if the postural output is sufficiently detailed (e.g. mean and variation of posture over time), if it controls for overall body posture e.g. sitting versus standing, if postural data can be synchronised with other inputs e.g. electromyography, and whether the device can provide feedback to facilitate motor learning. The methodological rigour of the devices considered whether they had evidence of adequate reliability (especially between-day and inter-rater), and validity compared to an appropriate reference standard. Finally, clinical utility considered whether the device has demonstrated whether it can differentiate between the posture of subjects with and without LBP, and if it has shown it can help reduce the severity of LBP as a feedback tool. All aspects were weighted equally, with a range of 1-3 points awarded per criterion.

Results

This review of the literature yielded a large number of remote postural monitors which are advocated as being capable of monitoring and/or providing feedback on dynamic spinal posture outside the laboratory. Devices based on similar measurement principles (e.g. accelerometry) were grouped together, but scored and appraised separately. The scores obtained by each device are displayed in Table 1. In addition, the advantages and disadvantages are described in further detail in the discussion.

Table 1: Scores obtained by technologies under criteria described in the methods

Criteria	FEG [a] Biometrics [b] OPM [c] Rachimeter[1]	FOG	Strain gauge	US	Accelerometers [a] SpineAngel [b] ActivPal [c] Analog [d] BSM	Inclinometers [a] Physiometer [b] Virtual Corset [c] PPRS[2]
Minimal interference	[a] 2 [b] 2 [c] 2	2	3	3	[a] 3 [b] 3 [c] 2 [d] 2	[a] 1 [b] 2 [c] 2
Ease of application	[a] 2 [b] 2 [c] 2	2	2	2	[a] 3 [b] 3 [c] 2 [d] 2	[a] 2 [b] 2 [c] 2
Planes measured	[a] 2 [b] 1 [c] 1	1	1	2	[a] 2 [b] 1 [c] 1 [d] 3	[a] 1 [b] 2 [c] 1
Measures lumbo-pelvic region directly	[a] 3 [b] 3 [c] 3	3	3	3	[a] 1 [b] 1 [c] 1 [d] 2	[a] 2 [b] 1 [c] 1
Angular output	[a] 3 [b] 3 [c] 3	3	1	1	[a] 3 [b] 1 [c] 3 [d] 3	[a] 3 [b] 3 [c] 3
Detailed postural output	[a] 3 [b] 2 [c] 3	3	3	3	[a] 3 [b] 1 [c] 2 [d] 3	[a] 3 [b] 3 [c] 3
Controls for overall body posture	[a] 3 [b] 1 [c] 1	3	1	1	[a] 1 [b] 3 [c] 1 [d] 1	[a] 3 [b] 1 [c] 1

Sychronising data	[a]3 [b]1 [c]3	1	1	1	[a]1 [b]1 [c]1 [d]1	[a]3 [b]3 [c]2
Provides feedback	[a]1 [b]3 [c]1	1	3	3	[a]3 [b]1 [c]3 [d]3	[a]1 [b]1 [c]1
Reliability	[a]2 [b]2 [c]2	2	2	2	[a]1 [b]1 [c]1 [d]2	[a]1 [b]1 [c]1
Validity	[a]3 [b]1 [c]2	2	3	2	[a]2 [b]1 [c]1 [d]1	[a]1 [b]1 [c]1
Differentiatin g LBP / non-LBP	[a]1 [b]1 [c]1	3	3	1	[a]1 [b]1 [c]3 [d]1	[a]1 [b]2 [c]1
Clinical effectiveness	[a]1 [b]2 [c]1	1	2	1	[a]2 [b]1 [c]1 [d]1	[a]1 [b]1 [c]1
Total (min=13; max = 39)	[a]29 [b]24 [c]25	27	28	25	[a]26 [b]19 [c]22 [d]25	[a]23 [b]23 [c] 20

FEG: Flexible Electrogoniometer; OPM: Orthosense Posture Monitor; FOG: Fibre-Optic Goniometer; US: Ultrasonic device; BSM: Back Strain Monitor; PPRS: Portable Posture Registration Set.
[1]Device combined with inclinometer and pressure sensor data; [2]Device combined with potentiometer

Discussion

As the results in Table 1 show, the variety of devices available for monitoring and providing feedback on spinal posture each have their own advantages and disadvantages. These will now be discussed for each type of device separately.

Flexible Electrogoniometers (FEG)
FEG's measure linear displacement, which is converted into angular data. Most are relatively small, flexible and discrete enough to be worn under clothing. Three types of FEG have been considered in this review.

The most common FEG (Biometrics Ltd, UK) is commonly used in peripheral limb research, where it is known to be reliable and valid (Rowe, Myles et al., 2001; Piriyaprasarth, Morris et al., 2008). Two of these FEG's can be used together to monitor lumbo-pelvic posture and lower-limb angle, to determine overall body posture simultaneously. Similarly, postural data can be collected simultaneously with trunk muscle electromyography, torsiometry, pressure sensors, or other inputs (Bible, Biswas et al., 2010). It can monitor both sagital and frontal plane posture. The output is expressed in degrees. It cannot provide feedback. It can provide quantitative angular data on mean lumbo-pelvic posture during the working day, and the duration spent in different ranges of lumbar flexion/extension. It is reliable in the assessment of lumbo-pelvic standing range of motion (ROM) between-days (Boocock, Jackson et al., 1994) and the assessment of sitting posture within-days (Dolan and Green, 2006). It has been shown to be valid compared to a flexicurve and a fluid-filled inclinometer (Boocock, Jackson et al., 1994), as well as other skin surface measures (Vieira and Coury, 2004) (all r>0.77). However, when validated against a better standard (X-ray of standing lumbar lordosis and standing lumbar ROM), the correlations obtained were only moderate (r=0.48-0.77) with the actual angular values obtained being significantly different (Thoumie, Drape et al., 1998). More recently, the accuracy of the device compared to X-ray measurement of lumbar ROM has been shown to be within 3° (Bible, Biswas et al., 2010). It has not been validated as a measure of sitting posture or seated ROM. It has been used in laboratory-based studies examining lumbar posture and movement patterns (Li and Haslegrave, 1999; Kasahara, Miyamoto et al., 2008). In a pilot study of four garage mechanics, it was used to analyse working lumbar posture outside the laboratory (Boocock, Jackson et al., 1994) with no difficulties. However, it has not been used in studies comparing subjects with and without LBP, so its ability to detect subtle differences in posture is unknown. Similarly, since it does not provide feedback, it is not suitable for feedback intervention studies.

The "Orthosense Posture Monitor" (OPM) (Orthosense Ltd) is another FEG used to monitor lumbo-pelvic posture outside the laboratory. It cannot differentiate between sitting and standing tasks, and therefore requires another input to control for this. Similarly, postural data cannot be collected simultaneously with other inputs e.g. trunk muscle electromyography. It can only monitor sagital plane postures. The output is expressed in degrees, but cannot provide quantitative angular data on mean lumbo-pelvic posture during the working day, and the duration spent in different ranges of lumbar flexion/extension. Instead, data on the number of "errors", and the duration spent, beyond a pre-determined threshold is calculated. It can provide real-time postural feedback. It has demonstrated very good between-day repeatability outside the laboratory (Dean and Dean, 2006). It has not been validated as a measure of lumbo-pelvic posture or ROM. It has been used effectively to modify lumbar posture movement patterns during a manual handling task in healthy subjects without LBP (Dean and Dean, 2006). It has also been shown to aid postural awareness in subjects with LBP subjects (Dean, Weinman et al., 2005), however it is unclear if this is associated with reduced LBP. There have been no published studies of its ability to discriminate between subjects with and without LBP, inside or outside the laboratory.

The "Rachimeter" (Vergara and Page, 2000) is another FEG used to monitor lumbo-pelvic posture outside the laboratory. It cannot differentiate between sitting and standing tasks, and therefore requires another input to control for this. It differs from the other electrogoniometers in that lumbar postural data is collected together with pelvic inclinometry and chair-backrest contact data (Vergara and Page, 2000; Vergara and Page, 2002). It can only monitor sagital plane postures. The output is expressed in degrees, and can provide quantitative angular data on mean lumbo-pelvic posture during the working day, and the duration spent in different ranges of lumbar flexion/extension. It cannot provide real-time postural feedback. It has demonstrated very good between-day repeatability (Vergara and Page, 2000). It has been validated as a measure of lumbo-pelvic posture against inclinometry (Vergara and Page, 2000). It has been used in a study demonstrating a link between postural variability and sitting discomfort (Vergara and Page, 2002). There have been no published studies of its ability to discriminate between subjects with and without LBP, inside or outside the laboratory, so its sensitivity to subtle differences in posture is unknown. Similarly, since it does not provide feedback, it is not suitable for feedback intervention studies.

Overall, most FEG's are simple to use and offer potential for further occupational research. They all carry the risk of their length being exceeded during flexion tasks. The Biometrics device has been subjected to the most rigorous analysis so far, and appears to be the best of these options at the moment.

Fibre-optic goniometers (FOG)

A fibre-optic goniometer (FOG) is based on the principle that spinal flexion changes the path of the light travelling along an optical fibre. This can be used to measure spinal posture since the loss of light varies according to the bending of the optical fibre (Stigant 2000). Similar to FEG's, these are relatively small, and discrete enough to be worn under clothing. Two FOG's can be used together to monitor lumbo-pelvic posture and lower-limb angle, to determine overall body posture simultaneously. Postural data cannot be collected simultaneously with other inputs e.g. trunk muscle electromyography. It can monitor sagital plane posture only. The output is expressed in degrees. It cannot provide feedback. It can provide quantitative angular data on mean lumbo-pelvic posture during the working day, and the duration spent in different ranges of lumbar flexion/extension. The reliability of the FOG has been established (Stigant 2000). The ability of the FOG to monitor lower limb posture and activity as well as overall body posture (sitting versus standing) has been validated against video assessment (Stigant 2000). It has been shown to be a valid measure of lumbo-pelvic movement compared to a flexible ruler, as well as other skin surface measures (Stigant 2000). However, it has not been validated against a better standard (e.g. X-ray or MRI). It has been used in occupational studies examining lumbar posture and movement patterns with minimal difficulties (Bell, 2008). It appears to be sensitive enough to detect subtle differences in posture between subjects with and without LBP (Bell, 2008). Since it does not provide feedback, the FOG is not suitable for feedback intervention studies.

Strain Gauges

The "BodyGuard" (BG) (Sels Instruments, Belgium) uses strain gauges to provide both real-time monitoring and feedback on lumbo-pelvic posture. It is very small, and discrete enough to be worn under clothing. It cannot differentiate between sitting and standing tasks, and therefore requires another input to control for this. Similarly, postural data cannot be collected simultaneously with other inputs e.g. trunk muscle electromyography. It can only monitor sagital plane postures. The output is not expressed in degrees, but instead relative to lumbo-pelvic ROM. They can provide quantitative angular data on mean lumbo-pelvic posture during the working day, and the duration spent in different ranges of lumbar flexion/extension. It has demonstrated very good between-day and inter-rater reliability during sagital plane tasks and postures in a laboratory (O'Sullivan, Galleotti et al., 2009). Unlike most other devices, it has been validated as a measure of lumbo-pelvic posture against digital video fluoroscopy (DVF) in both sitting and standing (Smets, Dekelver et al., 2010). It can discriminate between cyclists with and without LBP, and provision of feedback using the device has been associated with reduced pain (Van Hoof, Volkaerts et al., 2010), although this has not been examined in an occupational setting.

Ultrasonic devices

An ultrasonic (US) device (Orthoson, Weimar, Germany) can estimate spinal posture by calculating the distance between ultrasound sensors that are placed just lateral to the spine. It is capable of providing both real-time monitoring and feedback on lumbo-pelvic posture. It is small, and discrete enough to be worn under clothing. It cannot differentiate between sitting and standing tasks, and therefore requires another input to control for this. Similarly, postural data cannot be collected simultaneously with other inputs e.g. trunk muscle electromyography. It can only monitor sagital plane postures. The output is not expressed in degrees, but instead relative to lumbo-pelvic ROM. It can provide quantitative angular data on mean lumbo-pelvic posture during the working day, and the duration spent in different ranges of lumbar flexion/extension. This appears to have very good intra-rater reliability, both within-day and between-days (Friedrich, 2002). It has been validated against simple measures of spinal flexion such as inclinometry and the Schober method (Friedrich, 2002), but not against more sophisticated methods such as DVF or MRI. It is also able to discriminate between workers who spend most of the day working in flexed or extended trunk postures (Martin and Matthias, 2006). However, there have been no published studies of its ability to discriminate between subjects with and without LBP, inside or outside the laboratory. Similarly, there are no published studies on the effectiveness of using it as a postural feedback device.

Accelerometers

Accelerometers measure accelerations in one or more planes, which can then be converted into meaningful data regarding body postures and movements, so that they function similar to an inclinometer. For this review, several different ways of using accelerometers to determine spinal posture and movement have been considered. The results of the review suggest it is appropriate that these are seen as distinct ways of using accelerometers to monitor lumbo-pelvic posture.

The first method is using an accelerometer (SpineAngel, Movement Metrics, Hamilton, New Zealand) attached to the subjects belt to monitor pelvic rotation. This is intended to give an estimate of lumbo-pelvic flexion. This device is very small and discrete, and has the significant advantage that subjects can position it themselves easily. It cannot differentiate between sitting and standing tasks, and therefore requires another input to control for this. Similarly, postural data cannot be collected simultaneously with other inputs e.g. trunk muscle electromyography. It can monitor sagital and frontal plane posture. The output is expressed in degrees. It can also provide real-time postural feedback. It can provide quantitative angular data on mean lumbo-pelvic posture during the working day, and the duration spent in different ranges of lumbar flexion/extension. On the other hand, its placement means the output is likely to reflect pelvic tilt and trunk inclination rather than true lumbo-pelvic posture. It is reliable in the assessment of lumbo-pelvic posture and ROM within a single session in a laboratory (Intolo, Carman et al., 2010). However the reliability of the device has not been assessed between raters, or between different sessions or days. The device has been validated against a traditional motion analysis system for a variety of sitting and standing tasks (Intolo, Carman et al., 2010) in a laboratory. However the study used the device in a more secure position (taped directly on the skin) than occurs when used clinically, and the validity of the device when placed on a subject's belt may be less. It has not been used in studies comparing subjects with and without LBP, so its sensitivity to subtle differences in posture is unknown. It has been shown in case-studies that the device may have clinical utility (Horton and Abbott, 2008), although larger clinical trials are required to confirm this.

Another type of accelerometer (ActivPal, PAL Technologies, Glasgow, UK) appears to be very useful in discriminating overall body postures (e.g. sitting / standing / walking) (Ryan, Grant et al., 2008; Ryan, Grant et al., 2009). It has also recently been used to monitor the degree of movement in sitting (Telfer, Spence et al., 2009). Similar to the SpineAngel, it can also monitor postural data for several days. The use of a second ActivPal device on the thigh can differentiate between sitting and standing tasks. However, it can only monitor shifts in trunk posture, rather than spinal angle. The device therefore does not truly measure lumbo-pelvic posture, but instead the amount, and speed, of trunk movement. The reliability and validity of the device as a measure of lumbo-pelvic or spinal posture has not been established. However, since it is not attached directly to the lumbar spine or pelvis, its validity may be poor. It cannot provide real-time postural feedback. While the number of shifts and transitions of posture measured by the device is related to seated discomfort in healthy subjects (Telfer, Spence et al., 2009), it has not been tested in subjects with LBP. Furthermore, it has not demonstrated an ability to differentiate between tasks involving lumbo-pelvic flexion and extension. Since it does not provide feedback, the FOG is not suitable for feedback intervention studies.

Another accelerometer (Analog Devices Inc., USA) appears to be very useful at monitoring the duration spent in static or dynamic trunk postures, as well as determining the length of time spent in flexed postures (Wong, Lee et al., 2009). However, its placement on the lower thoracic spine means it may not accurately reflect lumbo-pelvic posture. It cannot differentiate between sitting and standing tasks, and therefore requires another input to control for this. It can monitor sagital plane posture only. The output is expressed in degrees. The reliability and validity of the device as a measure of lumbo-pelvic posture has not been established. However, since it is not attached directly to the lumbar spine or pelvis, its validity may be poor. It can provide real-time postural feedback, and significantly changed the trunk posture of a single healthy subject in a case-study (Lou, Bazzarelli et al., 2001). Multiple sensors can be combined to analyse overall body posture (Nevins, Durdle et al., 2002). It has not been used in studies comparing subjects with LBP, so its sensitivity to subtle differences in posture is unknown.

Finally, the "Back Strain Monitor" (BSM) involves two accelerometers being placed on the lumbo-pelvic region. It can analyse spinal motion in 3D. It cannot differentiate between sitting and standing tasks, and therefore requires another input to control for this. It can monitor sagital, frontal and coronal plane posture. The output is expressed in degrees. It can provide quantitative angular data on mean lumbo-pelvic posture during the working day, and the duration spent in different ranges of lumbar flexion/extension. It has very good inter-rater and intra-rater reliability, and is capable of providing real-time postural feedback (Ronchi, Lech et al., 2008). Similar to those devices mentioned above, other aspects require further investigation such as its validity, its ability to discriminate between LBP subjects and controls, and its usefulness as a feedback device.

Overall, accelerometers are very small and easy to apply, and allow normal functioning. At the moment, the SpineAngel appears to be the most useful of these devices. None of the accelerometers described allow postural data to be collected simultaneously with other inputs e.g. trunk muscle electromyography, and all carry a risk that the signal may drift over time.

Inclinometers

Inclinometers are devices which can measure body inclinations in one or more planes, which is then converted into meaningful data regarding body postures and movements. A wide variety of inclinometers have been used to analyse lumbo-pelvic ROM in the laboratory (O'Sullivan, Twomey et al., 1997; Madson, Youdas et al., 1999; Ng, Kippers et al., 2001; Kachingwe and Phillips, 2005), as their small size and simplicity makes them relatively user-friendly. Three inclinometers used in the workplace are described here.

One device (Physiometer PHY-400, Premed A/S, Oslo, Norway) has recently been used to analyse lumbo-pelvic posture in occupational workers. The device consists of three inclinometers (attached to the subjects' chest, pelvis and thigh). In this way, the device can differentiate between sitting and standing tasks, as well as monitoring lumbo-pelvic posture and movement. Furthermore, postural data is collected simultaneously with trunk muscle electromyography data. Collection of such a range of data however, requires a relatively large datalogger for data storage during data analysis, so that the device is larger than other options. It can only monitor sagital plane posture. The output is expressed in degrees. It cannot provide real-time postural feedback. It can provide quantitative angular data on mean lumbo-pelvic posture during the working day, and the duration spent in different ranges of pelvic tilt. The reliability and validity of the device has not been established. It has been used in studies comparing subjects with and without LBP, but did not detect any subtle differences in posture. This may be related to the fact that its placement means the output is likely to reflect pelvic and thoracic motion rather than true lumbo-pelvic posture. Since it does not provide feedback, it is not suitable for feedback intervention studies.

The "Virtual Corset" inclinometer (VC-323, Microstrain, Inc., Williston, VT) is placed on the mid-thoracic spine as a means of estimating overall trunk angle, rather than true lumbo-pelvic posture (Teschke, Trask et al., 2009; Trask, Teschke et al., 2010). It can be synchronised with other inputs e.g. electromyography. It can monitor both sagital and frontal plane motion. It cannot differentiate between sitting and standing tasks, and therefore requires another input to control for this. It can monitor sagital and frontal plane posture. The output is expressed in degrees. It does not provide feedback. Similar to many of the devices already mentioned, other aspects require further investigation such as its reliability, validity, and its ability to discriminate between LBP subjects and controls.

The "Portable Posture Registration Set" (PPRS) uses an inclinometer over the L2/3 region to analyse trunk flexion. It has been used successfully in a variety of occupational settings (Burdorf, Derksen et al., 1992; Derksen, Van Riel et al., 1994; Jansen, Burdorf et al., 2000). It estimates overall trunk angle, rather than true lumbo-pelvic posture. It can be synchronised with other inputs e.g. potentiometers, although this makes the device relatively large. It can only monitor sagital plane motion. It cannot differentiate between sitting and standing tasks, and therefore requires another input to control for this. The output is expressed in degrees. It does not provide feedback. Similar to many of the devices already mentioned, other aspects require further investigation such as its reliability, validity, and its ability to discriminate between LBP subjects and controls.

Other inertial sensor devices

A real-time gyroscopic system (containing gyroscopes, gravitometers and magnetometers) has been described, and is capable of 3D analysis of the lumbar spine (Lee, Laprade et al., 2003). Posture and movement data obtained is reliable within-session, but no other data is available currently. A similar approach to total spinal analysis (containing gyroscopes, accelerometers and magnetometers) has been validated against a laboratory-based system with good results (Goodvin, Park et al., 2006). While these hybrid systems are potentially useful, and worth further exploration, a recent study demonstrated that their accuracy is much better when combined with a traditional potentiometer/electrogoniometer (Plamondon, Delisle et al., 2007). Furthermore, similar to the aforementioned devices, the reliability, validity, and clinical utility of these devices should be further investigated.

The "best" method?

Overall, each of the devices has specific advantages and disadvantages. Most are feasible in terms of size and ease of application, especially the accelerometers. Each mechanism has its own limitations. For example accelerometers, gyroscopes and inertial sensors in general carry an inherent risk of signal drift. In contrast, there is a risk that the length of FEG's, FOG's and strain gauges could be exceeded during testing. No device meets all the criteria considering the parameters measured. For example, only one of the devices (Ronchi, Lech et al., 2008) analyses in 3D. While most analysed lumbo-pelvic posture directly, this was not the case for some (Burdorf, Derksen et al., 1992; Telfer, Spence et al., 2009; Teschke, Trask et al., 2009; Wong, Lee et al., 2009; Intolo, Carman et al., 2010). Some devices cannot provide true angular data (Martin and Matthias, 2006; O'Sullivan, Galleotti et al., 2009; Telfer, Spence et al., 2009), although posture relative to ROM may still be useful (Dankaerts, O'Sullivan et al., 2006). Similarly, most cannot differentiate between sitting and standing tasks (Burdorf, Derksen et al., 1992; Vergara and Page, 2000; Dean and Dean, 2006; Martin and Matthias, 2006; Ronchi, Lech et al., 2008; O'Sullivan, Galleotti et al., 2009; Teschke, Trask et al., 2009; Intolo, Carman et al., 2010), making data interpretation difficult. Synchronisation with other inputs, which is important to understand factors such as trunk muscle activation, is only possible for some devices (Burdorf, Derksen et al., 1992; Boocock, Jackson et al., 1994; Vergara and Page, 2000;

Mork and Westgaard, 2009; Teschke, Trask et al., 2009). Some devices are reliable for monitoring lumbar motion and posture (Dean and Dean, 2006; Dolan and Green, 2006; O'Sullivan, Galleotti et al., 2009). Only a few have been validated against traditional motion analysis systems (Stigant 2000; Intolo, Carman et al., 2010) or X-ray (Thoumie, Drape et al., 1998; Smets, Dekelver et al., 2010). Very few have demonstrated an ability to discriminate between subjects with and without LBP (Bell, 2008; Wong, Lee et al., 2009; Van Hoof, Volkaerts et al., 2010). In addition, even within those devices that offer postural feedback, very few have demonstrated that they can help facilitate lumbar posture awareness in healthy controls (Lou, Bazzarelli et al., 2001; Dean and Dean, 2006) or help reduce LBP (Horton and Abbott, 2008; Van Hoof, Volkaerts et al., 2010). Considering the use of EMG as a feedback tool in shoulder pain (Herrington, 1996; Madeleine, Vedsted et al., 2006), it is a little surprising that so little research has been done using EMG as a feedback device in LBP. However, postural data appears to be at least as important in LBP as trunk muscle activation (Ng, Burnett et al., 2008; Dankaerts, O'Sullivan et al., 2009). In considering these criticisms of the available devices, it must be accepted that no device may ever meet all the desired criteria. For example a device that adds consideration of overall body posture through monitoring lower limb posture immediately increases its size. In addition, the scoring system used refers to whether the technologies have been proven to meet the criteria. For example, if a device has not been validated as a measure of lumbo-pelvic posture, it received only 1/3 marks. This is not to say that the device is not valid, but simply reflects the lack of data to support its validity currently. It may be that these devices are capable of providing excellent postural data in occupational settings. However, before any one of these monitors can be proposed as the "best" choice, further development of each device is needed. Another issue is the fact that the choice made may depend on the budget available, and the precision, and duration, of data collection that is required (Trask, Teschke et al., 2007). In terms of costs, some of these devices are not currently available for purchase (Stigant 2000; Donatell, Meister et al., 2005; Mork and Westgaard, 2009). In the event that prolonged observation (e.g. a number of days) is required, options which do not attach to the skin with tape may be preferable (Intolo, Carman et al., 2010), even at the cost of reduced precision. In some situations, analysis of lower limb posture analysis or all three planes of motion may not be essential.

Other more indirect methods of analysing, and providing feedback on, lumbo-pelvic posture are also being developed. These include pressure mapping of bodyweight through the buttocks (Fenety, Putnam et al., 2000) and the use of "smart garments" (De Rossi, Carpi et al., 2003; Dunne, 2007; Wong and Wong, 2008) and "smart chairs" (Yoo, Yi et al., 2006). While at the moment the validity of many of these options is unclear, they are worthy of further evaluation. For example, one such system incorporates three tri-axial accelerometers into a garment, and has been validated against a laboratory-based motion analysis system with relatively small differences between them (Wong and Wong, 2008). This garment has also been used to modify trunk posture, albeit in pain-free subjects (Wong and Wong, 2008). In the meantime, simple visual observation (Murphy, Buckle et al., 2004), or using video or digital photographs (Womersley and May, 2006), may still be used by some, although the level of detail on lumbo-pelvic posture provided by these is very limited compared to those discussed in this review. Furthermore, visual observations may differ significantly from direct measurements (Burdorf, Derksen et al., 1992).

In conclusion, across all devices there is a need for greater validation, and more controlled, clinical intervention studies before strong recommendations can be made.

Role of Feedback

There is some evidence from stroke rehabilitation that extrinsic feedback may assist motor recovery (Van Vliet and Wulf, 2006). A recent review of remote monitoring and training devices highlighted that while progress is ongoing "clinical validation studies and models how to implement these services.....are largely lacking" in a wide variety of areas (Hermens and Vollenbroek-Hutton, 2008). The use of innovative technologies to enhance motor rehabilitation is being considered in a wide variety of areas apart from LBP (Liebermann, Buchman et al., 2006). A recent study (Magnusson, Chow et al., 2008) used a triaxial goniometer to provide feedback on spinal posture and movement to LBP subjects. The feedback device used virtual reality training linked to a software programme, so that participants received real-time 3D feedback on their spinal posture, and used the software to replicate target postures on a display screen. The biofeedback group had significantly better outcomes in pain, ROM and quality of life after treatment, compared to a control group who did not receive this biofeedback. Nevertheless, large controlled studies with medium- to long-term follow-up are needed to determine the length of this effect. Furthermore, the device used in this study (Magnusson, Chow et al., 2008) was much too large to be used in many occupational settings, similar to some other proposed monitoring (Marras, Fathallah et al., 1992) and postural biofeedback (Donatell, Meister et al., 2005) devices. The reduction in pain is however consistent with previous laboratory-based research showing that postural feedback can reduce spinal moments in manual workers (Kernozek, Iwasaki et al., 2006). Similarly, biofeedback can reduce shoulder muscle activity in computer users (Madeleine, Vedsted et al., 2006). However, while postural feedback may have an important role to play in the management of CLBP and related disorders (Bertoti and Gross, 1988; Metherall, Dymond et al., 1996; Dean and Dean, 2006; Voerman, Vollenbroek-Hutten et al., 2006; Voerman, Sandsjö et al., 2007; Brodbeck, Degen et al., 2010; Intolo, Carman et al., 2010), it is unlikely to be a panacea for CLBP, based on the results of previous studies (Stuckey, Jacobs et al., 1986; Flor and Birbaumer, 1993; Newton-John, Spence et al., 1995). Considering the multi-dimensional nature of NSCLBP, it is therefore important to consider the overall role of postural feedback in NSCLBP. It may be most appropriate as part of a multi-dimensional rehabilitation programme which considers the individuals NSCLBP within a biopsychosocial framework. It is proposed that it is likely to benefit primarily those with mechanically-provoked, direction-specific NSCLBP, especially when it is provided as part of a cognitive functional therapy approach (O'Sullivan, 2005).

Conclusion

It appears that no postural monitoring device currently exists which meets all the criteria considered desirable for occupational monitoring of LBP. Each of the devices reviewed have some specific advantages and disadvantages. Most devices have some face validity for the measurement of spinal posture, and offer the potential for more "real-world" research and interventions. However, there are significant gaps in the development of most technologies which should be addressed before they can be recommended for widespread use. Specifically, the validity of many devices as a measure of lumbo-pelvic posture has not been established. More controlled, clinical intervention studies using the feedback devices are required. Furthermore, the data provided by many devices is more limited than that which can be obtained in laboratories. Further research in occupational settings is required to investigate the role, and significance, of postural monitoring and feedback in the management of LBP.

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EVALUATING THE EFFECTIVENESS OF THE SAFE-T-CERT SAFETY MANAGEMENT SYSTEM IN REDUCING ERGONOMIC INCIDENTS

O. Kearns, M. O'Hara and M. Kelly

Department of Mechanical and Biomedical Engineering,
National University of Ireland, Galway

Abstract

Despite widespread implementation of certified safety management systems in the Republic of Ireland's construction sector, the industry is experiencing an average fatality rate of 7.2 per 100,000 and a non-fatal injury rate of 23 per 1000 workers. (HSA, 2010). Current data indicates that up to 40% [3000] of cases are attributable to ergonomic malpractice (HSA, 2009). This study describes a widely implemented accredited safety management system used for monitoring and assessing construction safety and health performance, entitled the Safe-T-Cert [STC], and looks to analyse how effective this system is at managing ergonomic factors. A questionnaire survey was distributed to 95% of all STC certified construction companies. A 38% response rate was achieved. The results demonstrate that Irish construction companies are struggling to manage ergonomic risk and concludes that a multitude of factors act as precursors to the high prevalence of injury/illness. The research showed deficiencies in how the STC scheme manages ergonomic risk and suggests recommendations for improvement.

Keywords: Safety Management System; Safe-T-Cert; Construction; Ergonomics.

Introduction

The construction sector is one of Ireland's most diverse and demanding areas of employment. The last decade saw unprecedented growth resulting in an industry that at its pinnacle accounted for 23% of Gross National Product and gave direct employment to approximately 300,000 people (DKM, 2008). However, with respect to occupational health and safety, the construction industry has been one of the worst performing sectors in Ireland. Statistics for the years 2002 to 2007 show a fatality rate of 7.2 per 100,000 workers and an injury rate of 2,300 per 100,000 workers (HSA, 2010). As a result of the high fatality rates, the industry has historically concentrated on controlling safety hazards as opposed to the less immediate hazards associated with occupational health. St John Holt (2006) claimed that due to the high levels of accidents, neglect of the less tangible health problems has developed. It is difficult to determine the extent of occupational injury related to ergonomic issues, and more difficult to determine the extent of injury in the Construction sector due to ergonomic issues. The Irish Injuries Board (2009) showed that in relation to employer liability claims, awards for construction were the highest, making up nearly 28% of all claims. Of these, 18% of claims were for lifting and handling and 3% for occupational physiological disorders (Injuries Board, 2009). The Health and Safety

Authority in relation to ergonomic causes/origins, make reference to ergonomic injury, stating that there were 19,500 incidences of dislocation/sprain/strain and 12,373 cases of stress/depression/anxiety across all sectors in 2008 (HSA, 2009).

Schneider and Susi (1994) documented how construction, by its very nature, is ergonomically hazardous, commonly requiring numerous awkward postures, heavy lifting and other forceful exertions. The development of good ergonomic practice has been slow in the sector. Helander as far back as 1980 documented that whereas considerable ergonomic advancement had occurred in most industries, and despite the significant costs associated with accidents and ill health, the construction sector has had no parallel experience and thus might profit considerably from an application of the ergonomic practices. Much of Helander's findings still resonate in more recent literature; Resse and Edison (1999) documented how the construction industry only became interested in ergonomics or at least acknowledged the existence of this field in recent years. Research by Bust *et al.* 2004) highlights how ergonomic risk originates with design and is exacerbated by customs and practice on site. Marras and Karwowski (2006) claimed that architects commonly design construction projects with the *"end user in mind, rather than the people who will construct them"*, thus concurring with previous work of Gambatese (2003) who claimed hazards are *"designed into"* construction projects. Hess et al (2004) found that each construction site possesses unique characteristics such a management philosophy, crew composition, weather, site constraints, and building design that makes comparison and universal ergonomic management across all sites impractical.

Studies have shown that organisations that implement an effective safety management system experience heightened levels of safety performance (Bennett, 2002; Robson et al., 2007; Bottani et al., 2009). The Safe-T-Cert (STC) is a widely implemented safety management system for the construction industry. This accredited system, launched in 2000, is based on the fundamental principles of the International Labour Office – Guidelines on Occupational Safety and Health management Systems (ILO-OSH2001). It was developed jointly by the Construction Employers Federation (CEF) in Belfast, and the Construction Industry Federation (CIF) in Dublin. Accreditation to the Safe-T-Cert scheme is a three stage process:

- **Stage 1 Application:** The construction company, upon deciding to pursue accreditation, pays an initial application fee and joins a list of Registered Applicants. A synopsis of the scheme requirements is made available and the applicant commences development of all obligatory measures needed to meet the certification criteria.
- **Stage 2 Audit:** Having implemented the required systems, the registered applicant then arranges a date with the STC scheme managers for an external audit of the provisions set out. During this time the auditor will examine safety documentation, conduct site inspections and interview staff in an attempt to verify the effectiveness of the organisation's safety management system.
- **Stage 3 Audit Results:** Upon completion of the audit, the STC scheme manager is furnished with a report and recommendations from the external auditor. Depending on the findings, the scheme manager will issue official notification to the applicant as to whether or not they meet the required standard for certification.

Upon successfully achieving the award, certification is valid for a period of one year. In addition, the scheme is underpinned by the principles of continuous improvement, as successful holders of the award are given a quantitative ranking each year, with the aim being to rise through the rankings to receive, and maintain, the top grading. The grading system extends from A to F where F = Fail.

The Documentation Audit and Ergonomics

As a minimum, the Safe-T-Cert documentation audit looks for proof of the following:

1. Employer/public liability insurance policies
2. Safety statement, organisational chart, responsibility matrix
3. Copy of current health and safety policy documentation
4. Risk assessments
5. Details of current safety plans and objectives
6. Copies of statutory inspection forms
7. Evidence of accident and ill-health reporting structures
8. Company occupational accident and ill-health history for the previous three years
9. Details of any enforcement activities during the previous twelve months and/or information on any voluntary closures
10. Emergency procedures
11. Job descriptions and staff competences
12. Sample method statements and copies of written health and safety procedures
13. Independent health and safety consultant reports

Enquiries with respect to ergonomics are not explicitly required and are at the discretion of the auditor.

Methodology

A questionnaire survey was undertaken to explore the extent of ergonomic considerations within the Safe-T-Cert scheme. Although the STC encompasses both Northern Ireland as well as the Republic, the survey was restricted to the Republic only. A sample of one hundred construction companies was chosen from the publicly published list of STC certified organisations. Given that there are 105 companies accredited to STC in the Republic of Ireland, ninety five percent of these companies were surveyed. The survey was sent electronically to *"safety officers, policy makers or those with knowledge and duty in relation to the organisation's safe operating procedures"*. The survey yielded a 38% response rate.

Results and Discussion

The survey consisted of twenty questions. Findings were split into respondents' direct experiences of the STC scheme, experiences of the sector, experience of related legislation and experience of the enforcing authorities. These areas were interrogated as they relate to the industry perspective of ergonomics. The majority of responses came from companies that have held STC accreditation for over 5 years (32%) followed by those with 1-3 years certification (29%), 0-1 years certification (24%) and those who have held accreditation for 3-5 years (15%).

The main findings were as follows:

- **87% of respondents believe that it is not possible to eliminate ergonomic risk factors from all construction tasks**. Such a high percentage suggests that ergonomic risk seems to be inherent within the industry.
- **40% of construction companies are not carrying out ergonomic risk assessments.** Despite the conducting of such assessments being a mandatory requirement pursuant to the Safety Health and Welfare at Work Act [S.I. No. 10 of 2005], and ergonomic

malpractice accounting for a significant proportion of all reported non-fatal incidents, and many companies are failing to carry out one of the most preliminary steps in hazard control.

- **74% of companies believe it is not reasonably practicable to risk assess all construction tasks for ergonomic hazards**. This leaves companies in a precarious position as all the risks have not been identified or quantified.
- **87% of respondents believe that designers are not giving adequate consideration to those involved in the construction process**. Such a high response rate suggests that designers are in general contravening their duty under the Construction Regulations to design work that is suited to the individual [Section 15 (1) of S.I. No. 504 of 2006].
- **95% of companies admitted to not using any scientific means of ergonomic assessment.** This concurs with the earlier findings of Buchholz *et al.* (1996) who documented how scientific means of quantifying ergonomic risk are rarely used in construction. Buchholz attributed this to difficulties associated with "*worker mobility, obtrusiveness and cost*". While such findings might apply to direct measurements using bio-instrumentation in the form of electro-goniometry, the same cannot be said about observational techniques of scientific assessment such as RULA, NIOSH or QEC. However, the survey indicated that only 5% of companies had experience with the use of such assessment tools. As a result, it could be argued that failure to employ means of scientific assessment leaves companies reliant on simple qualitative risk assessments that may be less effective than proven scientific approaches.
- **86% of companies do not have a stand alone ergonomic policy**. The development of an adequate prevention policy in relation to safety, health and welfare at work, which takes account of working conditions, social factors and the influence of factors related to the working environment, is an integral part of the Nine Principles of Prevention outlined in the General Applications Regulations S.I. No. 299 of 2007.
- **92% of companies declared that they have never employed the services of an Ergonomist**. This figure suggests that there is a high reliance on internal ergonomic management within the Irish construction industry. The crucial issue lies in whether internal staff are competent in assessing and controlling ergonomic risk. The Safety, Health and Welfare at Work Act, 2005 requires employers to obtain "*...where necessary, the services of a competent person (whether under a contract of employment or otherwise) for the purpose of ensuring, so far as is reasonably practicable, the safety, health and welfare at work of his or her employees*" [Section 8 (2)(*l*)].
- **84% of construction companies claim to be more concerned with safety hazards as opposed to ergonomic health hazards.** Such a strong response highlights how the industry is struggling to control safety in tandem with health on construction sites. This concurs with the earlier findings of Vedder and Carey (2005) who demonstrated that the focus in construction is on reducing accidents/injuries, and that from the industry point of view, ergonomics is therefore liable to be regarded as an additional cost factor rather than a benefit.

Legislation and the Health and Safety Authority:

- **Slightly over half of the construction companies surveyed [56%] believe that the Construction Regulations adequately address ergonomics**. Such an ambiguous split may be due to the complexity of the regulatory text, as the only definitive sections that address ergonomics are Sections 37 and 87, which relate to the ergonomic design of machines and equipment. However, subjective ergonomic references are made throughout the legislation in areas such as lighting, air space, room dimensions and ventilation. Employees who are not familiar with the entire spectrum of ergonomics may miss such indications.

- **When asked if there was "Particular Risk" in the construction sector, relating to ergonomics, 79% responded that there was.** Schedule 1 of the Construction Regulations [S.I. No. 504 of 2006] lists ten categories of "Particular Risks" within the industry. Although the list is described as 'non-exhaustive', it fails to mention ergonomics specifically. Nevertheless, the majority of respondents feel that there is a definite "Particular Risk" with respect to ergonomics.
- **87% of companies have not been asked for their ergonomic policies by clients.** In the vast majority of cases, clients are not requesting details of company policies relating to ergonomics at prequalification/tender stage.
- **64% of companies feel that the systems for reporting occupational ergonomic injuries are inadequate.** Such findings correlate to recent research on both a national and international level (Drummond, 2007, Eurogip, 2002) and highlights how the majority of respondents are aware of deficiencies pertaining to the 1993 General Application Regulations [S.I. No. 44 of 1993] reporting criteria with respect to accident reporting and dangerous occurrences.
- **When asked if the Health and Safety Authority had ever carried out an ergonomic inspection of their companies' construction sites, 95% replied that they had not.** One could argue that any visit from the authority will encompass an inspection of all site provisions and not solely focus on ergonomic practices. However, the authority's Programme of Works for 2009 referred to the fact that specific ergonomic inspections will be carried out, including: "*...fifty vibration inspections to monitor compliance...seventy manual handling and display screen equipment inspections...Increase workplace inspections in occupational health areas across a range of hazards including stress*" (HSA, 2009a). Such specific targeting does not seem to have reached the construction population as a whole, thus reiterating the importance of an on-site safety management system that addresses ergonomics.

Experiences of the Safe-T-Cert

Just over half the companies surveyed [56%] confirmed that Safe-T-Cert auditors have asked to see evidence of ergonomic risk assessment. Of those that have been asked to provide evidence of such assessment, 71% were examined for the provision of noise and vibration risk assessments. When addressing the subject of ergonomics, 36% of companies were of the opinion that the scheme's main focus is on manual handling. 59% believe the scheme does not focus enough on broader ergonomic issues such as thermal stress, working posture and cognitive strain.

Conclusion

Safety management systems are accredited standards designed to protect the safety of all parties connected to an occupational activity. To be fully effective, these systems must address ergonomics. One could argue that the term Safety Management System should be changed to *Health* and Safety Management System as these systems are the mediums employed to ensure both health *and* safety at work. In today's dynamic labour market, underperforming systems that do not encapsulate all areas of risk management have limited viability as deficiencies in risk control can have serious ramifications. On the other hand, the benefits for companies who actively engage in the promotion of good ergonomic practice are numerous, e.g. increased worker retention, less litigious action, and a reduction in down-time.

This study has identified some contributing factors that make the application of good ergonomics difficult within the construction sector. Areas of legislation, design, client requirements and the conduct of enforcing authorities were all found to be underperforming to some degree and should be addressed. Under the terms of the Construction Safety Partnership Plan 2008-2010 the Construction Industry Federation are required to *"ensure annual monitoring and review of Safe-T-Cert including new developments"*. As a consequence of issues raised in the presentation of this report the following recommendations are made:

Arrange discussion groups with representatives from certified companies to see how ergonomics can be better managed. Feedback from certified parties has clearly expressed that there are major challenges pertaining to ergonomics in construction. Such concerns could be addressed in structured meetings chaired by the CIF. In doing so, the CIF also has the ability to communicate finding to the Joint Standards Advisory Panel (JSAP) which includes client bodies, professional bodies, Health and Safety Authority, Health and Safety Executive Northern Ireland and Trade Unions.

Introduce a mandatory requirement for all companies to have an ergonomic policy. The STC has the potential to ensure that companies draft and implement the provisions of an ergonomic policy. Such policies show management commitment and also provide direction for on-site implementation of ergonomic best practice.

Promote the use of competent external parties in assessing ergonomic risk and in developing safe systems of work. The report has shown how the extent of use of Ergonomists is a statistical outlier in Irish construction. Further investigation should now take place, possibly with the involvement of the Construction Workers Health Trust and the Irish Ergonomics Society, to establish how best the services of registered Ergonomists could be promoted to the construction industry.

Ensure STC auditors request proof of ergonomic risk assessments during all site inspections. Current statistics show that only 56% of companies have been asked for such documentation. As a minimum, ever site audit from the STC scheme should incorporate a request to view ergonomic risk assessments. In addition, this report recommends that assessments should be evaluated to ensure they incorporate a holistic approach to ergonomics and are not solely restricted to manual handling

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HOW COMPANIES PERCEIVE THE POTENTIAL OF HUMAN FACTORS: A CASE STUDY FROM ITALY

Tiziana C. Callari, Alessandra Re

LIDEA InterDepartmental Laboratory of Applied Ergonomics - Department of Psychology
Università degli Studi di Torino
Via Verdi, 10
10124 Torino, Italy

Tel: +39 011670.2805
Fax. +39 011670.2061
e-mail: tiziana.callari@unito.it

Abstract

In Italy, the Legislative Decree no. 81/2008 regulates risk prevention associated with workplaces and makes specific reference to human factors principles application to prevent workers' ailments, fatigue and work-related stress. To what extent has this normative framework become an integral part of the Italian companies' culture and fostered a demand for ergonomic intervention and research? The study, carried out in a North-western Italian Region, aimed to explore how local companies perceive the potential of human factors to achieve an efficient and productive organisational system and to maximise the workers' comfort, safety and health. The case-study research method was chosen as it allows to investigate phenomena in-depth within a real-life context (Yin, 2009). The results show a widespread intervention on physical aspects, but also highlight an increasing attention to the cognitive and organisational factors, offering some experiences of improved production and competitiveness due to ergonomic principles application within the workplace.

Introduction

The prevention of accidents, incidents and occupational diseases in the workplace has always been a core subject in the European Community legislation, so far to be considered a social path strategy for the promotion of European workers' health and safety. Council Directives[1] were issued to ensure a higher degree of protection of workers at work through the implementation of preventive measures and through the information, consultation, balanced participation and training of workers and their representatives.

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[1] Council Directives no. 80/1107/EEC, no. 82/605/ EEC, no. 83/477/ EEC, no. 86/188/ EEC and no. 88/642/ EEC on the protection of workers from the risks related to exposure to chemical, physical and biological agents at work.
Council Directives no. 89/391/EEC, no. 89/654/EEC, no. 89/655/EEC, no. 89/656/ EEC, no. 90/269/ EEC, 0/270/ EEC, no. 90/394/ EEC, no. 90/679/ EEC, no. 93/88/ EEC, no. 95/63/EC, no. 97/42/EC, no. 98/24/EC, no. 99/38/EC, no. 99/92/EC, no. 2001/45/EC, no. 2003/10/EC, no. 2003/18/EC and no. 2004/40/EC on the improvements in the safety and health of workers at work.

As a consequence of this attention and requirements, the EU Member States have adopted several laws having the aim of identifying and controlling the risks associated with work activities and workplaces.
In Italy, the Legislative Decree no. 81/2008 - and its subsequent modifications and integrations come into force with the Legislative Decree no. 106 of 3 August 2009 - regulates risk prevention associated with workplaces. In general, it suggests ameliorative guidelines for hygiene and safety measures, and for workplace and organisation design. The Decree reformed, harmonised and replaced some of the most important Italian laws on the issues of occupational safety and health over the last sixty years.
The Legislative Decree contains many explicit references to the human factors principles application to prevent workers' ailments, fatigue and work-related stress. The references take into account the ergonomics wider field of research: physical (workplace design and working environment analysis, in order to investigate several parameters related with workplaces and workers exposure to possible hazardous agents, like illumination, noise, heat, etc.), cognitive (considering both mental workload and psycho-social stress risk, and usability criteria in designing HCI), to the wider organisational aspects.
To what extent has this normative framework become an integral part of the Italian companies' culture? Has it been translated into workplace design or at least in specific need and demand? Our research was part of a wider project carried out in the period March 2009-February 2010, and sponsored by the Directorate of Research and Innovation of the Piedmont Region. The project, titled "Models for ergonomics management and safety in the workplace"[2], was carried out in the Piedmont Region (North-western Italy). Exploring the companies' experiences and perceived ergonomics needs, we hypothesised that, due to the lacking tradition of human factors studies In Italy, the enterprises' demand was essentially shaped by vigilance committees requirements – principally oriented to physical ergonomics measures-, rather than by the potential use of human factors to achieve an efficient and productive organisational system and maximise the workers' comfort, safety and health.
The case study research method was adopted to understand the companies' experiences and perceived ergonomics needs in the Piedmont Region territory. This method is particularly indicated when dealing with a real-life phenomenon in-depth that cannot be divorced by its context (Yin, 2009). The results were analysed through the qualitative data analysis software ATLAS.ti. They show mostly a widespread knowledge and intervention on physical aspects within the workplace. Moreover, an increasing attention to the cognitive and organisational factors seem to begin to take root, in particular in big companies, with some experiences of improved production and competitiveness due to ergonomic principles application.

Methods

The research design was planned to understand the explicit and implicit ergonomic needs of the Piedmonts companies. To reach this objective a case-study research method was used, as it "*allows to retain the holistic and meaningful characteristics of real-life events*" and to understand complex social phenomena "*especially when the boundaries between phenomenon and context are not clearly evident*" (Yin, 2009).
The research design was organised in two main stages: a first "exploratory" stage followed by a "descriptive" one. The "exploratory" stage involved professional ergonomists from the private and public sector as *qualified witnesses* (Corbetta, 2003), to comment the current human factors Italian state-of-the art and suggest ameliorative aspects to the research design. The "descriptive"

[2] For further information go to the project website: http://www.ergonomia.corep.it/

stage was designed to cover both a top-down and bottom-up approach in the needs analysis, involving for the former the Italian three main Trade Unions (CGIL, CISL and UIL) and the Piedmont's Employers Associations (UI, API Torino, Casa Artigiani Piemonte); for the latter, 30 local companies of different sectors and dimensions. The objective of this stage was to investigate how and why human factors can represent a key-factor on safety and productivity aspects, and to state the on-going ergonomics best practices of the enterprises operating in the Piedmont Region.
The results were analysed through the qualitative data analysis software ATLAS.ti.

1. Exploratory stage

Sample

13 professional ergonomists from the academic and private sector, invited as *qualified witnesses* (Corbetta, 2003) to participate in a focus group.

Instruments and procedure

The focus group technique was used to investigate the consensus on, and the social context of (Fern, 2001) the ergonomics application in Italy. The following topics were explored:

- What is the ergonomics state-of-the-art in Italy, taking into account the last 20-year trend?
- Can human factors fail in its proposal to the Italian companies? Is it considered an added value or a mere added cost? Is ergonomics perceived as a constitutive part of the manufacturing process design?
- What are the most frequent ergonomics areas of application, with reference with its domains and specialisations?

The ergonomists then shared the research design to be carried out in the following "descriptive" stage.
The general ethical considerations were ensured. The focus group was tape-recorded and integrally transcribed.

2. Descriptive stage

Sample

The Italian three main Trade Unions (CGIL, CISL and UIL) and the Piedmonts Employers Associations (UI, API Torino, Casa Artigiani Piemonte) were involved in two focus groups aimed at defining the human factors needs of the Piedmonts' companies they represent.
Consequently, 30 enterprises from different economic activities and dimensions, operating in the Piedmont Region, were contacted using a snowball sampling. The companies were classified according to the ATECO code 2002, taking into account the hazardous sectors in the Piedmont Region (INAL, 2002-2006[3]).

Table 1. Economic activities analysed – ATECO code 2002 per company involved

Code	Type of activity	No of companies
DM	means of transport production	4
DA	food, beverages and tobacco industry	3
DB	textile industry and clothing	3
DG	chemicals and man made-fibres	1
DK	machines and machine tools	4
F	Constructions	2
G	wholesale and retail commerce, restoration	2

[3] For further information go to: http://bancadati.inail.it/prevenzionale/

H	hotels and restaurants	1
I	transports, storages and communications	4
K	real estate, renting, technologies, search, services	2
N	health and social services	4

Instruments and procedure

30 Managers, Workers Representative for Health and Safety (*Rls- Rappresentante dei lavoratori*) and Managers and Operators for Prevention and Protection Services (*RSPP- Rappresentante del Servizio di Prevenzione e Protezione*) were contacted for a semi-structured interview (Schensul, Schensul, & LeCompte, 1999)of about 60 minutes. The open-ended questions, shared and validated during the "exploratory" stage, contained the following aspects:

- Company data;
- Possible presence of a specific working group related to human factors;
- Successful and unsuccessful experiences related to human factors;
- Specific domains of application (physical ergonomics, environmental ergonomics, cognitive ergonomics, organisational ergonomics);
- Different typologies of human factors interventions (design, evaluation, training, accidents and near-miss analysis).

The interviewers were given a brief description of the purpose and procedure of the research, including the expected duration and the guarantee of anonymity. All the interviews were tape-recorded and integrally transcribed.

Data analysis

The data was categorised in a Hermeneutical Unit through the data analysis software ATLAS.ti. All the Primary Documents (each transcript from the 3 focus groups and the 30 interviews) were classified in codes and super-codes related to the main topics of the semi-structured interview (see Figure 1.) and in Families (according to the project's main objectives).

Every Primary Document's classification has been validated by three independent judges to achieve a high degree of consistency.

Figure 1. Table of main topics from semi-structured interview

Company data		
	Role of contact:	
	Sector:	
	Products/services:	
	No. employees	
	Place/province	

	NEEDS			ESPERIENCES AND AVAILABLE RESOURCES				R&D	
	of human factors (problem, methods/instruments, objectives ...)	training (past/future)	information access methods, norms, ...)	successful stories	unsuccessful stories	tools	external consultacy: consultants, university, centres of research, ...	evaluation (tools, workplace, processes and activities, products)	design (tools, workplace, processes and activities, products)
Physical ergonomics									
Environmental ergonomics									
Cognitive ergonomics									
Organisational ergonomics									

Results

The HF needs perceived by the ergonomists

Since the early 1990s, the Italian Ergonomics Society[4] (SIE) developed at a national level a theoretical framework that overcomes the classic definition of ergonomics as "crossing of disciplines" (Sperandio, 1984) in favour of a discipline with deep internal specialisations. With reference to that, the HF experts highlighted the difficulty for a staff-ergonomist to cover with his own competence all the ranges of intervention. It is therefore important both to make reference to an internal ergonomist, and to external independent organisations and/or centres of research involving ergonomists competent in specific domains, cooperating in integrated way.
Human factors are not merely considered an "added value" for companies to improve productivity and performance, since the concept "added value" refers to something optional. Ergonomics should rather be defined a "necessary cost", embedded in the production process, from the planning phase. Therefore, it is important to act from the educational and training level on the relevant decision making profiles, both engineers/designers, and management/ organisational experts, to respond to the companies demands on the organisational ergonomics issues.

The HF needs perceived by the Social partnership

The Piedmonts Employers Associations (UI, API Torino, Casa Artigiani Piemonte) agreed that the interest for human factors is higher for the physical aspects, i.e. biomechanics analysis. They did not perceive current concern for problems caused by cognitive aspects (like mental workload) or correlations between ergonomics and work organisation. They commented that the general companies' perception is ergonomics like a cost, a normative requirement, this applying in particular for SMEs. Few SMEs can afford to have professional ergonomists in payroll and often they delegate health and safety risk assessment to third parties. This is not presented as a pure delegation of responsibilities in the areas of injury prevention, workplace hygiene, worker health and safety, but also as a possibility to refer to professional experts updated with technical knowledge, law requirements and institutional deadlines. Companies need assessment instruments that can fit the law requirements and assure the same results if performed by different people.
The Italian three main Trade Unions (CGIL, CISL and UIL) pointed out how in this period of recession work conditions are under question. In a moment were companies are closing down, time production and workload are perceived as not negotiable. It seems companies are returning to time-motion study methods and therefore it appears important that human factors principles are trained to people designing production timing. Not only ergonomics principle are to be practice and implemented by employers, but by the employees themselves, to avoid situations were health and safety issues are under risk. The Trade Unions commented about the difficulties of the process for asking for the recognition of professional diseases, so that a high number of them is not recognised as such.

The HF needs perceived by the enterprises

The results showed a great attention from the enterprises on the issues related to safety, health and risk prevention, also as a result of Legislative Decree Law no. 626/1994 and 81/2008. The enterprises are becoming aware that security and health safeguard includes not only prevention from technical and environmental risks, but also attention to organisational, psychological and mental workload aspects.
The *physical ergonomics* is the most known and studied domain. Companies invest to reduce physical workload, in a view not only to improve the production process, but to meet the law and vigilance committees requirements. Workplace analyses are performed to comply with the law with a constant attention to problems related to manual handling of loads and possible

[4] For further information go to: http://www.societadiergonomia.it/

solutions linked to automation. It seems that Piedmont's companies are returning to time-motion study methods with more attention to the ergonomic aspects.

The *environmental ergonomics* is perceived just as subject to certain amount of working environment analysis, performed in order to investigate workers exposure to physical agents (such as electromagnetic radiation, noise and vibration), biological agents, chemical substances and to check the adequacy of illumination, temperature, humidity and ventilation in the workplaces. The environment is not analysed in terms of climate assessment and perceived work environment.

Companies showed polarised positions with reference to the *cognitive ergonomics* domain: from the one side, cognitive ergonomics is meant just related to attention and vigilance requirements from the production technology or in interaction with the software (HMI - human-machine interface); from the other hand, some companies are starting to be aware of the problems related to mental workload, as a crucial element embedded in the operativeness within a complex system. But still, mental workload is little either analysed or assessed.

There is still low knowledge on *usability* aspects and interventions are merely linked to adoption of functional requirements. This seems to lead to a form of "delocalisation of responsibility" for the cognitive workload: possible errors made from the worker when in interaction with the software are charged either to the machine, sent back to the producer for improvement, or directly to "the distracted" operator. Problems in using "troubled" software are solved with specific training or "usage tricks".

At last, coherently with the expectations, the *organisational ergonomics* domain has turned out to be the hardest to detect, both in the knowledge and practice. This does not mean that the companies are not aware of the organizational problems at a work system level: for some it is related to the ICT system; for others to the organisation improvement as pre-condition for physical ergonomics problems reduction.

Moreover, companies complain a discrepancy between prescribed work - what is indicated in risk assessment work analyses – and real work (Clot, 2006; Daniellou, 2005, Leplat, 1993) – what effectively is carried out. Suggestions are provided and workplaces are designed without involving either the operator or a direct analysis *in-situ.* This awareness, confirmed by some successful experiences, can be explained by a growing trend to analyse the working environment as an interconnected system for human factors interventions.

One of the fields in which companies keep on investing is *training*, sometimes urged by law requirements compliances, sometimes by concrete interests, as one of the possible processes to improve work situations. HF training target groups are all the people directly managing health and safety within the company, i.e. Workers Representative for Health and Safety, Managers and Operators for Prevention and Protection Services, designers, consultants, operators from vigilance committees, SMEs employers.

Use and development of *risk assessment instruments* are mainly related to the action of vigilance committees on physical ergonomics aspects (mainly check-lists, NIOSH, OCRA index). There are cases where these instruments are of difficult application as they seem to be not congruent with the characteristics of the real work analysed. This difficulty shows up in the analysis of not repetitive activities. For this reason, some companies have proceeded to design *ad-hoc* instruments taking into account the peculiarity of their productive activity. Risk assessment analyses are conducted by structured personnel or external consultants, depending on the companies' resources.

Finally, the companies show a specific attention in complying with the law obligation. On the other hand, the interviewers complained how the law is far from the real requirements and characteristics of the company, as if the assessments were like snapshot of the activity and the connected risks. Risk analysis instruments evaluate a situation as remaining the same over the time, always carried out by the same operator, while operators often change, and the working situation can be at risk of fast obsolescence. Consequently, some more structured companies appear to count on inner resources to carry out a constant monitoring of the activities; on the other hand, smaller-sized enterprises are more oriented to keep up with the law requirements.

Discussion

The study showed a widespread knowledge and intervention on physical aspects, in particular related to the necessity of positively responding to the Law's vigilance committee actions. Even if it is growing an attention to improve the workers' work conditions, the interventions are mostly concentrated on the workplace rather than in a view of a wider spillover effect on the organisational productive efficacy and competitiveness. The companies, even small enterprises, who carried out a work analysis to review some instrumental and organisational aspects, have assessed these experiences as positive not only for the workers, but for the organisation itself.
An increasing attention to the cognitive and organisational factors seem to begin to take root, in particular in larger companies, with some experiences of improved production and competitiveness due to organizational ergonomics principles application.
Training remains one of the key-factors to build competences within the companies; to create a culture toward an efficient safety and health management when it does not still exist, or to reinforce it when it is already applied. The main targets of training activities are the workers' representatives (Workers Representative for Health and Safety and Managers and Operators for Prevention and Protection Services), involved in update courses on law's application and risk assessments.

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