

Wearable simulations for ill-health conditions in construction

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Summary

Occupational ill-health and wellbeing is a significant challenge for workers in the civil engineering and construction sectors. The symptoms of many ill-health conditions become more severe over time and minor aches and pains in a young worker can develop into serious problems the older they get. Health and safety training has increased in recent years and site inductions are now ubiquitous. However, formal training methods seem to have little effect. Evidence-based, wearable simulations for common construction ill-health conditions have been developed from over 20 years of university-based research. The LUSKInS simulations provide experiential learning experience for dermatitis, hand-arm vibration syndrome, musculoskeletal disorders, noise induced hearing loss and respiratory disorders and are being trialled with young apprentices aiming to change their attitudes and behaviours.

Key words

Health & safety; safety & hazards; education & training

Why is occupational ill-health such a problem for construction?

Occupational illnesses are a significant problem for construction. The 2011/2012 UK Labour Force Survey estimated that 74000 people whose current or most recent job in the previous year was in construction, suffered from an illness (longstanding and new cases) which was caused or made worse by their current job (HSE 2013). A total of 818 000 working days or 0.4 days per worker in 2011/2012 were lost due to self-reported work related illness (HSE 2013). In addition, HSE have published figures that show that construction significantly exceeds the all-industry incidence rates with respect to musculoskeletal disorders, occupational dermatitis, work-related hearing loss, mesothelioma and asbestosis, with vibration-related disorders only being surpassed by the extractive industries (HSE 2009). The economic and human costs related to occupational illnesses are substantial, for example, sickness absence costs the UK economy an estimated £12 billion per annum (HSE 2013). It is therefore essential that workers' occupational health is taken seriously and managed properly.

Younger workers (aged 15-24) make up 24% of the construction workforce and, while they have a lower average risk of developing occupational illnesses than older workers, occupational illnesses often need cumulative exposure and or latency period to develop and may not always be recognised due to short term work contracts (ESAW 2007). Protecting the health of younger workers is critical to the sustainability and long term economic performance of the construction sector and also of great importance for the health and wellbeing of the young people themselves.

Table 1 shows the most prevalent ill-health conditions in construction (latest available data HSE, 2009). Other publications cover these conditions in considerable detail (e.g. McAleenan & Oloke 2010 and Gibb *et al.* 1999). Diffuse pleural thickening, mesothelioma and asbestosis are all directly linked to historical asbestos exposure. Stress is also a significant ill-health issue for construction. Other than these, the main ill-health conditions are: musculoskeletal disorders (affecting upper limb, spine/back and hands), dermatitis, asthma and occupational deafness.

Figure 1 LUSKInS Dermatitis Glove



Figure 2 Dermatitis Glove worn by an inquisitive apprentice bricklayer



Table 1 Construction and 'all industries' ill-health data, 2005-2007 (adapted from HSE, 2009a)

| Condition | Average annual rate per 100,000 | | | |
|-------------------------------|---|----------------|---|----------------|
| | Hospital cases reported by specialist doctors | | Disablement benefits prescribed disease cases | |
| | Construction | All industries | Construction | All industries |
| Diffuse Pleural Thickening | 28.5 | 4.6 | 12.8 | 5.8 |
| Mesothelioma | 14.5 | 2.7 | 44.7 | 2.8 |
| Asbestosis | 2.4 | 0.6 | 21.7 | 1.4 |
| All MSDs | 8.0 | 7.0 | 0.8 | n/a |
| <i>Upper Limb Disorders</i> | 6.0 | 5.0 | n/a | n/a |
| <i>Spine/Back Disorders</i> | 1.0 | 1.0 | n/a | 0.5 |
| <i>Vibration White Finger</i> | 1.0 | 0.4 | 6.5 | 0.8 |
| Dermatitis | 6.0 | 6.0 | 1.2 | 0.7 |
| Stress | 2.0 | 7.0 | n/a | 1.5 |
| Asthma | 1.0 | 1.0 | 0.9 | 0.0 |
| Occupational Deafness | n/a | n/a | 2.4 | 0.9 |

What is the role of training for health and safety?

Training is a fundamental requirement for preventing occupational illnesses and improving the industry's occupational health performance, particularly for younger workers who are still developing their attitudes, skills and competencies (Nyateka *et al.* 2012). The provision of training by employers, along with periodical refreshers is an explicit requirement of the UK's health and safety legislation and research emphasises its importance (Dufficy 2001, Loosemore *et al.* 2003, Linker *et al.* 2005, Mowlam *et al.* 2010, Burke *et al.* 2006). Inadequate or lack of, occupational health training has been identified as an important contributing factor to the high incidence rates within the industry (Tam and Fung 2011, Guo *et al.* 2012, Wallen and Mulloy 2006).

Why do participative techniques work better than 'chalk and talk'?

Much conventional learning practice, including most construction training courses, tends to focus on abstract knowledge over actual practice, relying particularly on traditional trainer-centred approaches (Nyateka *et al.* 2014). Workers are typically sat down in a classroom-like setting and spoken to by "experts" supported by PowerPoint, booklets and videos and are then expected to apply this abstracted knowledge later in the workplace (Gherardi and Nicolini 2002). These approaches isolate knowledge from practice and are often ineffective due to a failure to actively engage learners; the emphasis on auditory learning as opposed to styles such as visual or tactile learning; the assumption that all trainees learn at the same pace and have similar levels of understanding; and the risk of information loss due to their passive nature (Piercy *et al.* 2012).



Figure 3 Worker climbing ladder wearing upper limb disorders and HAVS simulations

Many education experts emphasise the way that knowledge is socially situated, particularly the role that activity, participation and experience play in learning (Abdulwahed & Nagy 2009; Goedert *et al.* 2011; Pasin & Giroux 2011 and White 2010). Experiential learning occurs when “knowledge is created through the transformation of experience” (Kolb 1984). Experiential training methods are increasing, albeit mainly in non-construction contexts (DeshPande & Huang 2009; Mawdesley *et al.* 2011; Li *et al.* 2007 and Piercy *et al.* 2012). Learning by doing distinguishes experiential learning from passive learning using traditional classroom-based lectures. Examples include simulations, role-plays, laboratories, fieldwork and live cases (Hawk & Shah 2007). Piercy *et al.* (2012) argue that experiential teaching has strengths including:

- active engagement of trainees in their own learning;
- stimulation of interest in the subject;
- opportunity to learn how to work in often diverse groups;
- acquisition of high order skills (teamwork, communication, conflict resolution, presentation);
- application of theory to practice, and,
- trying out ideas in a safe environment.

Recent literature highlights the need to embrace new ways of learning, actively engaging the learner (DeshPande & Huang 2009; Goedert *et al.* 2011; Mawdesley *et al.* 2011). Goedert *et al.* (2011) argue that simulation-based learning addresses the fundamental need to reinvigorate training methods and approaches in construction, which “have changed little in over a century”.

An innovative mechanism for increasing understanding is by empathic modelling “whereby an individual, using various props and scenarios, is able to simulate the deterioration of physical and perceptual abilities in everyday scenarios” (Nicolle and Maguire, 2003). The LUSKInS (Loughborough University **S**ensory **K**inesthetic **I**nteractive **S**imulations) can be worn by those without particular ill-health conditions to enable them to directly experience for themselves something of what it feels like to suffer the condition.

How were the LUSKInS wearable simulations developed?

Previous research and developments

The authors have been researching into occupational health in construction since the early 1990s (e.g. Gyi *et al.* 1998). The focus on ageing in construction grew from a broader interest in vulnerable

workers, which had previously focussed on migrant labour. This ageing research began in 2006 with research funding from SPARC, the research councils' pump priming initiative for strategic promotion of ageing research (e.g. Gibb *et al.* 2013). This was followed in 2008-2012 by work with the New Dynamics of Ageing programme, a multidisciplinary research initiative to ultimately improve the quality of life of older people (e.g. Yolande Williams *et al.* 2011). Other on-going work includes doctoral research funded by Age-UK, investigating construction workplace design to help people to work more healthily for longer, should they choose to (e.g. Eaves *et al.* 2014).

Alongside this research stream, Loughborough University has also been active in the design and application of wearable simulations for 20 years, building upon its development of its first whole body simulation of ageing, the 'Third Age Suit' in 1994. This was developed for Ford Motor Company to raise awareness of the needs of older drivers amongst the predominantly young design team leading to more empathically designed vehicles (Hitchcock *et al.*, 2001). A simulation of osteoarthritis was subsequently commissioned by Napp Pharmaceuticals to increase the prominence and understanding of the condition within the medical profession. This was later purchased by Stannah Stairlifts to improve the appreciation of osteoarthritis within their sales and designs teams. These simulations have also been employed in Europe, North and South America, Asia and Australia and across a range of domains (automotive, aerospace, architecture, health, finance, mobility, education and public engagement); always with the underlying aim of changing attitudes and behaviour through improved awareness. One reason for the success of the simulations is their contribution to the experiential learning process and, given the need for a stronger focus on occupational health within construction, it was considered that this approach could significantly contribute to training in this area.

LUSKInS development in more detail

Cook *et al.* (2009 & 2012) have covered the evidence-based development of the LUSKInS which was funded by the Engineering and Physical Sciences Research Council (more information on the research methods and data can be found on the ICE Journal website or is available from a.g.gibb@lboro.ac.uk). A comprehensive literature review and interviews with health professionals developed an appreciation of the health conditions based upon observations across a range of patients. Interviewees either had specific knowledge of construction occupational health or were specialists in the particular health conditions. Interviews with workers with the conditions added detailed, personal experiences. These complementary methods provided a data-rich underpinning to the research. Data were collated and analysed as follows:

- Description, symptoms, severity progression, frequency, impact and severity measures - used to inform the simulation design.
- Causes, risk, industry prevalence, aggravating factors, avoidance and treatment - used to provide context/rationale for the simulations.

A specification was developed and reviewed by specialist health professionals covering mild, moderate and severe forms of the five health conditions using this refined data. This research progressed beyond simulations developed solely from subjective data to those underpinned by objective measures, for example, objective data relating to noise induced hearing loss (NIHL) is provided in Table 2.

Table 2 LUSKInS - Occupational Health specification for noise-induced hearing loss (NIHL)

| | | Symptoms - Level of severity | | |
|-------------|-------------------------|---|--|---|
| | | Mild | Moderate | Severe |
| NIHL | (Objective data) | Selective hearing loss (around 4000 Hz) – only some words are missed. | Hearing loss progresses to middle frequencies (3000 – 6000 Hz) | High frequency hearing lost, low frequency hearing impaired (500-2000Hz). |
| | | Hearing loss at 21-40dB. (40dB equivalent to talking in a quiet voice). | Hearing loss at 41-70 dB. | Hearing loss at 71-95 dB. |

Development of the simulations was a creative, iterative process, driven by the specification requirements, and encompassing additional important design considerations including: goodness of

fit; ethics; cost; materials and technology; durability; and hygiene. As well as identifying items which would deliver the 'symptomatic' requirements of the simulations, further components were required to maintain these items in the appropriate position relative to the wearers' body e.g. gloves to which symptomatic elements for dermatitis and hand-arm vibration syndrome (HAVS) were secured.

Developmental workshops explored the extent to which the candidate items delivered the desired effect in a safe manner. For instance, itching powder to simulate dermatitis, whilst meeting the specification, was excluded due to a potential adverse reaction. The items were then further screened for inclusion against: goodness of fit; cost; anticipated robustness; ease of fitment/attachment within the simulation and hygiene. The prototyping stage combined the individual items into an integrated simulation.



Figures 4 & 5 MSD and HAVS simulations in action on site

Previous simulations were only concerned with conveying the overall sensory aspects of the symptoms. However, with dermatitis, the psychological impact is also significant e.g. some sufferers had a restricted social life because they are too embarrassed to go out. Therefore, photos and diagrams of dermatitis at mild, moderate and severe levels were provided to a special effects film modeller who produced gloves for each severity level. The glove format for the visual simulation was chosen to offer most realism to the wearer. However there were problems in the glove's development including the need to incorporate sufficient elasticity to accommodate a range of sizes since, traditionally, such work is bespoke to a specific actor. In addition each glove was hand finished and therefore costly, so the HAVS visual simulations were made as solid 3D silicone models.

A digital based system offered greatest flexibility and highest fidelity for noise induced hearing loss (NIHL) for the shape, number and accuracy of the audiograms. However this approach was rejected on cost grounds and a simplified, linear system employing a number of fixed filters adopted. This had audio inputs via a lapel-microphone, channelled through a selected filter, then delivered directly via earphones. The prototype struggled to represent the full impacts of the condition due to the direct conductance of external sounds, including the speaker's voice, through the skull and foam eartips, by-passing the attenuator. Therefore, the final solution replaced the face to face conversation with a mobile phone conversation so the speaker could be in a different room from the hearer.



Figure 6 Tactile dermatitis glove

How are these research outputs being applied in industry?

The National Construction College (NCC) and the Health and Safety Executive (HSE) reviewed the simulations as awareness raisers and identified design improvements. One training expert commented that “representation of the symptoms cannot be presented in any other way – they is a huge potential benefit for the industry”. The NCC agreed to a trial application to determine their effectiveness in driving attitudinal change in younger workers.



Figure 7 LUSKInS HAVS generating interest and engagement



Figure 8 Even in the packaging the visual simulations look impressive

The NCC is the largest training provider in Europe providing courses for new entrants to construction. The trial, involving construction apprentices in various trades including scaffolding, roofing, steeplejacks and plant operators, comprised:

- A preliminary attitudinal survey at the start of the first training course (n=161)
- Video-recorded and field-noted observations of existing courses (without LUSKInS) (Control sample) (n=91)

- Video-recorded and field-noted observations of courses implementing the simulations (n=70)
- A follow up survey at the end of the first course:
 - trainees not using LUSKInS (Control sample) (n=50)
 - trainees experiencing LUSKInS (n=62)
- In-depth recorded interviews with experienced trainers / health and safety practitioners (n=9) and trainees (n=16)

The majority (58%) of the apprentices were aged 21 years and under, 27% were between 22 and 24 and 15% were over 25. Despite this being their first industry training course, 79% said they had already received some health and safety training, with most citing either school or site inductions. However, most of this prior training (73%) had been non-interactive 'lectures' or formal tasks. DVDs (61%) and booklets (39%) had been used whilst 22% indicated some use of more hands-on approaches. These findings support previous studies (Deshpande and Huang, 2009; Gherardi and Nicolini, 2002), finding that classroom-based lectures remain the dominant training method in construction. 83% of apprentices' preferred highly active learning environments and engaging methods, even though they had not experienced these much previously. This is not surprising since, by choosing the apprenticeship route, they had chosen to leave the more academic environment of post-16 schooling. The findings about methods of training support Mowlam *et al.* (2010) and Goedert *et al.* (2011), who found a preference among young learners for interactive and innovative learning methods.

During the session observations, the researcher took field notes, comprising phrases, key words and quotes as well as sketches of the room and position of the participants. Full field notes provided a log of observations as well as recording the researcher's impressions and feelings.

It is notoriously difficult to obtain rigorous data regarding attitudinal or behavioural change as a result of interventions. A multiple baseline approach (e.g. Lingard *et al.* 1998) was not possible in this case but is planned for future trials. Notwithstanding, the application to date has clearly showed that the apprentices were far more engaged when using or observing the simulations and, their verbal feedback strongly supports the view that their understanding has grown and their attitudes towards health issues has changed for the better. Quotes from trainees included:

- *"Once I'm doing something practical, I remember it much easier"*
- *"I get a better understanding with a more hands-on approach to learning"*
- *"I get bored with handbooks and lectures"*
- *"Engaging keeps people alert and focussed"*
- *"I don't take in things from reading or being told, it's easier for me to watch and try out"*
- *"I concentrate and learn more with engaging methods and training is enjoyable"*



Figures 9 & 10 Apprentices trying on the LUSKInS simulations

The simulations definitely engaged the trainees and stimulated considerable discussion, for example:

- "...a lot of the older lads, they've got that now (hearing problems). I sound like a bit of a geek 'cos I always put my ear plugs in... obviously as a 50 year old you don't want to be going 'eh?' - That's how they do it."
- "You couldn't work like that (with severe HAVS)... especially what we're doing... working at height... if you can't grab something properly you could drop it and kill someone."
- "I've got 'girly' hands, me and I'm staying that way." (commenting on the dermatitis gloves)
- "You're pressured to get on with the job and you do it. You're standing there with loads of people around you saying: 'come on!' Your supervisor is there saying: 'come on guys!' So you just grab something and do it." (discussing manual handling whilst watching a classmate wearing the MSD simulation)

A young worker losing his hearing

The noise induced hearing loss (NIHL) demonstration required an apprentice to listen to music channelled from his phone through the NIHL equipment. They were asked to tell the group what they were experiencing as the settings were changed to simulate mild, moderate and finally severe NIHL conditions. Observing a classmate using the simulation, another worker realised that he had a problem with his hearing.

"My girlfriend accuses me of having 'selective' hearing and I have to turn the TV up very loud"

Apparently, on his site, a number of the older workers did not wear ear defenders and had difficulty hearing. His work involved applying fixings to a building using hand-held power tools close to his head and he had not been wearing any hearing protection. He had been told by the other workers to: "Man-up for a couple of weeks and you'll get used to it". He had not previously made a connection between the work and hearing problems of his fellow workers until the demonstration but was now determined to get his hearing checked and wear the PPE.

The discussion then opened up on the importance of speaking out against practices with risks to workers' health.

What does this mean for civil engineers and construction managers?

Research into age-exacerbated, occupational ill-health conditions in construction is continuing and yet workers are still behaving as if they were invincible and as if their bodies were immune to the combined effects of a harsh construction environment and the natural ageing process. The message is not penetrating the workforce, despite the increase in training and site inductions. More of the research needs to be made relevant to practice. In this case, the researchers have taken findings beyond theory and developed wearable simulations. The effectiveness of these simulations is being evaluated in the context of seeking to drive attitudinal change in young apprentices, hopefully to motivate them to play their part in reducing the likelihood that they will develop these conditions. More work is needed, but this is an encouraging start.

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