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Han T. Yeoh, Thurmon E. Lockhart & Xuefang Wu. *Non-fatal occupational falls on the same level.* Pages 153-165.

The purpose of this study was to describe antecedents and characteristics of same level fall injuries. Fall incidents and costs were compiled from the Bureau of Labor Statistics and other sources from 2006–2010. This study indicated that over 29% of 'fall on same level' injuries resulted in 31 or more workdays lost. The major source of injury was 'floors, walkways or ground surfaces', and the most affected body parts were the lower extremities and the trunk. With regard to gender and age, female workers had the highest risk of falls, while advancing age coincided with an increase in incidence rates. Overall, workers in the healthcare and social assistance industry, the transportation and warehousing industry, and the accommodation and food services industry had the highest risk for 'fall on same level' injuries. Furthermore, the overall compensation cost increased by 25% from 2006–2009. Along with existing evidence, these results may facilitate the design and implementation of preventative measures in the workplace and potentially reduce fall-related compensation costs.

Practitioner Summary: This research presents a unique and detailed analysis of non-fatal 'fall on same level' injuries in a large population of workers from various private industries in the USA. This information can be used to prioritise designing and implementing preventive measures and to provide workers with the understanding of risk factors associated with falls in the workplace.

- **Keywords:** falls, fall on same level, occupational injuries, characteristic of injured workers, consequences of occupational fall

Stephen Bao, Barbara Silverstein & Kate Stewart. *Evaluation of an ergonomics intervention among Nicaraguan coffee harvesting workers.* Pages 166-181.

This study evaluated an ergonomics intervention among Nicaraguan coffee harvesting workers, using electromyography and questionnaire survey techniques. Nicaraguan researchers were involved in the study so that they could gain hands-on experience with ergonomics research and applications, and eventually be the specialists conducting ergonomics interventions in Nicaraguan workplaces. Coffee harvesting activities were studied individually and physical hazards were identified accordingly. The results showed decreased muscle loading on the erector spinae muscle and improved comfort reporting in the back region compared to the commonly used baskets. This fulfils the design

objective of a newly developed bag that was used in the intervention to reduce physical workload on the coffee harvesting workers. Workers' opinion survey results showed some issues related to the size of the new bag and the lumbar–shoulder belt mechanism. This information can be used in the modification of the bag in the next design. Key players in the process have been identified.

Practitioner summary: Stimulating ergonomics activities in developing countries is suggested by many experts. This study provided an example from coffee workers in Nicaragua. Commonly used job evaluation procedures and physical load quantification methods were used. Ergonomics researchers and practitioners in developing countries may do similar projects on their own in the future.

- **Keywords:** developing countries, electromyography, discomfort survey, low back pain, work-related musculoskeletal disorders

Ari Widyanti, Dick de Waard, Addie Johnson & Ben Mulder. *National culture moderates the influence of mental effort on subjective and cardiovascular measures.* Pages 182-194.

Subjective measures of mental effort have been shown to be relatively insensitive in Indonesian participants. An open question is whether this insensitivity reflects how mental effort is experienced or how it is reported. We compared the performance, subjective workload ratings, heart rate and heart-rate variability (HRV) of 31 Dutch and 30 Indonesian participants under single- and dual-task conditions. Indonesians performed faster but less accurately and used a narrower range of subjective workload ratings than did the Dutch. Dutch participants showed a decrease in HRV both in the mid-frequency (MF) and high-frequency bands and an increase in heart rate during task performance compared with the resting period. Indonesians showed this pattern in the MF band only. The decrease of HRV in the MF band in both groups suggests that the relative insensitivity of subjective mental effort scales among Indonesians has to do with how workload is reported rather than with how it is experienced.

Practitioner summary: The sensitivity of the subjective measures of mental workload has been shown to depend on culture. Here, we show that heart-rate variability reacts similarly to workload in Eastern as in Western participants. This suggests that culture influences more how invested mental effort is reported than how it is experienced psychophysiologically.

- **Keywords:** heart-rate variability, mental effort, resting period, culture

Johannes Moskaliuk, Johanna Bertram & Ulrike Cress. *Training in virtual environments: putting theory into practice.* Pages 195-204.

Virtual training environments are used when training in reality is challenging because of the high costs, danger, time or effort involved. In this paper we argue for a theory-driven development of such environments, with the aim of connecting theory to practice and ensuring that the training provided fits the needs of the trained persons and their organisations. As an example, we describe the development of *VirtualPolice* (*ViPOL*), a training environment for police officers in a federal state of Germany. We provided the theoretical foundation for *ViPOL* concerning the feeling of being present, social context, learning motivation and perspective-taking. We developed a framework to put theory into practice. To evaluate our framework we interviewed the stakeholders of *ViPOL* and surveyed current challenges and limitations of virtual training. The results led to a review of a theory-into-practice framework which is presented in the conclusion.

Practitioner Summary: Feeling of presence, social context, learning motivation and perspective-taking are relevant for training in virtual environments. The theory-into-

practice framework presented here supports developers and trainers in implementing virtual training tools. The framework was validated with an interview study of stakeholders of a virtual training project. We identified limitations, opportunities and challenges.

- **Keywords:** virtual training, presence, social context, learning motivation, perspective-taking

Priyadarshini R. Pennathur, David Thompson, James H. Abernathy III, Elizabeth A. Martinez, Peter J. Pronovost, George R. Kim, Laura C. Bauer, Lisa H. Lubomski, Jill A. Marsteller & Ayse P. Gurses. *Technologies in the wild (TiW): human factors implications for patient safety in the cardiovascular operating room.* Pages 205-219.

We describe different sources of hazards from cardiovascular operating room (CVOR) technologies, how hazards propagate in the CVOR and their impact on cognitive processes. Previous studies have examined hazards from poor design of a specific CVOR technology. However, the impact of different CVOR technologies functioning in context is not clearly understood. In addition, the impact of non-design hazards in technology devices is unclear. Our study identified hazards from organisational, physical/environmental elements, in addition to design of technology in a CVOR. We used observations, follow-up interviews and photographs. With qualitative analyses, we categorised the different hazard sources and their potential impact on cognitive processes. Patient safety can be built into technologies by incorporating user needs in design, decision-making and implementation of medical technologies.

Practitioner summary: Effective design and implementation of technology in a safety-critical system requires prospective understanding of technology-related hazards. Our research fills this gap by studying different technologies in context of a CVOR using observations. Qualitative analyses identified different sources for technology-related hazards besides design, and their impact on cognitive processes.

- **Keywords:** patient safety, technology, hazards, cognition, cardiac operating room

Jonathan Davy & Matthias Göbel. *The effects of a self-selected nap opportunity on the psychophysiological, performance and subjective measures during a simulated industrial night shift regimen.* Pages 220-234.

This study compared the effects of a 1 h self-selected recovery period to those of a standard night shift arrangement (with a total break time of 1-h) over a simulated three-day night shift schedule in a laboratory setting. Results showed that the inclusion of the flexible nap scheme resulted in higher performance output, improvements in physiological strain responses and reduced sleepiness during each night shift and generally over the three-night cycle. Certain variables also revealed the impact of napping compared with the standard rest break condition on the circadian rhythm. The sleep diary records show that the inclusion of the current intervention did not significantly reduce daytime recovery sleep. The results suggest that the potential benefits of flexible napping may outweigh the logistical effort it requires in a workplace environment.

Practitioner summary: Consensus on appropriate napping strategies for shift work remains a challenge. This simulated night shift laboratory study sought to determine the effects of a 1-h self-selected nap opportunity relative to a normal shift set-up. The nap improved performance and decreased sleepiness, without affecting daytime sleep.

- **Keywords:** napping, fatigue, shift work, performance

Maxwell Fraser, Russell Conduit & James G. Phillips. *Effects of sleep deprivation on decisional support utilisation.* Pages 235-245.

To inform development of decisional support systems for the sleep deprived, this study examined the effect of sleep debt, time pressure and risk on the ability to use a decision aid. A total of 19 participants were tested when well rested and sleep deprived. Participants played computerised forms of Blackjack, which varied a 1- or 4-second response deadline, at two levels of risk, and could be supplied with online advice. Mean bets served as indications of confidence. Although confidence was less when play was fast or higher risk participants did not bet significantly less when sleep deprived, suggesting an impaired calibration of judgement that was supported by evidence of rallying. This failure to adjust confidence was accompanied by slower responses at low risk when sleep deprived. Sleep-deprived participants were less able to use decisional support under time pressure and made more errors without advice and time pressure.

Practitioner summary: Decisional support is becoming more pervasive. To inform development of decisional support systems to assist the sleep deprived, an experiment considered the use of decisional support as a function of time pressure and risk. Advisory systems require processing and will be less efficacious under time pressure when sleep deprived.

- **Keywords:** decisional support, sleep deprivation, risk, time pressure, recommenders

Roland Alonso, Mickaël Causse, François Vachon, Robert Parise, Frédéric Dehais & Patrice Terrier. *Evaluation of head-free eye tracking as an input device for air traffic control.* Pages 246-255.

The purpose of this study was to investigate the possibility to integrate a free head motion eye-tracking system as input device in air traffic control (ATC) activity. Sixteen participants used an eye tracker to select targets displayed on a screen as quickly and accurately as possible. We assessed the impact of the presence of visual feedback about gaze position and the method of target selection on selection performance under different difficulty levels induced by variations in target size and target-to-target separation. We tend to consider that the combined use of gaze dwell-time selection and continuous eye–gaze feedback was the best condition as it suits naturally with gaze displacement over the ATC display and free the hands of the controller, despite a small cost in terms of selection speed. In addition, target size had a greater impact on accuracy and selection time than target distance. These findings provide guidelines on possible further implementation of eye tracking in ATC everyday activity.

Practitioner Summary: We investigated the possibility to integrate a free head motion eye-tracking system as input device in air traffic control (ATC). We found that the combined use of gaze dwell-time selection and continuous eye–gaze feedback allowed the best performance and that target size had a greater impact on performance than target distance.

- **Keywords:** eye tracking, air traffic control, gaze selection, Fitts' law

Yu Zhang & David B. Kaber. *An empirical assessment of driver motivation and emotional states in perceived safety margins under varied driving conditions.* Pages 256-267.

Motivation models in driving behaviour postulate that driver motives and emotional states dictate risk tolerance under various traffic conditions. The present study used time and driver performance-based payment systems to manipulate motivation and risk-taking behaviour. Ten participants drove to a predefined location in a simulated driving environment. Traffic patterns (density and velocity) were manipulated to cause driver behaviour adjustments due to the need to conform with the social norms of the roadway. The driving environment complexity was investigated as a mediating factor in risk tolerance. Results revealed the performance-based payment system to closely relate to risk-taking behaviour as compared with the time-based payment system. Drivers conformed with social norms associated with specific traffic patterns. Higher roadway complexity led to a more conservative safety margins and speeds. This research contributes to the further development of motivational models of driver behaviour.

Practitioner Summary: This study provides empirical justification for two motivation factors in driver risk-taking decisions, including compliance with social norm and emotions triggered by incentives. Environment complexity was identified as a mediating factor in motivational behaviour model. This study also recommended safety margin measures sensitive to changes in driver risk tolerance.

- **Keywords:** driver motivation models, vehicle safety margins, traffic pattern, driver incentives, driving environment complexity

Peter Hofmann & Gerhard Rinkenauer. *Response preparation in a lane change task.* Pages 268-281.

Anticipation of future events is crucial for driving performance and safety. The aim of this study is to assess the relevance of theoretical frameworks of response preparation (response priming, movement integration theory) for driving. In a customised lane change task, valid and invalid primes were used to indicate the direction of the forthcoming lane changes. Reaction time (RT) and phase durations from steering movements served as dependent measures. In agreement with the theoretical considerations, we found a clear effect of validity on RT and steering kinematics. RTs were faster and the duration of the initial steering phase was shorter with valid than with invalid advance information. The experimental outcomes suggest that the theoretical considerations about benefits and costs of response preparation can be generalised to driving manoeuvres. Therefore, response priming paradigms might be well suited to investigate preparatory effects of advance information, e.g. in the context of advanced driving assistance systems.

Practitioner summary: Benefits and costs of response preparation were assessed in the context of driving. The findings suggest that the understanding of preparatory processes is of relevance to enhance driving performance and safety. It is possible to derive some implications that may be useful for the design of assistance and information systems.

- **Keywords:** response preparation, validity effect, steering dynamics, lane change manoeuvres, driving simulator

Stewart A. Birrell, Mark S. Young & Alex M. Weldon. *Vibrotactile pedals: provision of haptic feedback to support economical driving.* Pages 282-292.

The use of haptic feedback is currently an underused modality in the driving environment, especially with respect to vehicle manufacturers. This exploratory study evaluates the effects of a vibrotactile (or haptic) accelerator pedal on car driving performance and perceived workload using a driving simulator. A stimulus was triggered when the driver exceeded a 50% throttle threshold, past which is deemed excessive for

economical driving. Results showed significant decreases in mean acceleration values, and maximum and excess throttle use when the haptic pedal was active as compared to a baseline condition. As well as the positive changes to driver behaviour, subjective workload decreased when driving with the haptic pedal as compared to when drivers were simply asked to drive economically. The literature suggests that the haptic processing channel offers a largely untapped resource in the driving environment, and could provide information without overloading the other attentional resource pools used in driving.

Practitioner Summary: Overloaded or distracted drivers present a real safety danger to themselves and others. Providing driving-related feedback can improve performance but risks distracting them further; however, giving such information through the underused haptic processing channel can provide the driver with critical information without overloading the driver's visual channel.

- **Keywords:** driving, haptic feedback, eco-driving, acceleration, vibrotactile, workload

Stuart M. McGill, Leigh Marshall & Jordan Andersen. *Low back loads while walking and carrying: comparing the load carried in one hand or in both hands.* Pages 293-302.

This study investigates the consequences of carrying load in one hand versus both hands. Six participants walked carrying buckets containing various weights. The weight was either carried in one hand or distributed evenly between both hands. Electromyography, force plate and body kinematic data were input to a three-dimensional anatomically detailed model of the spine to calculate spine loading. Carrying loads in one hand resulted in more load on the low back than when the load was split between both hands. When carrying 30 kg in one hand, the low back compression exceeded 2800 N; however, splitting the load between hands reduced low back compression to 1570 N (reduction of 44%). Doubling the total load by carrying 30 kg in each hand actually produced lower spine compression than when carrying 30 kg in one hand. Balancing the load between both hands when carrying material has merit and should be considered when designing work.

Practitioner Summary: Carrying a load in one hand (30 kg) resulted in more spine load than splitting the same load between both hands (15 kg). When carrying double the load in both hands (30 kg in each hand vs. 30 kg in one hand), spine load decreased, suggesting merit in balancing load when designing work.

- **Keywords:** carrying, spine loads, electromyography, load carriage

D. Jonker, B. Rolander, I. Balogh, L. Sandsjö, K. Ekberg & J. Winkel. *Rationalisation in public dental care – impact on clinical work tasks and mechanical exposure for dentists – a prospective study.* Pages 303-313.

Swedish dentistry has been exposed to frequent rationalisation initiatives during the last half century. Previous research has shown that rationalisation often results in increased risk of developing work-related musculoskeletal disorders, thus reducing sustainability in the production system. In this prospective study, we assessed mechanical exposures among Swedish dentists in relation to specific rationalisations of clinical dental work during a six-year period. Body postures and movements of 12 dentists were assessed by inclinometry synchronised to video recordings of their work. No rationalisation effects could be shown in terms of a reduction in non-value-adding work ('waste'), and at job level, no major differences in mechanical exposure could be shown between baseline and follow-up. *Conclusion*: The present rationalisation measures in dentistry do not seem to

result in rationalisation at job level, but may potentially be more successful at the overall dental system level.

Practitioner summary: In contrast to many previous investigations of the mechanical exposure implications of rationalisation, the present rationalisation measures did not increase the level of risk for dentists. It is highlighted that all occupations involved in the production system should be investigated to assess production system sustainability.

- **Keywords:** loss analysis, sustainable production system, inclinometry, video analysis

Sunwook Kim & Maury A. Nussbaum. *Performance evaluation of a wearable inertial motion capture system for capturing physical exposures during manual material handling tasks.* Pages 314-326.

With a long-term goal of improving quantification of physical exposures in the workplace, this study examined the ability of a commercially available inertial motion capture (IMC) system in quantifying exposures during five different simulated manual material handling tasks. Fourteen participants repeated all these tasks in three 20 min sequential time blocks. Performance of the IMC system was compared against an optical motion capture (OMC) system ('gold standard') in terms of joint angles, angular velocities and moments at selected body parts. Though several significant changes in performance over time were found, the magnitudes of these were relatively small and may have limited practical relevance. The IMC system yielded peak kinematic values that differed by up to 28% from the OMC system. The IMC system, in some cases, incorrectly reflected the actual extremity positions of a participant, and which can cause relatively large errors in joint moment estimation. Given the potential limitations, practical recommendations are offered and discussed.

Practitioner Summary: Use of an inertial motion capture system can advance the quantification of physical exposures *in situ*. Results indicate a good potential capacity for capturing physical exposure data in the field for an extended period, while highlighting potential limitations. Future system application can help provide better understandings of dose-exposure relationships.

- **Keywords:** inertial motion capture, optical motion capture, physical exposures, manual material handling

Tom M. McLellan, Cathy Boscarino & E. J. Scott Duncan. *Physiological strain of next generation combat uniforms with chemical and biological protection: importance of clothing vents.* Pages 327-337.

This study examined whether vents in the arms, legs and chest of new protective assault uniforms (PTAU) reduced heat strain at 35°C during a low dressed state (DS_{low}), and subsequently improved tolerance time (TT) after transitioning to DS_{high} compared with the battle dress uniform and overgarment (BDU+O). Small but significant reductions in rectal temperature (T_{re}), heart rate and vapour pressures over the thigh and shin were observed during DS_{low} with vents open (37.9 ± 0.2°C, 120 ± 10 b/min, 3.7 ± 0.4 and 3.5 ± 1.0 kPa) versus closed (38.0 ± 0.1°C, 127 ± 5 b/min, 4.3 ± 0.3 and 4.6 ± 0.5 kPa). During DS_{high} T_{re} was reduced and TT increased significantly with the PTAUs (1.1 ± 0.2°C/h and 46 ± 24 min) versus BDU+O (1.6 ± 0.2°C/h and 33 ± 16 min). The vents marginally reduced heat strain during DS_{low} and extended TT during DS_{high} compared with BDU+O.

Practitioner Summary: Clothing vents in chemical and biological protective uniforms can assist with heat transfer in situations where the uniforms must be worn for extended

periods prior to exposure to a hazardous condition. Once the vents are closed, exposure time is increased and the increase in body temperature reduced.

- **Keywords:** uncompensable heat stress, core temperature, wind, evaporative heat loss