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**P. Salmon; A. Williamson; M. Lenné; E. Mitsopoulos-Rubens; C. M. Rudin-Brown. *Systems-based accident analysis in the led outdoor activity domain : application and evaluation of a risk management framework.* Pages 927 – 939.**

Safety-compromising accidents occur regularly in the led outdoor activity domain. Formal accident analysis is an accepted means of understanding such events and improving safety. Despite this, there remains no universally accepted framework for collecting and analysing accident data in the led outdoor activity domain. This article presents an application of Rasmussen's risk management framework to the analysis of the Lyme Bay sea canoeing incident. This involved the development of an Accimap, the outputs of which were used to evaluate seven predictions made by the framework. The Accimap output was also compared to an analysis using an existing model from the led outdoor activity domain. In conclusion, the Accimap output was found to be more comprehensive and supported all seven of the risk management framework's predictions, suggesting that it shows promise as a theoretically underpinned approach for analysing, and learning from, accidents in the led outdoor activity domain. **Statement of Relevance:** Accidents represent a significant problem within the led outdoor activity domain. This article presents an evaluation of a risk management framework that can be used to understand such accidents and to inform the development of accident countermeasures and mitigation strategies for the led outdoor activity domain.

- **Keywords:** accident analysis; Accimap; human factors; outdoor activity; risk management

**Jessie Y. C. Chen. *UAV-guided navigation for ground robot tele-operation in a military reconnaissance environment.* Pages 940 – 950.**

A military reconnaissance environment was simulated to examine the performance of ground robotics operators who were instructed to utilise streaming video from an unmanned aerial vehicle (UAV) to navigate his/her ground robot to the locations of the targets. The effects of participants' spatial ability on their performance and workload were also investigated. Results showed that participants' overall performance (speed and accuracy) was better when she/he had access to images from larger UAVs with fixed orientations, compared with other UAV conditions (baseline- no UAV, micro air vehicle and UAV with orbiting views). Participants experienced the highest workload when the

UAV was orbiting. Those individuals with higher spatial ability performed significantly better and reported less workload than those with lower spatial ability. The results of the current study will further understanding of ground robot operators' target search performance based on streaming video from UAVs. The results will also facilitate the implementation of ground/air robots in military environments and will be useful to the future military system design and training community.

- **Keywords:** human-robot interaction; military; navigation; spatial ability; UAV; UGV

**P. N. Squire; R. Parasuraman. *Effects of automation and task load on task switching during human supervision of multiple semi-autonomous robots in a dynamic environment.* Pages 951 – 961.**

The present study assessed the impact of task load and level of automation (LOA) on task switching in participants supervising a team of four or eight semi-autonomous robots in a simulated 'capture the flag' game. Participants were faster to perform the same task than when they chose to switch between different task actions. They also took longer to switch between different tasks when supervising the robots at a high compared to a low LOA. Task load, as manipulated by the number of robots to be supervised, did not influence switch costs. The results suggest that the design of future unmanned vehicle (UV) systems should take into account not simply how many UVs an operator can supervise, but also the impact of LOA and task operations on task switching during supervision of multiple UVs. The findings of this study are relevant for the ergonomics practice of UV systems. This research extends the cognitive theory of task switching to inform the design of UV systems and results show that switching between UVs is an important factor to consider.

- **Keywords:** automation; human factors; human-robot interaction; multitasking; task switching; unmanned vehicles

**Stephan Sandrock; Martin Schütte; Barbara Griefahn. *Mental strain and annoyance during cognitive performance in different traffic noise conditions.* Pages 962 – 971.**

In built-up areas, an increasing number of persons are affected by road traffic noise while performing mental work. This experimental study focused on annoyance and mental strain due to various noise scenarios. A total of 102 healthy, young persons (51 women, 51 men, aged 18-31 years) were randomly assigned to one of five experimental conditions determined by traffic flow (even, lumped) and traffic composition (20%, 40% heavy vehicles). While exposed to noise they performed a grammatical reasoning and a mathematical processing task. Performance and mental strain were not affected by any of the five noisy conditions. Individuals with high noise sensitivity were partially more annoyed and performed less than persons with low sensitivity. **Statement of Relevance:** The present study provides information about mental strain due to tasks with different cognitive demands and the role of noise sensitivity in various traffic noise conditions. The results show that measures aiming at the reduction of the proportion of heavy vehicles should additionally consider particular traffic flow.

- **Keywords:** annoyance; mental workload; noise; noise sensitivity; task performance

**Meinold T. Thielsch; Gerrit Hirschfeld. *High and low spatial frequencies in website evaluations.* Pages 972 – 978.**

Which features of websites are important for users' perceptions regarding aesthetics or usability? This study investigates how evaluations of aesthetic appeal and usability depend on high vs. low spatial frequencies. High spatial frequencies convey information on fine details, whereas low spatial frequencies convey information about the global layout. Participants rated aesthetic appeal and usability of 50 website screenshots from different domains. Screenshots were presented unfiltered, low-pass filtered with blurred targets or high-pass filtered with high-pass filtered targets. The main result is that low spatial frequencies can be seen to have a unique contribution in perceived website aesthetics, thus confirming a central prediction from processing fluency theory. There was no connection between low spatial frequencies and usability evaluations, whereas strong correlations were found between ratings of high-pass filtered websites and those of unfiltered websites in aesthetics and usability. This study thus offers a new perspective on the biological basis of users' website perceptions. This research links ergonomics to neurocognitive models of visual processing. This paper investigates how high and low spatial frequencies, which are neurologically processed in different visual pathways, independently contribute to users' perceptions of websites. This is very relevant for theories of website perceptions and for practitioners of web design.

- **Keywords:** aesthetics; spatial frequency; usability; website evaluation; website perception

**Errol R. Hoffmann; Michael C. Hui. *Movement times of different arm components. Pages 979 – 993.***

Data for ballistic and visually controlled movement times of different arm components are presented. Ballistic movement times gave strong support to the theoretical model that movement time is linearly related to the square-root of movement amplitude, for all arm components. It was found that there was a significant effect on movement time of the arm component being used. A scaling analysis showed that this time was linearly related to the product of the square-root of amplitude and the one-tenth power of limb mass moment of inertia. This relationship was found to be approximately true in the experiment. For visually controlled movements, movement time showed a significant interaction between Fitts' Index of Difficulty and arm component. The effect of arm component on movement time was stronger in visually controlled movements than in ballistic movements and did not allow the simple modelling in terms of limb mass moment of inertia as was possible with ballistic moves. **Statement of Relevance:** Different arm components take different times to move the same distance, dependent on their mass moments of inertia and muscle strength. The work investigated times for finger, wrist, forearm, and full-arm movements that are relevant to tasks such as manual assembly where there are alternative movement methods available for an operator.

- **Keywords:** arm; finger movements; hand; limbs; movement time; wrist

**Grant R. Tomkinson; Adam J. Clark; Peter Blanchonette. *Secular changes in body dimensions of Royal Australian Air Force aircrew (1971–2005). Pages 994 – 1005.***

The aim of this study was to quantify the secular changes in body dimensions of Royal Australian Air Force aircrew. Following corrections for methodological differences, two samples (matched for age and overall body size) of male aircrew measured in 1971 ( $n = 220$ ) and 2005 ( $n = 220$ ) were compared across 13 absolute and proportional body dimensions. Changes in means were expressed as standardised effect sizes and changes in distributional characteristics were expressed as the ratio of coefficients of variation and as changes in skew. Small secular increases (standardised effects sizes  $>0.2$ ) in age-matched aircrew were observed for mass, height, BMI, sitting height, buttock-knee length, waist girth, hip girth and waist:hip ratio, with a small decline observed for head girth. Changes in body dimensions were not independent of changes in overall body size

(except for head girth) and were not always uniform across the distribution. These changes in body size have implications for ensuring correct human-machine and human-equipment fit. **Statement of Relevance:** There have been small secular changes in body dimensions of RAAF aircrew between 1971 and 2005, although these secular changes have not always been uniform across the distribution. These secular changes in body dimensions have implications for ensuring correct human-machine and human-equipment fit and underscore the need for regular anthropometric surveys.

- **Keywords:** anthropometry; human-machine fit; military; secular changes

**R. S. Bridger; K. Brasher; A. Dew. *Work demands and need for recovery from work in ageing seafarers. Pages 1006 – 1015.***

This study was conducted on a population of seafarers serving in the Royal Fleet Auxiliary (RFA), the organisation providing support at sea to the Royal Navy. An investigation into work-related fatigue in RFA personnel onboard ships was carried out following changes to the regulations concerning maximum retirement age, to determine whether age was associated with recovery from work demands. A total of 322 personnel aged from 19 to 61 years were interviewed onboard seven RFA ships. The Need for Recovery scale was used to measure fatigue and work demands exposure was measured using the Baecke questionnaire and the NASA Task Load Index. It was found that older personnel did not have higher work-related fatigue than younger personnel. A measure of frustration at work was found to be most strongly related to work-related fatigue, even in seafarers who carried out physically demanding jobs. Work-related fatigue was found to accumulate over time in personnel who continued to be exposed to work demands onboard a ship. Finally, a relatively high level of work-related fatigue was found in the RFA sample as a whole, which may hold implications for management interventions. It was concluded that older personnel in the RFA can cope with the day-to-day demands of working life as well as younger personnel, possibly due to a 'survivor effect', whereby those personnel who do not cope as well with work demands leave and find a different job, leaving only those who successfully deal with the demands of working life at sea.

**Statement of Relevance:** In order to manage work demands in seafarers, it is important to identify the most fatiguing demands. Age is of interest because of the demographic ageing of the workforce. Age was not associated with a higher need for recovery. Psychological work demands had a greater effect on need for recovery than physical work demands.

- **Keywords:** ageing; need for recovery; work demands; shipping

**Daan Botje; Ilona Zoer; Martijn M. Ruitenbunrg; Monique H. W. Frings-Dresen; Judith K. Sluiter. *On-site observations of physical work demands of train conductors and service electricians in the Netherlands. Pages 1016 – 1023.***

The objective of the present study was to assess the exposure to physical work demands of train conductors and service electricians at a railway company in the Netherlands. On-site observations were performed using the Task Recording and Analysis on Computer observation system to identify the mean duration and frequency of tasks, activities and body postures. In total, 36 train conductors and 41 service electricians were observed for a net working day of 7 h. Results showed that train conductors and service electricians climbed a flight of stairs on average 249 and 258 times, respectively, and that service electricians worked above shoulder height for 65 min on average. In both jobs, guidelines were exceeded, e.g. duration of standing, the number of times climbing a flight of stairs, kneeling and squatting or working in awkward postures, which are risk factors for developing musculoskeletal complaints. Suggestions are made concerning how to reduce these risk factors. **Statement of Relevance:** Understanding physical work demands is essential for recognising risk factors for musculoskeletal disorders. Since train conductors

and service electricians in the Netherlands reported work-related complaints, on-site observations were performed to determine the duration and frequency of physical work demands. Risk factors were identified in both professions, providing insights concerning preventative measures.

- **Keywords:** on-site observations; railway; service electricians; train conductor; work demands

**Boyi Dai; Sangeun Jin; Xiaopeng Ning; Gary A. Mirka. *The effects of horizontal load speed and lifting frequency on lifting technique and biomechanics.* Pages 1024 – 1032.**

Lifting loads that have a horizontal velocity (e.g. lifting from a conveyor) is often seen in industry and it was hypothesised that the inertial characteristics of these loads may influence lifting technique and low back stress. Seventeen male participants were asked to perform lifting tasks under conditions of four horizontal load speeds (0 m/s, 0.7 m/s, 1.3 m/s and 2.4 m/s) and two lifting frequencies (10 and 20 lifts/min) while trunk motions and trunk muscle activation levels were monitored. Results revealed that increasing horizontal load speed from 0 m/s to 2.4 m/s resulted in an increase in peak sagittal angle (73° vs. 81°) but lower levels of peak sagittal plane angular acceleration (480°/s<sup>2</sup> vs. 4°/s<sup>2</sup>) and peak transverse plane angular acceleration (200°/s per s vs. 140°/s per s) and a consistent increase in trunk muscle co-activation. Participants used the inertia of the load to reduce the peak dynamics of the lifting motion at a cost of increased trunk flexion and higher muscle activity. **Statement of Relevance:** Conveyors are ubiquitous in industry and understanding the effects of horizontal load speed on the lifting motions performed by workers lifting items from these conveyors may provide some insight into low back injury risk posed by these tasks.

- **Keywords:** conveyor; electromyography; frequency; lifting; load speed; trunk kinematics

**Omid Haddad; Gary A. Mirka. *Hand-hold location and trunk kinematics during box handling.* Pages 1033 – 1038.**

Trunk kinematics variables have been shown to be related to low back injury risk during lifting tasks and it was hypothesised that changes in hand-hold positions could influence trunk kinematics and thereby risk. Fourteen subjects lifted a 5 or 10 kg box using four different hand placement locations (two symmetric and two asymmetric) while their trunk kinematics (position, velocity and acceleration in the sagittal, coronal and transverse planes) were captured using the lumbar motion monitor (LMM). These kinematics data were then used to calculate the probability of high risk group membership (PHRGM) as defined in the LMM risk assessment model. The results showed significant effects of hand placement on trunk kinematics, resulting in significant changes in the PHRGM variable ranging from a low of 20% in a the symmetric low load condition to a high of 38% under the asymmetric, 10 kg condition. **Statement of Relevance:** Manual materials handlers use a variety of hand-hold positions on boxes during lifting. Where a lifter grabs the box can influence the trunk kinematics during the lifting task and these kinematics have been shown to provide some insight into risk of low back injury. This study documents the trunk postures and kinematics as a function of hand-hold position.

- **Keywords:** hand placement; lumbar motion monitor; manual materials handling; trunk kinematics

**Chien-Chi Chang; Raymond W. McGorry; Jia-hua Lin; Xu Xu; Simon M. Hsiang. *Prediction accuracy in estimating joint angle trajectories using a***

**video posture coding method for sagittal lifting tasks. Pages 1039 – 1047.**

This study investigated prediction accuracy of a video posture coding method for lifting joint trajectory estimation. From three filming angles, the coder selected four key snapshots, identified joint angles and then a prediction program estimated the joint trajectories over the course of a lift. Results revealed a limited range of differences of joint angles (elbow, shoulder, hip, knee, ankle) between the manual coding method and the electromagnetic motion tracking system approach. Lifting range significantly affected estimate accuracy for all joints and camcorder filming angle had a significant effect on all joints but the hip. Joint trajectory predictions were more accurate for knuckle-to-shoulder lifts than for floor-to-shoulder or floor-to-knuckle lifts with average root mean square errors (RMSE) of 8.65°, 11.15° and 11.93°, respectively. Accuracy was also greater for the filming angles orthogonal to the participant's sagittal plane (RMSE = 9.97°) as compared to filming angles of 45° (RMSE = 11.01°) or 135° (10.71°). The effects of lifting speed and loading conditions were minimal. To further increase prediction accuracy, improved prediction algorithms and/or better posture matching methods should be investigated. **Statement of Relevance:** Observation and classification of postures are common steps in risk assessment of manual materials handling tasks. The ability to accurately predict lifting patterns through video coding can provide ergonomists with greater resolution in characterising or assessing the lifting tasks than evaluation based solely on sampling with a single lifting posture event.

- **Keywords:** lifting simulation; manual materials handling; posture matching; video coding

**T. Bernard; C. Ashley; J. Trentacosta; V. Kapur; S. Tew. Critical heat stress evaluation of clothing ensembles with different levels of porosity. Pages 1048 – 1058.**

A common metric of assessing the evaporative cooling potential of protective clothing is to assess the rate of diffusion of water vapour through the fabric. Another mechanism that supports evaporative cooling is convective transfer. Prototype porous coveralls were constructed to promote convective air flow with 0.0024 mm (0.06 inch) holes representing nominal openings of 0, 1, 2, 5, 10 and 20% of the garment surface area (called P00, P01, P02, P05, P10 and P20). The purpose of this study was to evaluate the ability of these porous coverall configurations to support evaporative cooling. The assessment measures were critical wet bulb globe temperature (WBGT) and apparent evaporative resistance via a progressive heat stress protocol. There was a progressive increase in critical WBGT with increases in convective permeability for P00, Saratoga™ Hammer, P01, work clothes and P02. There was no further increase for P05, P10 and P20. A similar pattern was found for diffusive permeability, with the exception of Saratoga™ Hammer, which suggested that the convective permeability could explain evaporative cooling better than diffusive permeability. **Statement of Relevance:** Protective clothing often interferes with evaporative cooling and thus increases the level of heat stress. While increased diffusion of water vapour is associated with lower evaporative resistances, the convective movement of water vapour is a dominant mechanism and better explains the role of the clothing in heat stress.

- **Keywords:** clothing; diffusion; convection; evaporative resistance; heat stress; WBGT