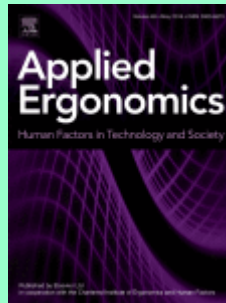


Applied Ergonomics - rok 2019, Volume 79

September 2019



Michael A. Rizzuto, Michael W.L. Sonne, Nicolas Vignais, Peter J. Keir. *Evaluation of a virtual reality head mounted display as a tool for posture assessment in digital human modelling software. Pages 1-8.*

The purpose of this work was to assess the feasibility of using a head mounted display with a motion capture system to simulate real world occupational tasks. Participants performed a pointing task under 3 conditions: (1) real environment (REA), (2) virtual environment with auditory stimulus (VEA) and (3) virtual environment with visual stimulus (VEV). End point error, movement time and peak fingertip velocity were calculated for each discrete point event. Upper extremity joint angles were calculated at the end-state for each point and did not significantly differ between real and virtual conditions. There was significantly greater target error in virtual conditions, compared to the real condition. Peak pointing velocity was slower and movement time was longer during virtual conditions. The similarity of joint angles between real and virtual conditions suggests future use of posture-based ergonomic assessments for use with virtual reality task simulations using Oculus Rift and Siemens Jack.

- **Keywords:** Virtual reality; Simulation; Training; Posture; Joint angles; Digital human model

Azam Maleki-Ghahfarokhi, Iman Dianat, Hossein Feizi, Mohammad Asghari –Jafarabadi. *Influences of gender, hand dominance, and anthropometric characteristics on different types of pinch strength: A partial least squares (PLS) approach. Pages 9-16.*

The relationships of demographic and anthropometric characteristics (17 dimensions related to the hand, wrist, and arm) with four different pinch strengths (lateral pinch, key pinch, three-jaw chuck pinch and tip-to-tip pinch strengths) were evaluated among 196 (96 males and 100 females) young adults aged 19–30 years. For both dominant and non-dominant hands, the lateral pinch was greatest, followed by the key pinch, three-jaw chuck pinch and tip-to-tip pinch strengths. Mean pinch strengths of the dominant and non-dominant hands of females varied between 62%–78% and 61%–73% of those exerted by males, respectively. Strength of the dominant hand was 5.3%–7.5% stronger than of that of the non-dominant hand, with this difference being generally higher in females than in males. Hand length and forearm length showed the strongest correlation with all types of pinch strengths exerted by both the dominant and non-dominant hands. In the partial least squares analysis, 10 out of 17 anthropometric indices including hand length, forearm length, arm length, middle finger width, thumb length, index finger

width, thumb width, wrist depth, palm depth and index finger depth had considerable loadings in the extracted component, explaining 37% of the total variance. These findings can fill the gap in the strength data, or used by health professionals and designers in the field.

- **Keywords:** Lateral pinch; Key pinch; Three-jaw chuck pinch; Tip-to-tip pinch; Anthropometry

Gregory Garrett, Hongwei Zhao, Adam Pickens, Ranjana Mehta, Leigh Preston, Amy Powell, Mark Benden. *Computer-based Prompt's impact on postural variability and sit-stand desk usage behavior; a cluster randomized control trial. Pages 17-24.*

Sit-to-stand workstations have been deployed in office environments to reduce sedentary behavior and improve worker's health. However, efforts to initiate and sustain long-term usage of sit-stand workstations has been a challenge, with primarily anecdotal evidence suggesting many employees cease using their sit-stand workstations once the newness diminishes. To objectively determine sit-stand workstation usage and what impact computer-based prompts would have on sit-stand desk use and sustainability, 200 office workers (118 control and 82 treatment) in two different geographic locations were continuously monitored over a 4 ½ month period, which consisted of a 6-week baseline and a 3-month experimental period. During the 3-month experimental period, computer-based prompts elicited a 229% increase in daily standing transitions which was sustained over the entire 3 months with 40% of the participants adhering to a pre-determined sit to stand schedule. These findings indicate that the use of computer-based prompts can be used to motivate employees to change their behavior regarding the use of sit-to-stand workstations.

- **Keywords:** Behavior change; Sit-stand desks; Motivation; Body discomfort

M. Smulders, A. Naddeo, N. Cappetti, E.D. van Grondelle, U. Schultheis, P. Vink. *Neck posture and muscle activity in a reclined business class aircraft seat watching IFE with and without head support. Pages 25-37.*

The purpose of this study is to research if a headrest benefits the comfort of the passenger and lowers muscle activity in the neck when sitting in a reclined (slouched) posture while watching in flight entertainment (IFE) in an aircraft business class seat. No significant differences in muscle activity in the musculus sternocleidomastoid and musculus trapezius pars descendant were found between the conditions with headrest and without headrest. A significant difference in expected comfort rating was found. Subjects indicated they expect to experience more comfort with a headrest when watching IFE for a duration of two movies during a long-haul flight. This study also found a significant difference in posture. In the condition without headrest the head was more upright compared to the condition with headrest. The lack of significant difference in muscle activity and the significant difference in posture may indicate that humans tend to look for a head position that is neutral, in the sense of minimal muscle effort. This study shows that the use of a headrest may benefit the comfort experience of the passenger during flight. However, further research is necessary on the design of the headrest and the long-term effects of head support on comfort, discomfort, muscle activity and fatigue for watching IFE in a slouched posture.

- **Keywords:** EMG; Posture; Neck angle; Aircraft seat; Headrest; Comfort; TV

Haerim Bak, Clive D'Souza, Gwanseob Shin. *Upper extremity muscular load during carpet vacuuming with household upright cleaners. Pages 38-44.*

Ergonomics of household vacuuming has received little attention despite the pervasive nature of this task. The aim of this study was to quantitatively assess the level of muscular load of the upper extremity during carpeted floor vacuuming with household upright cleaners, which represent the most common type of vacuum cleaners in the US. Eighteen participants conducted five different vacuuming tasks with three upright cleaner models. Electromyography data from seven upper extremity muscles were recorded and analyzed. Normalized muscle activation levels were significantly higher in women compared to men across the five tasks for each muscle group. Median muscular load ranged from 4.5% to 47.5% of the maximum voluntary contraction capacity for female participants and from 2.7% to 23.6% for male participants. These results suggest that household vacuuming with upright vacuum cleaners is physically intensive work, especially for women. Study findings have potential implications for the design of upright vacuum cleaners.

- **Keywords:** Carpet vacuuming; Upright cleaner; EMG

Scott R. Walter, Magdalena Z. Raban, Johanna I. Westbrook. *Visualising clinical work in the emergency department: Understanding interleaved patient management.* Pages 45-53.

We present a unique data visualisation approach, called workflow time charts, to illustrate the sequential and multi-dimensional nature of work in emergency departments. Using 40h of data from direct observations of emergency physicians, we applied the charts to visualise patient-stratified physicians' work as a continuous temporal process, including distinguishing tasks of different types and representing external prompts (similar to interruptions) and multitasking performance. The charts showed frequent changes in the nature of observed activities, with interleaved multitasking a constant feature and external prompts often clustered in time. Evidence of seniority-related differences in work were apparent with consultants switching between more concurrent patients and receiving more frequent clinical prompts than junior physicians, illustrating their overseeing and advice-giving role. The ubiquity of interleaved multitasking suggests a need to focus on developing individual strategies to support frequent cognitive switching. Work that appears fragmented at physician level may form part of a flexible and robust system, rather than an error-prone set of isolated individual behaviours.

- **Keywords:** Clinical work; Interruptions; Multitasking; Emergency department; Visualisation

Jodi Oakman, Rwth Stuckey, Natasha Kinsman. *Using evidence to support the design of submarine control console workstations.* Pages 54-65.

Purpose: This paper outlines an approach to develop practical guidelines to support the design of submarine control console workstations. **Method:** Guideline development was undertaken for 13 physical design criteria, provided to the research team. Data was gathered from four sources: a systematic literature review, relevant standards, population specific anthropometric data, and user focus groups. The systematic review included risk of bias, quality assessment and evidence synthesis. **Results & Conclusion:** The systematic review retrieved 43 relevant articles in relation to seven of the 13 design criteria. Very few high-quality studies were identified. The combined evidence available from each of the four data sources was collated and used to provide a set of guidelines for each of the 13 criteria, highlighting the importance of the use of multiple data sources. This approach has applicability beyond this study where the need exists to collate evidence sources beyond the scientific literature.

- **Keywords:** Guidelines; Workstation; Musculoskeletal disorders; Submarines; Systematic review

Alain Chavallaz, Adrian Schwaninger, Stefan Michel, Juergen Sauer. *Work design for airport security officers: Effects of rest break schedules and adaptable automation. Pages 66-75.*

This study investigated whether there is empirical support for the current EU regulation mandating breaks of at least 10 min after each period of 20 min continuously reviewing X-ray images in airport security screening. As a second goal, it examined whether providing more autonomy to airport security officers (in the form of spontaneous rest breaks and adaptable automation) would improve their performance and subjective state. Seventy-two student participants had to indicate the presence (or absence) of a threat item (either a gun or a knife) in a series of grey-scaled X-ray images of cabin baggage. Three work-rest schedules were examined: spontaneous breaks (i.e. participants could take breaks at any time), two 5-min breaks and two 10-min breaks during a 1-h testing session. Furthermore, half of the participants were assisted in their task by an adaptable support system offering three levels of automation: (1) no support, (2) cues indicating the presence of a potential threat item, and (3) cues indicating the exact location of a potential threat item. Results showed no performance differences between break regimes, which suggests that there may be viable alternatives to the current EU regulations. It also emerged that providing participants with adaptable automation did not lead to better detection performance but resulted in a less positive response bias than participants without automatic support. Implications for current aviation security regulations are discussed.

- **Keywords:** Adaptable automation; Airport security; Visual inspection; System reliability; Performance

Richelle Baker, Pieter Coenen, Erin Howie, Ann Williamson, Leon Straker. *The musculoskeletal and cognitive effects of under-desk cycling compared to sitting for office workers. Pages 76-85.*

Alternate work positions are being considered as a way to address sedentary behaviour for office workers. This study evaluated the effect of two hours of just-sitting versus sitting while under-desk cycling on musculoskeletal discomfort and cognitive function (sustained attention and creative problem solving). To consider mechanisms, muscle fatigue, kinematics and mental state were also measured. Discomfort increased significantly across all body areas with knee and ankle discomfort greater (in a clinically meaningful manner) in under-desk cycling. Sustained attention reaction time was the only cognitive measure to show a difference between conditions (slower for under-desk cycling [β -34.82 CI (-62.12 to -7.53)]). There was no evidence of muscle fatigue, while kinematic differences between conditions were identified. Mental state deteriorated over time in both conditions. This study found no clear benefit of under-desk cycling compared to just-sitting for musculoskeletal health and cognitive function measures.

- **Keywords:** Musculoskeletal; Cognitive function; Alternate work position

P.A. Hancock. *The humane use of human beings? Pages 91-97.*

The closing of loops exerts magical effects. This powerful act sculpts both the structural form and the functional expression of the systems which accrue from this ultimate connection. Systems and societies are each erected upon, and composed of, such intricate webs of self-correcting and self-shaping influences. However, without appropriate feedback regulation, these loops can become, in a utilitarian sense, dysfunctional. This is as true for social architectures as it is for any intentionally designed technological system. Here, a sequence of examples are used to expose an evident

divergence between what is espoused for our social systems and what is actually enacted therein. Failure of regulation and associated diminution or even disconnection of such regulatory loops leads to an evident and growing dissonance between aspiration and reality. The first two of these examples used here are rather facile and even trivial while the third example is much more serious. All examples provide insight concerning, and expose the ways in which, a fuller understanding of cybernetic principles may rectify such discordant circumstances, at least in principle if not in practice.

Thierry Morineau, John M. Flach. The heuristic version of Cognitive Work Analysis: A first application to medical emergency situations. Pages 98-106.

Cognitive Work Analysis is an original method that seeks to describe work systems made up of nested sets of constraints, from ecological constraints imposed by the work domain to cognitive constraints. This top-down approach starts with a work domain model in order to analyze and specify contexts of activity. To complement this method, we propose a bottom-up version of Cognitive Work Analysis focusing on contexts of activity and depicting how operators adapt to the ecological constraints. Based on Rasmussen's Dynamic Safety Model, the ecological constraints involved are those bounding the workspace in which operators dynamically navigate with control loops, strategies, work organization, and competencies. This analysis relies on the simulation of specific contexts of activity. A first illustrative application of this framework to a simulated medical emergency situation with a team of nurses and nursing aids shows that this framework can help identify design issues.

- **Keywords:** Heuristic cognitive work analysis; Simulation; Medical emergency

Diego Luiz de Mattos, Rafael Ariento Neto, Eugenio Andrés Díaz Merino, Fernando Antônio Forcellini. *Simulating the influence of physical overload on assembly line performance: A case study in an automotive electrical component plant.* Pages 107-121.

Although the workstations of a Brazilian automotive electrical harness production line are set close to TAKT time (the production rate required to meet demand), factory performance is compromised regarding: (i) sick leaves due to occupational disease (105 employees last year) and (ii) a production rate at only 42% of capacity. Our objective was to simulate the performance of a production line balanced against physical overload by the addition of an extra workstation. Based on ergonomic work analysis, the study applied System Dynamics at the global observation stage to obtain a systemic interpretation of the factors involved in production line performance. According to the indicators, the alternative configuration reduced physical overload by 36%, which would result in a sick leave rate of 50.8 employees/year (51.6% lower than the current configuration), as well as a production rate at 99% of capacity (a 92.7% increase over the current configuration). We found that reducing physical overload allows the "workforce control" loop to govern the system, producing favorable results. We conclude that setting the work cycle overly close to TAKT time leads to overload, due to the shorter recovery times at the end of each cycle. Thus, it is necessary to seek a balance between efficiency gains through downtime reduction and the physiological recovery of workers.

- **Keywords:** Physical overload; System dynamics; Ergonomics; Human factors; Production line balance

Chenling Li, Tao Tang, Maria Mikela Chatzimichailidou, Gyuchan Thomas Jun, Patrick Waterson. *A hybrid human and organisational analysis*

method for railway accidents based on STAMP-HFACS and human information processing. Pages 122-142.

Safety is a constant priority for the railway industry and there are numerous hazards in and around the rail system which may result in damage to train and environment, human injury and fatalities. Low levels of human and organisational performance have been shown to be a prime cause of railway accidents and a number of accident models and methods have been developed in order to probe deeper into the role played by organisational factors in accident causation. The Systems-Theoretical Accident Modelling and Processes (STAMP) method for example, represents a promising systematic and systemic way of examining sociotechnical systems such as the railway. Another method, the Human Factors Analysis and Classification System (HFACS), based upon Reason's model of human error in an organisational context, has also proved popular as a human factors accident analysis framework. However, human factors elements are still somewhat limited and under-specified and these managerial and social issues within an organisation are simply regarded as sources of failure in the control constraints of STAMP. HFACS likewise, categorises accident data rather than analysing it in more depth. In this context, a hybrid human and organisational analysis method based on HFACS-STAMP (HFACS-STAMP method for railway accidents, HS-RAs) is proposed to identify and analyse human and organisational factors involved in railway accidents. Using the categories of human errors derived from HFACS and the structured systematic analysis process of STAMP, the HS-RAs method provides a mechanism by which active failures can promulgate across organisations and give a systemic analysis of human error in accidents. Combined with human information processing, the HS-RAs method gives a detailed causal analysis of human errors from receiving information to implement control actions. At last, the HS-RAs method is demonstrated using a case study of the 2011 Yong-Wen railway collision. A number of prominent accident causes of human factors are revealed and necessary countermeasures are proposed to avoid the recurrence of similar accidents. The HFACS-STAMP hybrid method has several advantages and can contribute to railway safety by providing a detailed analysis of the role of human error in railway accidents.

- **Keywords:** Human and organisational factors; STAMP; HFACS; Human information processing; Accident analysis; Yong-Wen railway accident

Travis J. Wiltshire, Sune Vork Steffensen, Stephen M. Fiore. Multiscale movement coordination dynamics in collaborative team problem solving. Pages 143-151.

During collaborative problem solving (CPS), coordination occurs at different spatial and temporal scales. This multiscale coordination should play a functional role in facilitating effective collaboration. To evaluate this, we conducted a study of computer-based CPS with 42 dyadic teams. We used cross-wavelet coherence to examine movement coordination, extracted from videos, at several scales, and tested whether the observed coordination was greater than expected due to chance and due to task demands. We found that coordination at scales less than 2s was greater than chance and at most scales (except 16s, 1m, and 2m), was greater than expected due to task demands. Lastly, we observed that coherence at .25s and 1s scales was predictive of performance. However, when including relative phase, our results suggest that higher in-phase movement coordination at the 1s scale was the strongest predictor of CPS performance. Further, we used growth curve modeling to examine how movement coordination changes across the duration of the task and whether this is moderated by CPS performance. We found that coordination over the duration of the CPS task is quadratic (a U shape) and that better performing teams have higher coordination with a shallower curve. We discuss these findings and their relevance to understanding how low-level movement coordination facilitates CPS.

- **Keywords:** Coordination; Collaboration; Problem solving; Team performance; Dynamical systems; Synchrony

Stephen J. Guastello, Anthony N. Correro, David E. Marra. *Cusp catastrophe models for cognitive workload and fatigue in teams. Pages 152-168.*

The use of two cusp catastrophe models has been effective for untangling the effects of cognitive workload, fatigue, and other complications on the performance of individuals. This study is the first to use the two models to separate workload and fatigue effects on team performance. In an experiment involving an emergency response simulation, 360 undergraduates were organized into 44 teams. Workload was varied by team size, number of opponents, and time pressure. The cusp models for workload and fatigue were more accurate for describing trends in team performance criteria compared to linear alternatives. Individual differences in elasticity-rigidity were less important than subjective workload and experimental conditions as control variables. Fluid intelligence within the team was an important compensatory ability in the fatigue model. Results further supported the nonlinear paradigm for the assessment of cognitive workload and fatigue and demonstrated its effectiveness for understanding team phenomena.

- **Keywords:** Cognitive workload; Fatigue; Teams; Resilience; Cusp catastrophe; Emergency response

Waldemar Karwowski, David Kern, Atsuo Murata, Tareq Ahram, Edgar Gutiérrez, Nabin Sapkota, Tadeusz Marek. *The complexity of human performance variability on watch standing task. Pages 169-177.*

The primary objective of this study was to examine the complexity of human temporal variability of topside roving watch task in naval operations concerning the reported times of ship status and to explore the potential presence of chaotic behavior and fractal properties of the reported log times. Topside rover reporting time intervals recorded in the deck logs of the USS Jason Dunham over the 2013–2015 period were analyzed to understand the underlying complexity of the watch standing task that is critical to the success of naval operations. The results on the 0–1 test, analysis of the largest Lyapunov exponents, as well the exploration of the fractal dimension and 1/f spectral analyses, showed that the fluctuation of standing watch time reports data exhibits chaotic and fractal system properties. The critical implications of the study findings for the human-centered design of complex systems were also discussed.

- **Keywords:** Complexity; Human performance variability; Chaos; Nonlinear systems dynamics; Fractals; Watch standing task

