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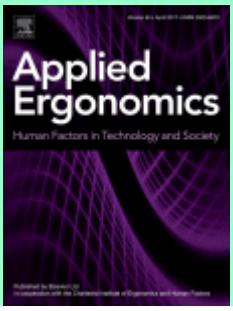

Benjamin Noah, Jingwen Li, Ling Rothrock. *An evaluation of touchscreen versus keyboard/mouse interaction for large screen process control displays*. Pages 1-13.

he objectives of this study were to test the effect of interaction device on performance in a process control task (managing a tank farm). The study compared the following two conditions: a) 4K-resolution 55‟ screen with a 21” touchscreen versus b) 4K-resolution 55” screen with keyboard/mouse. The touchscreen acted both as an interaction device for data entry and navigation and as an additional source of information. A within-subject experiment was conducted among 20 college engineering students. A primary task of preventing tanks from overfilling as well as a secondary task of manual logging with situation awareness questions were designed for the study. Primary Task performance (including tank level at discharge, number of tank discharged and performance score), Secondary Task Performance (including Tank log count, performance score), system interaction times, subjective workload, situation awareness questionnaire, user experience survey regarding usability and condition comparison were used as the measures. Parametric data resulted in two metrics statistically different means between the two conditions: The 4K-keyboard condition resulted in faster Detection + Navigation time compared to the 4K-touchscreen condition, by about 2 s, while participants within the 4K-touchscreen condition were about 2 s faster in data entry than in the 4K-keyboard condition. No significant results were found for: performance on the secondary task, situation awareness, and workload. Additionally, no clear significant differences were found in the non-parametric data analysis. However, participants showed a slight preference for the 4K-touchscreen condition compared to the 4K-keyboard condition in subjective responses in comparing the conditions. Introducing the touchscreen as an additional/alternative input device showed to have an effect in interaction times, which suggests that proper design considerations need to be made. While having values shown on the interaction device provides value, a potential issue of visual distraction exists when having an additional visual display. The allocation of visual attention between primary displays and the touchscreen should be further investigated.

- **Keywords:** Touchscreen; Interaction method; Process control display; Touch input

Baisheng Nie, Xin Huang, Yang Chen, Anjin Li, Ruming Zhang, Jinxin Huang. *Experimental study on visual detection for fatigue of fixed-position staff*. Pages 1-11.

Fatigue can lead to decreased work performance and poorer safety and health condition. Fatigue is ubiquitous in production and in life, while the research on it is mainly concentrated in the automotive driving, aircraft piloting and other fields, and it is insufficient to study on the fatigue of fixed-position staff. This paper puts forward a non-contact visual image method, which can monitor the extent of fatigue of fixed-position staff. Fatigue threshold used in judgment is obtained by processing the recorded data of visual images of the experimental subjects when fatiguing and by analyzing eye closure time, percentage of eyelid closure (PERCLOS) value, frequency and number of blinks. The results show that there is significant difference among the four indicators before and after experiment subjects undergo fatigue. The fatigue of experimental subjects is obvious when eye closure time is 3.5 s/min, PERCLOS value 6%, and blink frequency 0.4 times/s. This provides a reference for a wider range of detection of fatigue and a method for avoiding mistakes and accidents.

- **Keywords:** Fatigue; PERCLOS; Image processing

Mathilde François, Philippe Crave, François Osiurak, Alexandra Fort, Jordan Navarro. *Digital, analogue, or redundant speedometers for truck driving: Impact on visual distraction, efficiency and usability*. Pages 12-22.

Existing literature does not draw conclusions as to which speedometer type is better for truck driving. A digital speedometer would be more beneficial when obtaining absolute and relative readings, while an analogue speedometer would be more efficient and less distracting when detecting dynamic speed changes. Redundant speedometers, which simultaneously present digital and analogue speedometers, appear increasingly in vehicles, but no information is available on their ergonomic qualities. This study compared three speedometers: digital speedometers, analogue speedometers, and redundant speedometers. This study compared the efficiency, usability and visual distraction measures for all three types of speedometers in a simulated truck driving setting. The task-dependant results were confirmed for the digital and analogue speedometer. The redundant speedometer combined the benefits of each type presented separately, which highlights interesting theoretical and applied implications.

- **Keywords:** Speedometer design; Truck interface; Redundant displays

Conor McGinn, Aran Sena, Kevin Kelly. *Controlling robots in the home: factors that affect the performance of novice robot operators*. Pages 23-32.

For robots to successfully integrate into everyday life, it is important that they can be effectively controlled by laypeople. However, the task of manually controlling mobile robots can be challenging due to demanding cognitive and sensorimotor requirements. This research explores the effect that the built environment has on the manual control of domestic service robots. In this study, a virtual reality simulation of a domestic robot control scenario was developed. The performance of fifty novice users was evaluated, and their subjective experiences recorded through questionnaires. Through quantitative and qualitative analysis, it was found that untrained operators frequently perform poorly at navigation-based robot control tasks. The study found that passing through doorways accounted for the largest number of collisions, and was consistently identified as a very difficult operation to perform. These findings suggest that homes and other human-orientated settings present significant challenges to robot control.

- **Keywords:** User-centered design; Man-machine interaction; Virtual reality; Human-robot interaction

Ya-Hsien Ko. *The effects of luminance contrast, colour combinations, font, and search time on brand icon legibility*. Pages 33-40.

This study explored and identified the effects of luminance contrast, colour combinations, font, and search time on brand icon legibility. A total of 108 participants took part in the experiment. As designed, legibility was measured as a function of the following independent variables: four levels of luminance contrast, sixteen target/background colour combinations, two fonts, and three search times. The results showed that a luminance contrast of 18:1 provided readers with the best legibility. Yellow on black, yellow on blue, and white on blue were the three most legible colour combinations. One of this study's unique findings was that colour combinations may play an even more important role than luminance contrast in the overall legibility of brand icon design. The 12-s search time corresponded with the highest legibility. Arial font was more legible than Times New Roman. These results provide some guidance for brand icon and product advertisement design.

- **Keywords:** Luminance contrast; Colour combinations; Brand icon legibility

Erin K. Howie, Pieter Coenen, Amity C. Campbell, Sonia Ranelli, Leon M. Straker. *Head, trunk and arm posture amplitude and variation, muscle activity, sedentariness and physical activity of 3 to 5 year-old children during tablet computer use compared to television watching and toy play*. Pages 41-50.

Young children (ages 3 to 5) are using mobile touchscreen technology, including tablet computers, yet little is known on the potential musculoskeletal and physical activity implications of its use. This within-subject laboratory study (n = 10) examined head, trunk and arm postures, upper trapezius muscle activity, and total body and upper limb physical activity during playing with tablets compared to during TV watching and playing with non-screen toys. Overall, this study found that during tablet play children had greater mean head, trunk and upper arm angles compared to both TV watching and toy play. Conversely, compared to toy play, children playing with tablets had lesser trunk, upper arm and elbow postural variation, lesser trapezius activity, more time sitting and lesser physical activity. Thus, to minimize potential musculoskeletal and sedentary risks, non-screen toy play should be encouraged and education and guidelines provided for parents and caretakers to support wise use of tablets.

- **Keywords:** Technology; Biomechanics; Kinematics; Sedentary; Preschool

Jin Tao, Niu Yafeng, Zhou Lei. *Are the warning icons more attentional?* Pages 51-60.

The rapid growth of attention to visual warnings is a representation of the adaptive behavior of humans. However, the ways warning icons attract attention in the cognition context has yet to be clarified. This research aims to investigate cognitive mechanism of warning icons under various perceptual loads. The results of Experiment A, whose average attentional capture effect of the warning icons (69 ms) was significantly higher than that of the ordinary icons (35 ms), show that compared with ordinary icons, warning icons are prioritized in processing under both high and low perceptual loads. Besides, the attention capturing abilities of non-target warning icons are the same under high and low perceptual loads. To isolate the effects of salient visual features and semantics, warning icons in Experiment B are replaced with transposed icons with saliency but no semantics. The attentional capture effect of warning icons is found to be significantly smaller under high load than under low load, so the effect in Experiment A can be attributed to the semantics of warning icons. In Experiment C the icons of negative and neutral semantics without salient frames are used as interfering stimuli,

and the RT to the negative icons (823 ms) was longer than both the RT to the neutral icons (780 ms) and to the no interference icons (743 ms) (P < 0.001), which show that negative icons have stronger attention capturing ability than neutral icons. This research verifies that the semantics of icons is vital, and icons with salient visual features and negative semantics can enhance attentional capture effect.

- **Keywords:** Cognitive mechanism; Warning icons; Graphics semantics; Salience; Working load

Jung Hyup Kim, Xiaonan Yang. *Applying fractal analysis to pupil dilation for measuring complexity in a process monitoring task*. Pages 61-69.

This laboratory experiment was designed to use fractal dimension as a new method to analyze pupil dilation to evaluate the level of complexity in a multitasking environment. By using the eye-head integrated tracking system, we collected both pupil responses and head positions while participants conducted both process monitoring task and Multi-Attribute Task Battery (MATB-II) tasks. There was a significant effect of scenario complexity on a composite index of multitasking performance (Low Complexity » High Complexity). The fractal dimension of pupil dilation was also significantly influenced by complexity. The results clearly showed that the correlation between pupil dilation and multitasking performance was stronger when the pupil data was analyzed by using the fractal dimension method. The participants showed a higher fractal dimension when they performed a low complexity multitasking scenario. The findings of this research help us to advance our understanding of how to evaluate the complexity level of real-world applications by using pupillary responses.

- **Keywords:** Pupil dilation; Fractal dimension; Human-in-the-loop simulation

Maryam Zahabi, Patricia Machado, Mei Ying Lau, Yulin Deng, Carl Pankok Jr., Joseph Hummer, William Rasdorf, David B. Kaber. *Driver performance and attention allocation in use of logo signs on freeway exit ramps*. Pages 70-80.

The objective of this research was to quantify the effects of driver age, ramp signage configuration, including number of panels, logo format and sign familiarity, on driver performance and attention allocation when exiting freeways. Sixty drivers participated in a simulator study and analysis of variance models were used to assess response effects of the controlled manipulations. Results revealed elderly drivers to demonstrate worse performance and conservative control strategies as compared to middle-aged and young drivers. Elderly drivers also exhibited lower off-road fixation frequency and shorter off-road glance durations compared to middle-aged and young drivers. In general, drivers adopted a more conservative strategy when exposed to nine-panel signs as compared to six-panel signs and were more accurate in target detection when searching six-panels vs. nine and with familiar vs. unfamiliar logos. These findings provide an applicable guide for agency design of freeway ramp signage accounting for driver demographics.

- **Keywords:** Roadway logo signs; Driving simulation; Exit ramp; Driver distraction; Highway safety

George M. Sammonds, Neil J. Mansfield, Mike Fray. *Improving long term driving comfort by taking breaks: how break activity affects effectiveness*. Pages 81-89.

During long duration journeys, drivers are encouraged to take regular breaks. The benefits of breaks have been documented for safety; breaks may also be beneficial for comfort. The activity undertaken during a break may influence its effectiveness.

Volunteers completed 3 journeys on a driving simulator. Each 130 min journey included a 10 min break after the first hour. During the break volunteers either stayed seated, left the simulator and sat in an adjacent room, or took a walk on a treadmill. The results show a reduction in driver discomfort during the break for all 3 conditions, but the effectiveness of the break was dependent on activity undertaken. Remaining seated in the vehicle provided some improvement in comfort, but more was experienced after leaving the simulator and sitting in an adjacent room. The most effective break occurred when the driver walked for 10 min on a treadmill. The benefits from taking a break continued until the end of the study (after a further hour of driving), such that comfort remained the best after taking a walk and worst for those who remained seated. It is concluded that taking a break and taking a walk is an effective method for relieving driving discomfort.

- **Keywords:** Driving comfort; Automotive; Taking breaks; Seating

Walter Talamonti, Louis Tijerina, Mike Blommer, Radhakrishnan Swaminathan, Reates Curry, R. Darin Ellis. *Mirage events & driver haptic steering alerts in a motion-base driving simulator: a method for selecting an optimal HMI*. Pages 90-104.

This paper describes a new method, a 'mirage scenario,' to support formative evaluation of driver alerting or warning displays for manual and automated driving. This method provides driving contexts (e.g., various Times-To-Collision (TTCs) to a lead vehicle) briefly presented and then removed. In the present study, during each mirage event, a haptic steering display was evaluated. This haptic display indicated a steering response may be initiated to drive around an obstacle ahead. A motion-base simulator was used in a 32-participant study to present vehicle motion cues similar to the actual application. Surprise was neither present nor of concern, as it would be for a summative evaluation of a forward collision warning system. Furthermore, no collision avoidance maneuvers were performed, thereby reducing the risk of simulator sickness. This paper illustrates the mirage scenario procedures, the rating methods and definitions used with the mirage scenario, and analysis of the ratings obtained, together with a multi-attribute utility theory (MAUT) approach to evaluate and select among alternative designs for future summative evaluation.

- **Keywords:** Psychophysics; Driving simulator; Pair comparisons; Simulated mirage event; Optimization; MAUT; Haptic steering wheel; Forward collision; Evasive steering

Bruno Leban, Gianfranco Fancello, Paolo Fadda, Massimiliano Pau. *Changes in trunk sway of quay crane operators during work shift: A possible marker for fatigue?* Pages 105-111.

This study investigated changes in task-induced trunk sway of quay crane operators during a four-hour shift performed in a dedicated simulator as an indicator of postural control system effectiveness. Using a pressure sensitive mat placed on the seat pan, center-of-pressure (COP) time series were acquired and processed to calculate sway area, path length and COP displacements and velocities. The results show a well-defined linear trend for sway path and area, with significant increases starting from 65 to 155 min of work respectively. This indicates non-optimized trunk control most likely originated by the combination of physical and cognitive workload and suggests a possible role of long-term monitoring of trunk sway of crane operators as a useful tool in detecting non-optimized movements potentially associated with deteriorating performance.

- **Keywords:** Sitting posture; Trunk; Postural sway; Quay crane

J. Prairie, A. Plamondon, D. Larouche, S. Hegg-Deloye, P. Corbeil. *Paramedics' working strategies while loading a stretcher into an ambulance*. Pages 112-122.

For paramedics, loading a stretcher into an ambulance is an activity with a high risk of back injury and accidents. The objective of this study was to document strategies paramedics use at work while loading a powered stretcher into an ambulance. A total of 249 stretcher loading operations performed by 58 paramedics, and 51 semistructured post-intervention interviews were analyzed. Almost three quarters of loading operations required additional actions (e.g., raising the shoulders and additional lifting) to insert the stretcher into the cot fastener system in the ambulance. Some strategies that were necessary to complete the stretcher loading operation seemed to have negative impacts on the workers' health, such as repositioning the stretcher. This action wastes time and requires significant physical efforts, as it is usually done alone. This study suggests some potential solutions, related to equipment, training, workers and work organization, to reduce the risk of injury while loading stretchers.

- **Keywords:** Cot; Musculoskeletal disorders; Prevention; Ergonomics; Emergency medical service

Vy Vu, Anthony Walker, Nick Ball, Wayne Spratford. *Ankle restrictive firefighting boots alter the lumbar biomechanics during landing tasks*. Pages 123-129.

Firefighters incur high incidences of lower back and body injuries. Firefighting boots, with specific design requirements, have been shown to reduce ankle range of motion. This reduction has been associated with impaired force dissipation and lower body kinematic alterations. Thus, the aim of this study was to determine the relationship between firefighting boots, lumbar biomechanics and load carriage during landing. Our data indicates that when wearing firefighting boots, lumbar forces increased and kinematics changed in frontal and transverse planes. These changes may be occurring due to the restrictive shaft of the firefighting boot reducing ankle range of motion. Comparisons between unloaded and loaded conditions also showed increased changes in lumbar biomechanics, independent of footwear worn. Therefore, wearing firefighting boots, in addition to operational loading, may be placing firefighters at greater risk of lumbar injuries. Future research investigating firefighting boots and additional load carriage on lower body biomechanics during landing is recommended.

- **Keywords:** Firefighting boots; Lumbar; Landing

J.F.M. Molenbroek, T.J. Albin, P. Vink. *Thirty years of anthropometric changes relevant to the width and depth of transportation seating spaces, present and future.* Pages 130-138.

This paper reports the results of an investigation into changes in body shape anthropometry over the past several decades and discusses the impact of those changes on seating in transport, especially airliners. Changes in some body shape dimensions were confirmed in a sample of students at TU Delft; several of the changes, e.g. hip breadth, seated, are relevant to the ongoing design of seating. No change in buttock knee length was observed. The fit between current user anthropometry and current airline seat design, especially regarding seat width, was investigated. A comparison of the average current seat breadth with global anthropometric data suggests that accommodation may be problematic, with less than optimal width for passengers' shoulder and elbow widths.

- **Keywords:** Transportation seating; Anthropometry; Secular trends in anthropometry; Airline seating; Transportation seating

Lin Lu, Fadel M. Megahed, Richard F. Sesek, Lora A. Cavuoto. *A survey of the prevalence of fatigue, its precursors and individual coping mechanisms among U.S. manufacturing workers*. Pages 139-151.

Advanced manufacturing has resulted in significant changes on the shop-floor, influencing work demands and the working environment. The corresponding safety-related effects, including fatigue, have not been captured on an industry-wide scale. This paper presents results of a survey of U.S. manufacturing workers for the: prevalence of fatigue, its root causes and significant factors, and adopted individual fatigue coping methods. The responses from 451 manufacturing employees were analyzed using descriptive data analysis, bivariate analysis and Market Basket Analysis. 57.9% of respondents indicated that they were somewhat fatigued during the past week. They reported the ankles/feet, lower back and eyes were frequently affected body parts and a lack of sleep, work stress and shift schedule were top selected root causes for fatigue. In order to respond to fatigue when it is present, respondents reported coping by drinking caffeinated drinks, stretching/doing exercises and talking with coworkers. Frequent combinations of fatigue causes and individual coping methods were identified. These results may inform the design of fatigue monitoring and mitigation strategies and future research related to fatigue development.

- **Keywords:** Advanced Manufacturing; Fatigue; Risk factors; Market Basket Analysis

Christopher S. Pan, Sharon S. Chiou, Tsui-Ying Kau, Bryan M. Wimer, Xiaopeng Ning, Paul Keane. *Evaluation of postural sway and impact forces during ingress and egress of scissor lifts at elevations*. Pages 152-162.

Workers are at risk when entering (ingress) or exiting (egress) elevated scissor lifts. In this study, we recorded ground impact forces and postural sway from 22 construction workers while they performed ingress and egress between a scissor lift and an adjacent work surface with varying conditions: lift opening designs, horizontal and vertical gaps, and sloped work surfaces. We observed higher peak ground shear forces when using a bar-and-chain opening, with larger horizontal gap, with the lift surface more than 0.2 m below the work surface, and presence of a sloped (26°) work surface. Similar trends were observed for postural sway, except that the influence of vertical distance was not significant. To reduce slip/trip/fall risk and postural sway of workers while ingress or egress of an elevated scissor lift, we suggest scissor lifts be equipped with a gate-type opening instead of a bar-and-chain design. We also suggest the lift surface be placed no more than 0.2 m lower than the work surface and the horizontal gap between lift and work surfaces be as small as possible. Selecting a non-sloped surface to ingress or egress a scissor lift is also preferred to reduce risk.

- **Keywords:** Scissor lifts; Ingress; Egress; Fall hazard; Construction

Kanako Goto, Kaoru Abe. *Gait characteristics in women's safety shoes*. Pages 163-167.

Although workers in Japan are required to wear safety footwear, there is concern about occupational accidents that occur when wearing safety shoes. This study aimed to analyze the effect of wearing hardsoled safety shoes on both spatiotemporal gait characteristics and the muscle activity in the lower extremities. Seventeen young women participated in this study. A 5-m gait trial and a surface electromyography trial were

conducted while the women walked in either safety shoes or sports shoes. Paired t-tests were performed to analyze the differences in gait characteristics when walking in the two different pairs of shoes. Walking in safety shoes was associated with a significant increase in vastus lateralis, biceps femoris and tibialis anterior activity. This increased muscle activity in the lower extremities is likely compensating for the lower flexibility of the safety shoes.

- **Keywords:** Gait; Personal protective equipment; Electromyography

Leandro L. Di Stasi, Carolina Díaz-Piedra, Juan Francisco Ruiz-Rabelo, Héctor Rieiro, Jose M. Sanchez Carrion, Andrés Catena. *Quantifying the cognitive cost of laparo-endoscopic single-site surgeries: gaze-based indices*. Pages 168-174.

Despite the growing interest concerning the laparo-endoscopic single-site surgery (LESS) procedure, LESS presents multiple difficulties and challenges that are likely to increase the surgeon's cognitive cost, in terms of both cognitive load and performance. Nevertheless, there is currently no objective index capable of assessing the surgeon cognitive cost while performing LESS. We assessed if gaze-based indices might offer unique and unbiased measures to quantify LESS complexity and its cognitive cost. We expect that the assessment of surgeon's cognitive cost to improve patient safety by measuring fitness-for-duty and reducing surgeons overload. **Methods:** Using a wearable eye tracker device, we measured gaze entropy and velocity of surgical trainees and attending surgeons during two surgical procedures (LESS vs. multiport laparoscopy surgery [MPS]). None of the participants had previous experience with LESS. They performed two exercises with different complexity levels (Low: Pattern Cut vs. High: Peg Transfer). We also collected performance and subjective data. **Results:** LESS caused higher cognitive demand than MPS, as indicated by increased gaze entropy in both surgical trainees and attending surgeons (exploration pattern became more random). Furthermore, gaze velocity was higher (exploration pattern became more rapid) for the LESS procedure independently of the surgeon's expertise. Perceived task complexity and laparoscopic accuracy confirmed gaze-based results. **Conclusion:** Gaze-based indices have great potential as objective and non-intrusive measures to assess surgeons' cognitive cost and fitness-for-duty. Furthermore, gaze-based indices might play a relevant role in defining future guidelines on surgeons' examinations to mark their achievements during the entire training (e.g. analyzing surgical learning curves).

- **Keywords:** LESS; Surgical skills assessment; Patient safety; Eye metrics; Neuroergonomics

Muhammad Tufail, KwanMyung Kim. *Effects of cursor freeze time on the performance of older adult users on mouse-related tasks*. Pages 175-182.

This study determines the optimum range of cursor freeze time (CFT) for basic target acquisition tasks. The effect of five levels of CFT was measured on double-clicking, clicking, and drag-and-drop operations, along with the inconvenience perceived by users at these levels. Older adult users find these standard mouse operations challenging because of slipping and accidental cursor movement. In this study, 24 older adult participants (13 males and 11 females) performed the abovementioned tasks repeatedly across five levels of CFT (0, 200, 400, 600, and 800 ms) and rated their perceived inconvenience at each level. CFT was found to have a significant effect on the three basic target acquisition tasks as well as the inconvenience perceived by participants. Performance on the drag-and-drop task was negatively influenced when the CFT was increased from 600 to 800 ms. The analysis suggests that a CFT of 200–400 ms is the optimum range for improved performance on the tasks.

- **Keywords:** Cursor freeze time; Target acquisition tasks; Perceived inconvenience

Joonho Chang, Andris Freivalds, Neil A. Sharkey, Yong-Ku Kong, H. Mike Kim, Kiseok Sung, Dae-Min Kim, Kihyo Jung. *Investigation of index finger triggering force using a cadaver experiment: effects of trigger grip span, contact location, and internal tendon force*. Pages 183-190.

A cadaver study was conducted to investigate the effects of triggering conditions (trigger grip span, contact location, and internal tendon force) on index finger triggering force and the force efficiency of involved tendons. Eight right human cadaveric hands were employed, and a motion simulator was built to secure and control the specimens. Index finger triggering forces were investigated as a function of different internal tendon forces (flexor digitorum profundus + flexor digitorum superficialis = 40, 70, and 100 N), trigger grip spans (40, 50, and 60 mm), and contact locations between the index finger and a trigger. Triggering forces significantly increased when internal tendon forces increased from 40 to 100 N. Also, trigger grip spans and contact locations had significant effects on triggering forces; maximum triggering forces were found at a 50 mm span and the most proximal contact location. The results revealed that only 10–30% of internal tendon forces were converted to their external triggering forces.

- **Keywords:** Triggering force; Force efficiency; Trigger grip span; Contact location; Internal tendon force

Thomas Franke, Madlen Günther, Maria Trantow, Josef F. Krems. *Does this range suit me?: range satisfaction of battery electric vehicle users*. Pages 191-199.

User satisfaction is a vital design criterion for sustainable systems. The present research aimed to understand factors relating to individually perceived range satisfaction of battery electric vehicle (BEV) users. Data from a large-scale BEV field trial (N = 72) were analyzed. Apart from an initial drop in range satisfaction, increasing practical experience was related to increased range satisfaction. Classical indicators of users' mobility profiles (daily travel distances) were only weakly related to lower range satisfaction (not significant), after controlling for practical experience and preferred coverage of mobility needs. The regularity/predictability of users' mobility patterns, the percentage of journeys not coverable because of range issues, and users' individual comfortable range accounted for variance in range satisfaction. Finally, range satisfaction was related to key indicators of general BEV acceptance (e.g., purchase intentions). These results underline the complex dynamics involved in individual range satisfaction, as well as its central role for BEV acceptance.

- **Keywords:** Battery electric vehicles; Range; User satisfaction; Acceptance; Field study

Stephen Walmsley, Andrew Gilbey. *Debiasing visual pilots' weather-related decision making*. Pages 200-208.

Pilots who decide to continue a flight into deteriorating weather conditions, rather than turn back or divert, are a significant cause of fatal crashes in general aviation. Earlier research has suggested that cognitive biases such as the anchoring effect and confirmation bias are implicated in many decisions to continue into worsening weather. In this study, we explored whether a simple debiasing technique, 'considering the alternative', reduced the effect of these two potentially fatal biases. Despite the study being adequately powered, our attempts to reduce the effects of biases were both unsuccessful. Negative findings such as these are particularly useful in aviation, as they

can provide information on what does not work in this high stakes industry, even though such strategies may work elsewhere.

- **Keywords:** Aviation; Debiasing; Anchoring effect; Confirmation bias

Wenguo Zhao, Yan Ge, Weina Qu, Kan Zhang, Xianghong Sun. *The duration perception of loading applications in smartphone: effects of different loading types*. Pages 223-232.

The loading time of a smartphone application is an important issue, which affects the satisfaction of phone users. This study evaluated the effects of black loading screen (BLS) and animation loading screen (ALS) during application loading on users' duration perception and satisfaction. A total of 43 volunteers were enrolled. They were asked to complete several tasks by clicking the icons of each application, such as camera or message. The duration of loading time for each application was manipulated. The participants were asked to estimate the duration, evaluate the loading speed and their satisfaction. The results showed that the estimated duration increased and the satisfaction for loading period declined along with the loading time increased. Compared with the BLS, the ALS prolonged the estimated duration, and lowered the evaluation of speed and satisfaction. We also discussed the tendency and key inflection points of the curves involving the estimated duration, speed evaluation and satisfaction with the loading time.

- **Keywords:** Loading time; Duration estimation; Satisfaction; Smartphone

Steven L. Fischer, Kathryn E. Sinden, Renee S. MacPhee. *Identifying the critical physical demanding tasks of paramedic work: towards the development of a physical employment standard*. Pages 233-239.

Public safety related occupations including police, fire and military commonly apply physical employment standard (PES) to facilitate job matching, an approach to evaluate if candidates demonstrate acceptable physical capabilities as required to perform the job safely and effectively. In Canada, paramedics remain as one of the few public safety occupations without an evidence-based, validated PES. The purpose of this study was to document and describe the physical demands of paramedic work and to identify the most physically demanding tasks. These outcomes are essential to inform the design and development of an evidence-based PES for the paramedic sector. Physical demands of paramedic work were documented and described using a direct observation-based task analysis technique. Five paramedic's were trained to document the physical demands of their work, then applied their training to observe more than 90 calls over the course of 20 full 12-h work shifts. Physical demands data were then listed in a survey, administered service-wide, where 155 frontline paramedics identified critically demanding tasks and rank-ordered physical demands from not physically demanding to very strongly demanding. Critically important and physically demanding tasks were identified such as: transferring a patient; loading or unloading a stretcher in to or out of the ambulance; performing CPR; and, raising and lowering a stretcher. It is important that a paramedic-based PES evaluate a candidate's physical capabilities to perform the critical and physically demanding tasks identified in this study.

- **Keywords:** Physical employment standard; Paramedics; Bona fide occupational requirement; Job-matching

Helene Jones, Anne Roudaut, Anna Chatzimichali, Kevin Potter, Carwyn Ward. *The Dibber: designing a standardised handheld tool for lay-up tasks*. Pages 240-254.

We present an application of engineering and ergonomics principles in the design of a standardised tool, The Dibber, which is a tool with multiple geometric features to fit the diversity of lay-up tasks used in the composites industry. The Dibber is the result of a design process, which consists of a series of observations and prototyping to extract geometric requirements for lay-up tasks. To demonstrate that it is possible to design a standardised tool prototypes of the Dibber were distributed and 91 participants gave feedback. Our results are positive and show consistent patterns of use across industry sectors, as well as between novice and expert laminators.

- **Keywords:** Handheld tools; Standardised tools; Design; Aerospace industry; Composites manufacturing

Nicole E. Werner, Seema Malkana, Ayse P. Gurses, Bruce Leff, Alicia I. Arbaje. *Toward a process-level view of distributed healthcare tasks: Medication management as a case study*. Pages 255-268.

We aim to highlight the importance of using a process-level view in analyzing distributed healthcare tasks through a case study analysis of medication management (MM). MM during older adults' hospital-to-skilled-home-healthcare (SHHC) transitions is a healthcare process with tasks distributed across people, organizations, and time. MM has typically been studied at the task level, but a process-level is needed to fully understand and improve MM during transitions. A process-level view allows for a broader investigation of how tasks are distributed throughout the work system through an investigation of interactions and the resultant emergent properties. We studied MM during older adults' hospital-to-SHHC transitions through interviews and observations with 60 older adults, their 33 caregivers, and 79 SHHC providers at 5 sites associated with 3 SHHC agencies. Study findings identified key cross-system characteristics not observable at the task-level: (1) identification of emergent properties (e.g., role ambiguity, loosely-coupled teams performing MM) and associated barriers; and (2) examination of barrier propagation across system boundaries. Findings highlight the importance of a process-level view of healthcare delivery occurring across system boundaries.

- **Keywords:** Process; Sociotechnical system; Work system; Medication management; System boundaries; Transitional care; Frail elderly; Home care agencies

Joonho Chang, Kihyo Jung. *Development of a press and drag method for hyperlink selection on smartphones*. Pages 269-276.

The present study developed a novel touch method for hyperlink selection on smartphones consisting of two sequential finger interactions: press and drag motions. The novel method requires a user to press a target hyperlink, and if a touch error occurs he/she can immediately correct the touch error by dragging the finger without releasing it in the middle. The method was compared with two existing methods in terms of completion time, error rate, and subjective rating. Forty college students participated in the experiments with different hyperlink sizes (4-pt, 6-pt, 8-pt, and 10-pt) on a touch-screen device. When hyperlink size was small (4-pt and 6-pt), the novel method (time: 826 msec; error: 0.6%) demonstrated better completion time and error rate than the current method (time: 1194 msec; error: 22%). In addition, the novel method (1.15, slightly satisfied, in 7-pt bipolar scale) had significantly higher satisfaction scores than the two existing methods (0.06, neutral).

- **Keywords:** Mobile website navigation; Press and drag; Smartphone; interaction

Seyed M. Miran, Chen Ling, Joseph J. James, Alan Gerard, Lans Rothfusz. *User perception and interpretation of tornado probabilistic hazard information: comparison of four graphical designs*. Pages 277-285.

Effective design for presenting severe weather information is important to reduce devastating consequences of severe weather. The Probabilistic Hazard Information (PHI) system for severe weather is being developed by NOAA National Severe Storms Laboratory (NSSL) to communicate probabilistic hazardous weather information. This study investigates the effects of four PHI graphical designs for tornado threat, namely, "four-color"," red-scale", "grayscale" and "contour", on users' perception, interpretation, and reaction to threat information. PHI is presented on either a map background or a radar background. Analysis showed that the accuracy was significantly higher and response time faster when PHI was displayed on map background as compared to radar background due to better contrast. When displayed on a radar background, "grayscale" design resulted in a higher accuracy of responses. Possibly due to familiarity, participants reported four-color design as their favorite design, which also resulted in the fastest recognition of probability levels on both backgrounds. Our study shows the importance of using intuitive color-coding and sufficient contrast in conveying probabilistic threat information via graphical design. We also found that users follows a rational perceiving-judging-feeling-and acting approach in processing probabilistic hazard information for tornado.

- **Keywords:** Natural hazard; Decision-making; Probabilistic information; Color coding; Contrast

Martin Kruusimagi, Sarah Sharples, Darren Robinson. *Living with an autonomous spatiotemporal home heating system: exploration of the user experiences (UX) through a longitudinal technology intervention-based mixed-methods approach*. Pages 286-308.

Rising energy demands place pressure on domestic energy consumption, but savings can be delivered through home automation and engaging users with their heating and energy behaviours. The aim of this paper is to explore user experiences (UX) of living with an automated heating system regarding experiences of control, understanding of the system, emerging thermal behaviours, and interactions with the system as this area is not sufficiently researched in the existing homes setting through extended deployment. We present a longitudinal deployment of a quasi-autonomous spatiotemporal home heating system in three homes. Users were provided with a smartphone control application linked to a self-learning heating algorithm. Rich qualitative and quantitative data presented here enabled a holistic exploration of UX. The paper's contribution focuses on highlighting key aspects of UX living with an automated heating systems including (i) adoption of the control interface into the social context, (ii) how users' vigilance in maintaining preferred conditions prevailed as a better indicator of system over-ride than gross deviation from thermal comfort, (iii) limited but motivated proactivity in system-initiated communications as best strategy for soliciting user feedback when inference fails, and (iv) two main motivations for interacting with the interface – managing irregularities when absent from the house and maintaining immediate comfort, latter compromising of a checking behaviour that can transit to a system state alteration behaviour depending on mismatches. We conclude by highlighting the complex socio-technical context in which thermal decisions are made in a situated action manner, and by calling for a more holistic, UX-focused approach in the design of automated home systems involving user experiences.

- **Keywords:** User-experience; UX; Design; Human-computer interaction; Hci; Spatiotemporal heating; Application; Interface; Longitudinal; Home heating; Technology intervention

Kingsley Fletcher, Andrew Neal, Gillian Yeo. *The effect of motor task precision on pupil diameter*. Pages 309-315.

It is well established that an increase in cognitive task demands is associated with increased pupil diameter. However, the effect of increased motor task demands on pupil diameter is less clear. Previous research indicates that higher motor task complexity increases pupil diameter but suggests that higher motor task precision demands may decrease pupil diameter during task movement. The current study investigated the effect of increased motor task precision on pupil diameter using a Fitts' Law movement task to manipulate motor response precision. Increased precision demands were associated with reduced pupil diameter during the response preparation and response execution phases of the movement trials. This result has implications for the interpretation of pupil diameter as an index of workload during tasks which involve precise motor movements.

- **Keywords:** Pupil diameter; Task demands; Motor tasks; Precision

O.A. Zielinska, C.B. Mayhorn, M.S. Wogalter. *Connoted hazard and perceived importance of fluorescent, neon, and standard safety colors*. Pages 326-334.

Objective: The perceived hazard and rated importance of standard safety, fluorescent, and neon colors are investigated. **Background:** Colors are used in warnings to enhance hazard communication. Red has consistently been rated as the highest in perceived hazard. Orange, yellow, and black are the next highest in connoted hazard; however, there is discrepancy in their ordering. Safety standards, such as ANSI Z535.1, also list colors to convey important information, but little research has examined the perceived importance of colors. In addition to standard safety colors, fluorescent colors are more commonly used in warnings. Understanding hazard and importance perceptions of standard safety and fluorescent colors is necessary to create effective warnings. **Methods:** Ninety participants rated and ranked a total of 33 colors on both perceived hazard and perceived importance. **Results:** Rated highest were the safety red colors from the American National Standard Institute (ANSI), International Organization for Standardization (ISO), and Federal Highway Administration (FHWA) together with three fluorescent colors (orange, yellow, and yellow-green) from 3 M on both dimensions. Rankings were similar to ratings except that fluorescent orange was the highest on perceived hazard, while fluorescent orange and safety red from the ANSI were ranked as the highest in perceived importance. **Conclusion:** Fluorescent colors convey hazard and importance levels as high as the standard safety red colors. **Application:** Implications for conveying hazard and importance in warnings through color are discussed.

- **Keywords:** Warnings; Color; Safety; Hazard; Risk; Importance

Jakob Rodseth, Edward P. Washabaugh, Ali Al Haddad, Paula Kartje, Denise G. Tate, Chandramouli Krishnan. *A novel low-cost solution for driving assessment in individuals with and without disabilities*. Pages 335-344.

Brake reaction time is a key component to studying driving performance and evaluating fitness to drive. Although commercial simulators can measure brake reaction time, their cost remains a major barrier to clinical access. Therefore, we developed open-source software written in C-sharp (C#) for measuring driving related reaction times, which includes a subject-controlled vehicle with straight-line dynamics and several testing scenarios. The software measures both simple and cognitive load based reaction times and can use any human interface device compliant steering wheel and pedals. Measures from the software were validated against a commercial simulator and tested for reproducibility. Further, experiments were performed using hand controls in both able-

bodied and spinal cord injured patients to determine clinical feasibility for disabled populations. The software demonstrated high validity when measuring brake reaction times, showed excellent test-retest reliability, and was sensitive enough to determine significant brake reaction time differences between able-bodied and spinal cord injured subjects. These results indicate that the proposed simulator is a simple and feasible low-cost solution to perform brake reaction time tests and evaluate fitness to drive.

- **Keywords:** Driving assessment; Driving fitness; SCI; Braking reaction time; Cognitive load; Low-cost simulator

A. Hulme, P.M. Salmon, R.O. Nielsen, G.J.M. Read, C.F. Finch. *From control to causation: validating a 'complex systems model' of running-related injury development and prevention*. Pages 345-354.

Introduction: There is a need for an ecological and complex systems approach for better understanding the development and prevention of running-related injury (RRI). In a previous article, we proposed a prototype model of the Australian recreational distance running system which was based on the Systems Theoretic Accident Mapping and Processes (STAMP) method. That model included the influence of political, organisational, managerial, and sociocultural determinants alongside individual-level factors in relation to RRI development. The purpose of this study was to validate that prototype model by drawing on the expertise of both systems thinking and distance running experts. **Materials and methods:** This study used a modified Delphi technique involving a series of online surveys (December 2016- March 2017). The initial survey was divided into four sections containing a total of seven questions pertaining to different features associated with the prototype model. Consensus in opinion about the validity of the prototype model was reached when the number of experts who agreed or disagreed with survey statement was ≥75% of the total number of respondents. **Results:** A total of two Delphi rounds was needed to validate the prototype model. Out of a total of 51 experts who were initially contacted, 50.9% (n = 26) completed the first round of the Delphi, and 92.3% (n = 24) of those in the first round participated in the second. Most of the 24 full participants considered themselves to be a running expert (66.7%), and approximately a third indicated their expertise as a systems thinker (33.3%). After the second round, 91.7% of the experts agreed that the prototype model was a valid description of the Australian distance running system. **Conclusion:** This is the first study to formally examine the development and prevention of RRI from an ecological and complex systems perspective. The validated model of the Australian distance running system facilitates theoretical advancement in terms of identifying practical system-wide opportunities for the implementation of sustainable RRI prevention interventions. This 'big picture' perspective represents the first step required when thinking about the range of contributory causal factors that affect other system elements, as well as runners' behaviours in relation to RRI risk.

- **Keywords:** Systems ergonomics; STAMP; Sports injury prevention; Running injury

C.C. Roossien, J. Stegenga, A.P. Hodselmans, S.M. Spook, W. Koolhaas, S. Brouwer, G.J. Verkerke, M.F. Reneman. *Can a smart chair improve the sitting behavior of office workers?* Pages 355-361.

Prolonged sitting can cause health problems and musculoskeletal discomfort. There is a need for objective and non-obstructive means of measuring sitting behavior. A 'smart' office chair can monitor sitting behavior and provide tactile feedback, aiming to improve sitting behavior. This study aimed to investigate the effect of the feedback signal on sitting behavior and musculoskeletal discomfort. In a 12-week prospective cohort study (ABCB design) among office workers (n = 45) was measured sitting duration and posture, feedback signals and musculoskeletal discomfort. Between the study phases,

small changes were observed in mean sitting duration, posture and discomfort. After turning off the feedback signal, a slight increase in sitting duration was observed (10 min, p = 0.04), a slight decrease in optimally supported posture (2.8%, p < 0.01), and musculoskeletal discomfort (0.8, p < 0.01) was observed. We conclude that the 'smart' chair is able to monitor the sitting behavior, the feedback signal, however, led to small or insignificant changes.

- **Keywords:** Sedentary behavior; Smart sensor chair; Tactile feedback

Jing Qiao, Lishan Sun, Xiaoming Liu, Jian Rong. *Reducing the impact of speed dispersion on subway corridor flow*. Pages 362-368.

The rapid increase in the volume of subway passengers in Beijing has necessitated higher requirements for the safety and efficiency of subway corridors. Speed dispersion is an important factor that affects safety and efficiency. This paper aims to analyze the management control methods for reducing pedestrian speed dispersion in subways. The characteristics of the speed dispersion of pedestrian flow were analyzed according to field videos. The control measurements which were conducted by placing traffic signs, yellow marking, and guardrail were proposed to alleviate speed dispersion. The results showed that the methods of placing traffic signs, yellow marking, and a guardrail improved safety and efficiency for all four volumes of pedestrian traffic flow, and the best-performing control measurement was guardrails. Furthermore, guardrails' optimal position and design measurements were explored. The research findings provide a rationale for subway managers in optimizing pedestrian traffic flow in subway corridors.

- **Keywords:** Pedestrian behavior; Subway corridor; Speed dispersion; Pedestrian experiment; Organization optimization

Johanna M. Silvennoinen, Tuomo Kujala, Jussi P.P. Jokinen. *Semantic distance as a critical factor in icon design for in-car infotainment systems*. Pages 369-381.

In-car infotainment systems require icons that enable fluent cognitive information processing and safe interaction while driving. An important issue is how to find an optimised set of icons for different functions in terms of semantic distance. In an optimised icon set, every icon needs to be semantically as close as possible to the function it visually represents and semantically as far as possible from the other functions represented concurrently. In three experiments (N = 21 each), semantic distances of 19 icons to four menu functions were studied with preference rankings, verbal protocols, and the primed product comparisons method. The results show that the primed product comparisons method can be efficiently utilised for finding an optimised set of icons for time-critical applications out of a larger set of icons. The findings indicate the benefits of the novel methodological perspective into the icon design for safety-critical contexts in general.

- **Keywords:** Safety-critical user interfaces; Icon; Semantic distance

Michael Y. Lin, Ana Barbir, Jack T. Dennerlein. *Evaluating biomechanics of user-selected sitting and standing computer workstation*. Pages 382-388.

A standing computer workstation has now become a popular modern work place intervention to reduce sedentary behavior at work. However, user's interaction related to a standing computer workstation and its differences with a sitting workstation need to be understood to assist in developing recommendations for use and set up. The study compared the differences in upper extremity posture and muscle activity between user-

selected sitting and standing workstation setups. Twenty participants (10 females, 10 males) volunteered for the study. 3-D posture, surface electromyography, and user-reported discomfort were measured while completing simulated tasks with each participant's self-selected workstation setups. Sitting computer workstation associated with more non-neutral shoulder postures and greater shoulder muscle activity, while standing computer workstation induced greater wrist adduction angle and greater extensor carpi radialis muscle activity. Sitting computer workstation also associated with greater shoulder abduction postural variation (90th–10th percentile) while standing computer workstation associated with greater variation for should rotation and wrist extension. Users reported similar overall discomfort levels within the first 10 min of work but had more than twice as much discomfort while standing than sitting after 45 min; with most discomfort reported in the low back for standing and shoulder for sitting. These different measures provide understanding in users' different interactions with sitting and standing and by alternating between the two configurations in short bouts may be a way of changing the loading pattern on the upper extremity.

- **Keywords:** Office work; Workstation; Musculoskeletal disorders

Zhao Guo, Rachael Bei Yee, Kyung-Ryoul Mun, Haoyong Yu. *Experimental evaluation of a novel robotic hospital bed mover with omni-directional mobility*. Pages 389-397.

Bed pushing during patient transfer is one of the most physically demanding and yet common tasks in the hospital setting. Powered bed movers have been increasingly introduced to hospitals to reduce physiological strains on the users. This study introduces and quantifies the manpower efficiency and health benefits of a novel robotic-assisted omni-directional hospital bed transporter (SESTO Bed Mover) in comparison with a conventional manual transport stretcher (Stryker Trauma Stretcher 1037) and a powered transport stretcher (HOSPIMEK HMPT 740), which has a fifth powered wheel providing power assistance only in the forward direction. A total of 14 subjects were recruited (7 porters and 7 students) and were tasked to complete a course within a controlled lab environment. It is concluded that the robotic bed mover is able to halve the required manpower to push hospital beds as compared to conventional bed pushing without any additional physiological strain, potentially improving efficiency by two-fold. Electromyography (EMG) patterns showed that users relied on the shoulder and back muscles in a fashion similar to conventional pushing, further confirming the intuitive drive of the robotic bed mover. Overall, the robotic bed mover shows reduced physical demands, less manpower required for patient transport and reduced back muscle activities, which strongly suggest health benefits for workers in the hospital.

- **Keywords:** Hospital bed mover; Omni-directional mobility; Physiological strain; Electromyography (EMG)

A. Villarroya, P. Arezes, S. Díaz de Freijo, F. Fraga. *Validity and reliability of the HEMPA method for patient handling assessment*. Pages 209-222.

Specific methods currently exist to assess occupational hazards resulting from patient handling in the healthcare sector, according to ISO/TR 12296. They are all similar in nature, but with a different analysis perspective; for that reason a comparison of the most relevant methods was performed in a previous research. As a result, a basis of a new tool that integrates the complementary aspects of those methods was proposed. To verify the validity and reliability of that method, a study within a hospital setting was carried out in five medical and surgical units of a public health institution. Based on the obtained results, the analysed method (called HEMPA) proved to be valid and reliable. Also, this method reflects a positive correlation between risk and damage and correctly quantifies risks regarding patient's dependence.

- **Keywords:** Risk assessment; Patient handling; Hospitals; Ergonomics; HEMPA

Benjamin Wolfe, Jonathan Dobres, Ruth Rosenholtz, Bryan Reimer. *More than the Useful Field: Considering peripheral vision in driving*. Pages 316-325.

Applied research on driving and basic vision research have held similar views on central, fovea-based vision as the core of visual perception. In applied work, the concept of the Useful Field, as determined by the Useful Field of View (UFOV) test, divides vision between a "useful" region towards the center of the visual field, and the rest of the visual field. While compelling, this dichotomization is at odds with findings in vision science which demonstrate the capabilities of peripheral vision. In this paper, we examine driving research from this new perspective, and argue for the need for an updated understanding of how drivers acquire information about their operating environment using peripheral vision. The concept of the Useful Field and the UFOV test are not discarded; instead we discuss their strengths, limitations, and future directions. We discuss key findings from vision science on peripheral vision, and a theory that provides insights into its capabilities and limitations. This more complete basic science understanding of peripheral vision informs appropriate use of the UFOV and the Useful Field in driving research going forward.

- **Keywords:** UFOV; Useful field of view; Peripheral vision; Visual attention

Juan Luis Higuera-Trujillo, Juan López-Tarruella Maldonado, Carmen Llinares Millán. *Psychological and physiological human responses to simulated and real environments: a comparison between Photographs, 360° Panoramas, and Virtual Reality*. Pages 398-409.

Psychological research into human factors frequently uses simulations to study the relationship between human behaviour and the environment. Their validity depends on their similarity with the physical environments. This paper aims to validate three environmental-simulation display formats: photographs, 360° panoramas, and virtual reality. To do this we compared the psychological and physiological responses evoked by simulated environments set-ups to those from a physical environment setup; we also assessed the users' sense of presence. Analysis show that 360° panoramas offer the closest to reality results according to the participants' psychological responses, and virtual reality according to the physiological responses. Correlations between the feeling of presence and physiological and other psychological responses were also observed. These results may be of interest to researchers using environmental-simulation technologies currently available in order to replicate the experience of physical environments.

- **Keywords:** Virtual reality; 360° Panorama; Validity; Psychological human responses; Physiological human responses

Nicolas Vignais, Fabien Bernard, Gérard Touvenot, Jean-Claude Sagot. *Physical risk factors identification based on body sensor network combined to videotaping*. Pages 410-417.

The aim of this study was to perform an ergonomic analysis of a material handling task by combining a subtask video analysis and a RULA computation, implemented continuously through a motion capture system combining inertial sensors and electrogoniometers. Five workers participated to the experiment. Seven inertial measurement units, placed on the worker's upper body (pelvis, thorax, head, arms, forearms), were implemented through a biomechanical model of the upper body to continuously provide trunk, neck, shoulder and elbow joint angles. Wrist joint angles

were derived from electrogoniometers synchronized with the inertial measurement system. Worker's activity was simultaneously recorded using video. During post-processing, joint angles were used as inputs to a computationally implemented ergonomic evaluation based on the RULA method. Consequently a RULA score was calculated at each time step to characterize the risk of exposure of the upper body (right and left sides). Local risk scores were also computed to identify the anatomical origin of the exposure. Moreover, the video-recorded work activity was time-studied in order to classify and quantify all subtasks involved into the task. Results showed that mean RULA scores were at high risk for all participants (6 and 6.2 for right and left sides respectively). A temporal analysis demonstrated that workers spent most part of the work time at a RULA score of 7 (right: 49.19 ± 35.27%; left: 55.5 ± 29.69%). Mean local scores revealed that most exposed joints during the task were elbows, lower arms, wrists and hands. Elbows and lower arms were indeed at a high level of risk during the total time of a work cycle (100% for right and left sides). Wrist and hands were also exposed to a risky level for much of the period of work (right: 82.13 ± 7.46%; left: 77.85 ± 12.46%). Concerning the subtask analysis, subtasks called 'snow thrower', 'opening the vacuum sealer', 'cleaning' and 'storing' have been identified as the most awkward for right and left sides given mean RULA scores and percentages of time spent at risky levels. Results analysis permitted to suggest ergonomic recommendations for the redesign of the workstation. Contributions of the proposed innovative system dedicated to physical ergonomic assessment are further discussed.

- **Keywords:** Physical ergonomics; Inertial measurement unit; Manual tasks; Risk of exposure; Musculoskeletal disorders

Xu Xu, Michelle Robertson, Karen B. Chen, Jia-hua Lin, Raymond W. McGorry. *Using the Microsoft Kinect™ to assess 3-D shoulder kinematics during computer use*. Pages 418-423.

Shoulder joint kinematics has been used as a representative indicator to investigate musculoskeletal symptoms among computer users for office ergonomics studies. The traditional measurement of shoulder kinematics normally requires a laboratory-based motion tracking system which limits the field studies. In the current study, a portable, low cost, and marker-less Microsoft Kinect™ sensor was examined for its feasibility on shoulder kinematics measurement during computer tasks. Eleven healthy participants performed a standardized computer task, and their shoulder kinematics data were measured by a Kinect sensor and a motion tracking system concurrently. The results indicated that placing the Kinect sensor in front of the participants would yielded a more accurate shoulder kinematics measurements then placing the Kinect sensor 15° or 30° to one side. The results also showed that the Kinect sensor had a better estimate on shoulder flexion/extension, compared with shoulder adduction/abduction and shoulder axial rotation. The RMSE of front-placed Kinect sensor on shoulder flexion/extension was less than 10° for both the right and the left shoulder. The measurement error of the front-placed Kinect sensor on the shoulder adduction/abduction was approximately 10° to 15°, and the magnitude of error is proportional to the magnitude of that joint angle. After the calibration, the RMSE on shoulder adduction/abduction were less than 10° based on an independent dataset of 5 additional participants. For shoulder axial rotation, the RMSE of front-placed Kinect sensor ranged between approximately 15° to 30°. The results of the study suggest that the Kinect sensor can provide some insight on shoulder kinematics for improving office ergonomics.

- **Keywords:** Office ergonomics; Motion tracking; Shoulder biomechanics; Workstation design

Wonil Lee, Edmund Seto, Ken-Yu Lin, Giovanni C. Migliaccio. *An evaluation of wearable sensors and their placements for analyzing*

***construction worker's trunk posture in laboratory conditions*. Pages 424-436.**

This study investigates the effect of sensor placement on the analysis of trunk posture for construction activities using two off-the-shelf systems. Experiments were performed using a single-parameter monitoring wearable sensor (SPMWS), the ActiGraph GT9X Link, which was worn at six locations on the body, and a multi-parameter monitoring wearable sensor (MPMWS), the Zephyr BioHarness™3, which was worn at two body positions. One healthy male was recruited and conducted 10 experiment sessions to repeat measurements of trunk posture within our study. Measurements of upper-body thoracic bending posture during the lifting and lowering of raised deck materials in a laboratory setting were compared against video-captured observations of posture. The measurements from the two sensors were found to be in agreement during slow-motion symmetric bending activities with a target bending of ≤45°. However, for asymmetric bending tasks, when the SPMWS was placed on the chest, its readings were substantially different from those of the MPMWS worn on the chest or under the armpit.

- **Keywords:** Work-related musculoskeletal disorder; Accelerometer for inclinometry; Construction worker

Jiayin Chen, Calvin Or. *Assessing the use of immersive virtual reality, mouse and touchscreen in pointing and dragging-and-dropping tasks among young, middle-aged and older adults*. Pages 437-448.

This study assessed the use of an immersive virtual reality (VR), a mouse and a touchscreen for one-directional pointing, multi-directional pointing, and dragging-and-dropping tasks involving targets of smaller and larger widths by young (n = 18; 18–30 years), middle-aged (n = 18; 40–55 years) and older adults (n = 18; 65–75 years). A three-way, mixed-factorial design was used for data collection. The dependent variables were the movement time required and the error rate. Our main findings were that the participants took more time and made more errors in using the VR input interface than in using the mouse or the touchscreen. This pattern applied in all three age groups in all tasks, except for multi-directional pointing with a larger target width among the older group. Overall, older adults took longer to complete the tasks and made more errors than young or middle-aged adults. Larger target widths yielded shorter movement times and lower error rates in pointing tasks, but larger targets yielded higher rates of error in dragging-and-dropping tasks. Our study indicated that any other virtual environments that are similar to those we tested may be more suitable for displaying scenes than for manipulating objects that are small and require fine control. Although interacting with VR is relatively difficult, especially for older adults, there is still potential for older adults to adapt to that interface. Furthermore, adjusting the width of objects according to the type of manipulation required might be an effective way to promote performance.

- **Keywords:** Virtual reality; Human-computer interaction; Older adults

Shuchisnigdha Deb, Daniel W. Carruth, Richard Sween, Lesley Strawderman, Teena M. Garrison. *Efficacy of virtual reality in pedestrian safety research*. Pages 449-460.

Advances in virtual reality technology present new opportunities for human factors research in areas that are dangerous, difficult, or expensive to study in the real world. The authors developed a new pedestrian simulator using the HTC Vive head mounted display and Unity software. Pedestrian head position and orientation were tracked as participants attempted to safely cross a virtual signalized intersection (5.5 m). In 10% of 60 trials, a vehicle violated the traffic signal and in 10.84% of these trials, a collision between the vehicle and the pedestrian was observed. Approximately 11% of the

participants experienced simulator sickness and withdrew from the study. Objective measures, including the average walking speed, indicate that participant behavior in VR matches published real world norms. Subjective responses indicate that the virtual environment was realistic and engaging. Overall, the study results confirm the effectiveness of the new virtual reality technology for research on full motion tasks.

- **Keywords:** Head-tracking technology; Pedestrian simulator; User experience

Runyu L. Greene, David P. Azari, Yu Hen Hu, Robert G. Radwin. *Visualizing stressful aspects of repetitive motion tasks and opportunities for ergonomic improvements using computer vision*. Pages 461-472.

Patterns of physical stress exposure are often difficult to measure, and the metrics of variation and techniques for identifying them is underdeveloped in the practice of occupational ergonomics. Computer vision has previously been used for evaluating repetitive motion tasks for hand activity level (HAL) utilizing conventional 2D videos. The approach was made practical by relaxing the need for high precision, and by adopting a semi-automatic approach for measuring spatiotemporal characteristics of the repetitive task. In this paper, a new method for visualizing task factors, using this computer vision approach, is demonstrated. After videos are made, the analyst selects a region of interest on the hand to track and the hand location and its associated kinematics are measured for every frame. The visualization method spatially deconstructs and displays the frequency, speed and duty cycle components of tasks that are part of the threshold limit value for hand activity for the purpose of identifying patterns of exposure associated with the specific job factors, as well as for suggesting task improvements. The localized variables are plotted as a heat map superimposed over the video, and displayed in the context of the task being performed. Based on the intensity of the specific variables used to calculate HAL, we can determine which task factors most contribute to HAL, and readily identify those work elements in the task that contribute more to increased risk for an injury. Work simulations and actual industrial examples are described. This method should help practitioners more readily measure and interpret temporal exposure patterns and identify potential task improvements.

- **Keywords:** Occupational ergonomics; Physical stress exposure; Work design; Work related musculoskeletal disorders

Jibo He, William Choi, Yan Yang, Junshi Lu, Xiaohui Wu, Kaiping Peng. *Detection of driver drowsiness using wearable devices: a feasibility study of the proximity sensor*. Pages 473-480.

Background: Drowsiness is one of the major factors that cause crashes in the transportation industry. Drowsiness detection systems can alert drowsy operators and potentially reduce the risk of crashes. In this study, a Google-Glass-based drowsiness detection system was developed and validated. **Methods:** The proximity sensor of Google Glass was used to monitor eye blink frequency. A simulated driving study was carried out to validate the system. Driving performance and eye blinks were compared between the two states of alertness and drowsiness while driving. **Results:** Drowsy drivers increased frequency of eye blinks, produced longer braking response time and increased lane deviation, compared to when they were alert. A threshold algorithm for proximity sensor can reliably detect eye blinks and proved the feasibility of using Google Glass to detect operator drowsiness. **Applications:** This technology provides a new platform to detect operator drowsiness and has the potential to reduce drowsiness-related crashes in driving and aviation.

- **Keywords:** Driver drowsiness; Wearable device; Proximity sensor

Vito Modesto Manghisi, Antonio Emmanuele Uva, Michele Fiorentino, Vitoantonio Bevilacqua, Gianpaolo Francesco Trotta, Giuseppe Monno. *Real time RULA assessment using Kinect v2 sensor*. Pages 481-491.

The evaluation of the exposure to risk factors in workplaces and their subsequent redesign represent one of the practices to lessen the frequency of work-related musculoskeletal disorders. In this paper we present K2RULA, a semi-automatic RULA evaluation software based on the Microsoft Kinect v2 depth camera, aimed at detecting awkward postures in real time, but also in off-line analysis. We validated our tool with two experiments. In the first one, we compared the K2RULA grand-scores with those obtained with a reference optical motion capture system and we found a statistical perfect match according to the Landis and Koch scale (proportion agreement index = 0.97, k = 0.87). In the second experiment, we evaluated the agreement of the grand-scores returned by the proposed application with those obtained by a RULA expert rater, finding again a statistical perfect match (proportion agreement index = 0.96, k = 0.84), whereas a commercial software based on Kinect v1 sensor showed a lower agreement (proportion agreement index = 0.82, k = 0.34).

- **Keywords:** Kinect v2; RULA; Ergonomics

Liyun Yang, Wilhelmus J.A. Grooten, Mikael Forsman. *An iPhone application for upper arm posture and movement measurements*. Pages 492-500.

There is a need for objective methods for upper arm elevation measurements for accurate and convenient risk assessments. The aims of this study were (i) to compare a newly developed iOS application (iOS) for measuring upper arm elevation and angular velocity with a reference optical tracking system (OTS), and (ii) to compare the accuracy of the iOS incorporating a gyroscope and an accelerometer with using only an accelerometer, which is standard for inclinometry. The iOS–OTS limits of agreement for static postures (9 subjects) were −4.6° and 4.8°. All root mean square differences in arm swings and two simulated work tasks were <6.0°, and all mean correlation coefficients were >0.98. The mean absolute iOS–OTS difference of median angular velocity was <13.1°/s, which was significantly lower than only using an accelerometer (<43.5°/s). The accuracy of this iOS application compares well to that of today's research methods and it can be useful for practical upper arm measurements.

- **Keywords:** Work-related musculoskeletal disorders; Accelerometer; Gyroscope

Kapil Chalil Madathil, Joel S. Greenstein. *An investigation of the efficacy of collaborative virtual reality systems for moderated remote usability testing*. Pages 501-514.

Collaborative virtual reality-based systems have integrated high fidelity voice-based communication, immersive audio and screen-sharing tools into virtual environments. Such three-dimensional collaborative virtual environments can mirror the collaboration among usability test participants and facilitators when they are physically collocated, potentially enabling moderated usability tests to be conducted effectively when the facilitator and participant are located in different places. We developed a virtual collaborative three-dimensional remote moderated usability testing laboratory and employed it in a controlled study to evaluate the effectiveness of moderated usability testing in a collaborative virtual reality-based environment with two other moderated usability testing methods: the traditional lab approach and Cisco WebEx, a web-based conferencing and screen sharing approach. Using a mixed methods experimental design, 36 test participants and 12 test facilitators were asked to complete representative tasks on a simulated online shopping website. The dependent variables included the time taken

to complete the tasks; the usability defects identified and their severity; and the subjective ratings on the workload index, presence and satisfaction questionnaires. Remote moderated usability testing methodology using a collaborative virtual reality system performed similarly in terms of the total number of defects identified, the number of high severity defects identified and the time taken to complete the tasks with the other two methodologies. The overall workload experienced by the test participants and facilitators was the least with the traditional lab condition. No significant differences were identified for the workload experienced with the virtual reality and the WebEx conditions. However, test participants experienced greater involvement and a more immersive experience in the virtual environment than in the WebEx condition. The ratings for the virtual environment condition were not significantly different from those for the traditional lab condition. The results of this study suggest that participants were productive and enjoyed the virtual lab condition, indicating the potential of a virtual world based approach as an alternative to conventional approaches for synchronous usability testing.

- **Keywords:** Collaborative virtual reality systems; Moderated usability testing; Remote testing

Zahra Sedighi Maman, Mohammad Ali Alamdar Yazdi, Lora A. Cavuoto, Fadel M. Megahed. *A data-driven approach to modeling physical fatigue in the workplace using wearable sensors*. Pages 515-529.

Wearable sensors are currently being used to manage fatigue in professional athletics, transportation and mining industries. In manufacturing, physical fatigue is a challenging ergonomic/safety "issue" since it lowers productivity and increases the incidence of accidents. Therefore, physical fatigue must be managed. There are two main goals for this study. First, we examine the use of wearable sensors to detect physical fatigue occurrence in simulated manufacturing tasks. The second goal is to estimate the physical fatigue level over time. In order to achieve these goals, sensory data were recorded for eight healthy participants. Penalized logistic and multiple linear regression models were used for physical fatigue detection and level estimation, respectively. Important features from the five sensors locations were selected using Least Absolute Shrinkage and Selection Operator (LASSO), a popular variable selection methodology. The results show that the LASSO model performed well for both physical fatigue detection and modeling. The modeling approach is not participant and/or workload regime specific and thus can be adopted for other applications.

- **Keywords:** Analytics; Feature selection; Penalized regression; Physical fatigue

Jose Antonio Diego-Mas, Rocio Poveda-Bautista, Diana Garzon-Leal. *Using RGB-D sensors and evolutionary algorithms for the optimization of workstation layouts*. Pages 530-540.

RGB-D sensors can collect postural data in an automatized way. However, the application of these devices in real work environments requires overcoming problems such as lack of accuracy or body parts' occlusion. This work presents the use of RGB-D sensors and genetic algorithms for the optimization of workstation layouts. RGB-D sensors are used to capture workers' movements when they reach objects on workbenches. Collected data are then used to optimize workstation layout by means of genetic algorithms considering multiple ergonomic criteria. Results show that typical drawbacks of using RGB-D sensors for body tracking are not a problem for this application, and that the combination with intelligent algorithms can automatize the layout design process. The procedure described can be used to automatically suggest new layouts when workers or processes of production change, to adapt layouts to specific workers based on their ways to do the tasks, or to obtain layouts simultaneously optimized for several production processes.

- **Keywords:** RGB-D sensors; Workstation layout; Genetic algorithms

Rahil Mehrizi, Xu Xu, Shaoting Zhang, Vladimir Pavlovic, Dimitris Metaxas, Kang Li. *Using a marker-less method for estimating L5/S1 moments during symmetrical lifting*. Pages 541-550.

The aim of this study is to analyze the validity of a computer vision-based method to estimate 3D L5/S1 joint moment during symmetrical lifting. An important criterion to identify the non-ergonomic lifting task is the value of net moment at L5/S1 joint. This is usually calculated in a laboratory environment which is not practical for on-site biomechanical analysis. The validity of the proposed method, was assessed externally by comparing the results with a lab-based reference method and internally by comparing the estimated L5/S1 joint moments from top-down model and bottom-up model. It was shown that no significant differences in peak and mean moments between the two methods and intra-class correlation coefficients revealed excellent reliability of the proposed method (>0.91). The proposed method provides a reliable tool for assessment of lower back loads during occupational lifting and can be an alternative when the use of marker-based motion tracking systems is not possible.

- **Keywords:** Marker-less motion capture; Lifting; Computer vision

Xiaoyu Chen, Ran Jin. *Statistical modeling for visualization evaluation through data fusion*. Pages 551-561.

There is a high demand of data visualization providing insights to users in various applications. However, a consistent, online visualization evaluation method to quantify mental workload or user preference is lacking, which leads to an inefficient visualization and user interface design process. Recently, the advancement of interactive and sensing technologies makes the electroencephalogram (EEG) signals, eye movements as well as visualization logs available in user-centered evaluation. This paper proposes a data fusion model and the application procedure for quantitative and online visualization evaluation. 15 participants joined the study based on three different visualization designs. The results provide a regularized regression model which can accurately predict the user's evaluation of task complexity, and indicate the significance of all three types of sensing data sets for visualization evaluation. This model can be widely applied to data visualization evaluation, and other user-centered designs evaluation and data analysis in human factors and ergonomics.

- **Keywords:** Data fusion; Data visualization; Electroencephalogram (EEG); Eye tracking; User-centered designs; Visualization evaluation

Pierre Plantard, Hubert P.H. Shum, Anne-Sophie Le Pierres, Franck Multon. *Validation of an ergonomic assessment method using Kinect data in real workplace conditions*. Pages 562-569.

Evaluating potential musculoskeletal disorders risks in real workstations is challenging as the environment is cluttered, which makes it difficult to accurately assess workers' postures. Being marker-free and calibration-free, Microsoft Kinect is a promising device although it may be sensitive to occlusions. We propose and evaluate a RULA ergonomic assessment in real work conditions using recently published occlusion-resistant Kinect skeleton data correction. First, we compared postures estimated with this method to ground-truth data, in standardized laboratory conditions. Second, we compared RULA scores to those provided by two professional experts, in a non-laboratory cluttered workplace condition. The results show that the corrected Kinect data can provide more accurate RULA grand scores, even under sub-optimal conditions induced by the workplace environment. This study opens new perspectives in musculoskeletal risk

assessment as it provides the ergonomists with 30 Hz continuous information that could be analyzed offline and in a real-time framework.

- **Keywords:** Kinect; RULA; Real work condition

Sang D. Choi, Liangjie Guo, Donghun Kang, Shuping Xiong. *Exergame technology and interactive interventions for elderly fall prevention: asystematic literature review*. Pages 570-581.

Training balance and promoting physical activities in the elderly can contribute to fall-prevention. Due to the low adherence of conventional physical therapy, fall interventions through exergame technologies are emerging. The purpose of this review study is to synthesize the available research reported on exergame technology and interactive interventions for fall prevention in the older population. Twenty-five relevant papers retrieved from five major databases were critically reviewed and analyzed. Results showed that the most common exergaming device for fall intervention was Nintendo Wii, followed by Xbox Kinect. Even though the exergame intervention protocols and outcome measures for assessing intervention effectiveness varied, the accumulated evidences revealed that exergame interventions improved physical or cognitive functions in the elderly. However, it remains inconclusive whether or not the exergame-based intervention for the elderly fall prevention is superior to conventional physical therapy and the effect mechanism of the exergaming on elderly's balance ability is still unclear.

- **Keywords:** Exergame technology; Fall prevention; Ageing