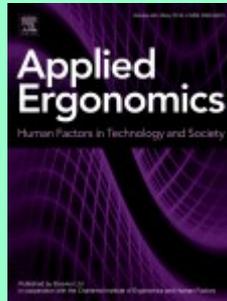


Applied Ergonomics - rok 2020, Volume 85

May 2020



Kyungdoh Kim, Robert W. Proctor, Gavriel Salvendy. Emotional factors and physical properties of ballpoint pens that affect user satisfaction: Implications for pen and stylus design.

Many studies of ballpoint pens have been conducted. However, those studies have not considered the emotional factors that can enhance user experience. Styluses resemble ballpoint pens in many ways, which are widely available in a variety of styles. Therefore, in the present study, we explored the physical and emotional attributes that improve user satisfaction with typical ballpoint pens, with the goal of also understanding what factors might be important for stylus design. First, 14 emotional factors associated with the pens were derived. Second, 16 different types of ball-point pens were measured for six physical properties. Then, an experiment was performed to assess user satisfaction and emotional factors for pens. The House of Quality (HOQ) was used to obtain the chief physical properties. Results showed that to increase user satisfaction it is necessary to make pens be comfortable, fine, refined, deep, and natural. Also, we found that for high user satisfaction pens need to be heavier and longer, have thick and antislip grips and thin nibs, and their center of gravity should be located close to the nib to increase user satisfaction.

- **Keywords:** Ballpoint pens; Styluses; Emotion; House of quality; User experience

Joshua P. Drost, Mark D. Shafer, Tamara Reid Bush. Comfortable leg splay of mid-sized males in automotive seats.

Many factors affect the comfort of automotive seats including pressure distribution, vibration, temperature, and backrest inclination. However, one aspect of seating that has not been well studied is leg splay; splay is a rotation at the hips which causes the knees to move outward. The work presented here identified the ranges of "comfortable" splay in different styles of seats and related changes in seating pressure due to leg splay. Sixteen midsized male participants were tested in six seats: a flat control, three mid-sized sedan, a sports car, and a pickup truck. Participants sat with two leg conditions: 1) shoulder width apart and 2) rotating their legs to splay to a self-identified, comfortable position. For each test, the participant placed his left leg on a foot support and right leg on a depressible pedal to mimic a driving position. In each posture, leg angle and seat pan pressures were collected. Of the seats tested, the flat wooden seat had the highest possible splay (24.5°). The three sedan seats had similar splay angles (16.1–18.5°). The lowest splay values were in the sports car seat (8.96°) and truck seat (7.46°). This reduction in splay was attributed to the more aggressive bolsters in the sports car and a higher seat design position in the pickup truck seat. Following participant splay the

pressures in the seat bolsters increased while the pressure in the left thigh and left buttocks regions decreased. By determining the comfortable ranges of splay and how pressure distribution is affected, seat designers and automobile manufacturers can use these data when evaluating seat designs and occupant positioning.

- **Keywords:** Automotive; Comfort; Seating

Katarina Katić, Rongling Li, Wim Zeiler. *Machine learning algorithms applied to a prediction of personal overall thermal comfort using skin temperatures and occupants' heating behavior.*

Thermal comfort modeling has been of interest in built environment research for decades. Mostly the modeling approaches focused on an average response of a large group of building occupants. Recently, the focus has been shifted towards personal comfort models that predict individuals' thermal comfort responses. Currently, thermal comfort responses are collected from the occupants via survey. This study explored if the thermal comfort of individuals could be predicted using machine learning algorithms while relying on the set of collected inputs from an experiment. The model was developed using experimental data including collected from a previously performed experiment in the climate chamber. Two different approaches based on the output data (thermal sensation and thermal comfort votes) and five different sets of input variables were explored. The algorithms tested were Support Vector Machine with four different Kernel functions (Linear, Quadratic, Cubic and Gaussian) and Ensemble Algorithms (Boosted trees, Bagged trees and RUSBoosted trees). The combination of occupants' heating behavior with a personal comfort system (PCS), skin temperatures, time and environmental data were used for the development of personal comfort models to predict individuals' thermal preference. The study investigated the novel combination of inputs such as the use of skin temperature and settings of the personalized heating system as parameters in predicting personal thermal comfort. The results showed that personal comfort models among all tested approaches and subjects showed the best median accuracy of 0.84 using RUSBoosted trees. Individually looking, the approach using thermal sensation output produced better prediction accuracy. On the other hand, the models based on inputs that consisted of PCS control behavior and mean and hand skin temperatures produced the best prediction accuracy when assessing all tested algorithms. The main limitation of the study is the number of test subjects, and further recommendation is to perform more experiments.

- **Keywords:** Personal comfort model; Thermal comfort; Machine learning; Skin temperature; Personalized heating system

Zihao Wang, Renke He, Ke Chen. *Thermal comfort and virtual reality headsets.*

This study proposed to investigate the thermal properties and subjective thermal discomfort of five virtual reality headsets, and their relationships. Twenty-seven university students used each of the five headsets for 45 min. Microclimate temperature and relative humidity were measured by miniature dataloggers. Infrared thermography was used to measure temperature distribution on the contact points between user's face and the headsets. Participants reported subjective thermal discomfort associated with using each headset. The average microclimate temperature and relative humidity increased by 7.8 °C and 3.5% respectively after headset use. Overall subjective thermal discomfort increased along with duration of use and came primarily from the display. Applying the linear mixed-effects model showed that subjective thermal discomfort is positively correlated with duration of use, microclimate temperature, relative humidity and display coverage area. Conversely, thermal discomfort is negatively correlated with total coverage area, with microclimate temperature acting as the most significant

contributing factor. The headsets were ranked by pairing the objective measurements with subjective evaluations.

- **Keywords:** Virtual reality headsets; Thermal comfort; Microclimate

Junsig Wang, Jason C. Gillette. *Mediolateral postural stability when carrying asymmetric loads during stair negotiation.*

The purpose of this study was to assess postural stability in the medial-lateral (ML) direction when carrying unilateral and bilateral loads during stair negotiation. Twenty-four healthy young adults were instructed to ascend and descend a three step staircase under three load conditions: no load, 20% body mass (BM) bilateral load, and 20% BM unilateral load. A modified time-to-contact (TTC) method was proposed to evaluate postural stability during stair negotiation. Carrying unilateral loads required more rapid postural adjustments as evidenced by lower minimum ML TTC and ML TTC percentage as compared bilateral loads and no load during stair descent. In addition, lower ML TTC and TTC percentage were found for loaded limb stance for stair descent. Taken together, unilateral loads and the loaded leg during stair descent are of concern when considering postural stability during load carriage. These results illustrate differing postural control challenges for stair ascent and descent during load carriage.

- **Keywords:** Asymmetric load; Postural control; Stair negotiation; Time-to-contact; Center of pressure

Joseph Ulbrich, Robert Swader, George Petry, Benjamin L. Cox, Runyu L. Greene, Kevin W. Eliceiri, Robert G. Radwin. *A syringe adapter for reduced muscular strain and fatigue.*

Workers in hospitals, clinics, and contract research organizations who repetitively use syringes have an increased risk for musculoskeletal disorders. This study developed and tested a novel syringe adapter designed to reduce muscle strain associated with repetitive fluid draws. Three syringe plunger extension methods (ring-finger, middle-finger, and syringe adapter) were studied across twenty participants. Electromyogram signals for the flexor digitorum superficialis and extensor digitorum muscles were recorded. The syringe adapter required 31% of the 90th percentile flexor muscle activity as compared to the ring-finger syringe extension method, and 45% the 90th percentile flexor muscle activity as compared to the middle-finger method ($p < 0.001$). The greatest differences were observed when the syringe was near full extension. Although the syringe adapter took more time than the other syringe extension methods (1.5 times greater), it greatly helped reduce physical stress associated with repetitive, awkward syringe procedures.

- **Keywords:** Healthcare workers; Ergonomic tools; Musculoskeletal disorders

Carolyn M. Sommerich, Steven A. Lavender, Kevin D. Evans, Elizabeth B.-N. Sanders, Sharon Joines, Sabrina Lamar, Radin Zaid Radin Umar, Wei-Ting Yen, SangHyun Park. *Collaborating with radiographers to address their work-related musculoskeletal discomfort.*

The prevalence of musculoskeletal (MSK) symptoms in radiographers is high, similar to other healthcare occupations that involve high levels of physical exertion (e.g. patient handling; grasping and moving equipment). Reports of interventions to reduce MSK discomfort in radiographers are limited. A participatory approach was used to investigate daily challenges, needs, and opportunities for developing interventions to address exposures to many of the risk factors that contribute to MSK symptoms in radiographers. In this paper, we present the expressed needs of experienced radiographers (including

assistance with patient handling, security, supportive design of equipment and work spaces), along with their evaluations of several intervention concepts intended to address some of those needs. We also report results from tests of three prototype interventions stemming from this participatory process that demonstrate the potential for new engineering control concepts to reduce the physical effort associated with some of the most common tasks radiographers perform.

- **Keywords:** Musculoskeletal injury; Intervention design; Healthcare

Matthew J. Maley, Geoffrey M. Minett, Aaron J.E. Bach, Kelly L. Stewart, Ian B. Stewart. *Extending work tolerance time in the heat in protective ensembles with pre- and per-cooling methods.*

Objectives: Investigate whether a range of cooling methods can extend tolerance time and/or reduce physiological strain in those working in the heat dressed in a Class 2 chemical, biological, radiological, nuclear (CBRN) protective ensemble. **Methods:** Eight males wore a Class 2 CBRN ensemble and walked for a maximum of 120 min at 35 °C, 50% relative humidity. In a randomised order, participants completed the trial with no cooling and four cooling protocols: 1) ice-based cooling vest (IV), 2) a non-ice-based cooling vest (PCM), 3) ice slushy consumed before work, combined with IV (SLIV) and 4) a portable battery-operated water-perfused suit (WPS). Mean with 95% confidence intervals are presented. **Results:** Tolerance time was extended in PCM (46 [36, 56] min, $P = 0.018$), SLIV (56 [46, 67] min, $P < 0.001$) and WPS (62 [53, 70] min, $P < 0.001$), compared with control (39 [30, 48] min). Tolerance time was longer in SLIV and WPS compared with both IV (48 [39, 58 min]) and PCM ($P \leq 0.011$). After 20 min of work, HR was lower in SLIV (121 [105, 136] beats·min⁻¹), WPS (117 [101, 133] beats·min⁻¹) and IV (130 [116, 143] beats·min⁻¹) compared with control (137 [120, 155] beats·min⁻¹) (all $P < 0.001$). PCM (133 [116, 151] beats·min⁻¹) did not differ from control. **Conclusion:** All cooling methods, except PCM, utilised in the present study reduced cardiovascular strain, while SLIV and WPS are most likely to extend tolerance time for those working in the heat dressed in a Class 2 CBRN ensemble.

- **Keywords:** Heat stress; Cardiovascular strain; Thermal strain; Thermoregulation; Body cooling; Occupational

Sarah-Maria Castritius, Heiko Hecht, Johanna Möller, Christoph J. Dietz, Patric Schubert, Christoph Bernhard, Simone Morvilus, Christian T. Haas, Sabine Hammer. *Acceptance of truck platooning by professional drivers on German highways. A mixed methods approach.*

Truck platoon driving is a current branch of automated driving, which has the potential to radically change the work routine of professional drivers. In a platoon system, one truck (semi-)automatically follows a lead truck with a reduced distance, which produces significant savings in fuel and enables better traffic flow. In a current application of truck platoon driving, the following vehicle operates at level-2 automation. Thus, the driver of the following truck merely has to supervise the semi-automated system, which takes over steering and speed control when engaged. Level-2 truck platoon driving had not been tested with professional drivers in real traffic before. We hypothesized that user acceptance would improve after the experience of platoon driving. Quantitative questionnaires and qualitative interviews were conducted with 10 drivers before and after an extensive Autobahn experience. The results show a clear increase of acceptance after the experience. Platoon driving was evaluated to be more useful, easier to use, and safer after the experience. Besides perceived driving safety, the prestige of truck platooning, the perceived usefulness of the system, and general technology affinity co-determined user acceptance.

- **Keywords:** Truck platoon driving; Technology acceptance; Professional driver

Ruth Madigan, Richard Romano. *Does the use of a head mounted display increase the success of risk awareness and perception training (RAPT) for drivers?*

The PC-based driver training programme, Risk Awareness and Perception Training (RAPT) has been successful in improving young drivers' hazard anticipation and mitigation responses in both simulator and on-road studies. The current research aimed to evaluate the success of an adaptation of this training for the UK context, along with investigating the impact of the presentation modality on RAPT effectiveness. Traditionally RAPT has been delivered on a PC monitor, which does not allow the same range of head and eye movements that drivers use when on the road. Thus, it was anticipated that the 360° field-of-view provided by Head Mounted Display (HMD) technology would provide a more ecologically valid experience, facilitating deeper processing and encoding of driving relevant scanning patterns, and an increased capacity to identify potentially hazardous areas of a driving scenario. Using a between-subjects design, three different training modalities were compared - a PC-based version using still images (PC-Stills), a HMD version using still images (HMD-Stills), and a HMD version using videos (HMD-video). All three training groups' performance on the UK Hazard Perception test was compared to that of a control group, who received no training. Results indicated that the adaptation of the training materials for the UK context was successful, with all three training programmes leading to performance improvements in the RAPT tests. Although participants in the HMD-video condition required more attempts to pass the training, this group showed the greatest improvement in hazard perception scores from the pre- to the post-training tests. Results also showed scenario-based differences between the modalities, suggesting that the success of different versions of RAPT may be linked to the type of risky scenario being targeted.

- **Keywords:** Hazard anticipation; Risk awareness; Driver training; Head mounted display

Lucia Botti, Francesco Gabriele Galizia, Cristina Mora, Giorgio Zecchi. *A thorough investigation on pushing activities in industry: The impact of the variation in the speed of motion and load conditions on initial and sustained forces.*

Pushing and pulling wheeled objects represent a significant part of manual material handling activities in industry. Medical investigations and epidemiological studies proved the correlation between such activities and the occurrence of lumbago, low back pain and adverse effects on the shoulders. The ISO 11228-2:2007 provides the recommended limits for pushing and pulling. Such values are the results of psychophysical studies realized under prescribed speed conditions referring to a slow walk. However, observation of real industrial and service sector environments reveals that workers are required to perform pushing activities at higher speed of motion. The aim of this study was to investigate the impact of the variation in the speed of motion and load conditions on push forces. 96 subjects performed a total of 2592 trials consisting of pushing an industrial trolley for warehouse applications, at different speed values and load conditions. Results confirm the presence of correlation between the increasing speed of motion and push forces. The findings have practical value for researchers, occupational physicians and ergonomics practitioners.

- **Keywords:** Push force; Initial force; Sustained force; Speed of motion; Industrial trolley

Jennie A. Jackson, Divya Srinivasan, Svend Erik Mathiassen. *Consistent individual motor variability traits demonstrated by females performing a*

long-cycle assembly task under conditions differing in temporal organisation.

Research suggests an association between motor variability (MV) during repetitive work and work-related musculoskeletal disorders (MSDs). However, whether MV is a consistent individual trait, even across working conditions or tasks, remains unknown. This study assessed whether individual MV traits were consistent during complex work performed under different temporal conditions. Fifteen women performed cyclic assembly under four conditions differing in pace and organisation (line-type, batch-type). MV of trapezius muscle activity and upper arm elevation was quantified and partitioned into variance components. For all MV metrics, a non-zero between-subjects variance was found, indicating consistent individual MV traits across conditions. Variance between subjects was higher for electromyography (EMG) MV metrics compared with kinematic metrics. Our results showed individuals exhibited consistent MV traits across working conditions differing in pace and production process. Further research is needed to understand whether MV is an individual predictive factor for MSD onset or progression.

- **Keywords:** Motor control; Trapezius electromyography; Upper arm elevation angle

Michael J. Proulx, David J. Brown, Tayfun Lloyd-Esenkaya, Jack Barnett Leveson, Orlin S. Todorov, Samuel H. Watson, Alexandra A. de Sousa. Visual-to-auditory sensory substitution alters language asymmetry in both sighted novices and experienced visually impaired users.

Visual-to-auditory sensory substitution devices (SSDs) provide improved access to the visual environment for the visually impaired by converting images into auditory information. Research is lacking on the mechanisms involved in processing data that is perceived through one sensory modality, but directly associated with a source in a different sensory modality. This is important because SSDs that use auditory displays could involve binaural presentation requiring both ear canals, or monaural presentation requiring only one – but which ear would be ideal? SSDs may be similar to reading, as an image (printed word) is converted into sound (when read aloud). Reading, and language more generally, are typically lateralised to the left cerebral hemisphere. Yet, unlike symbolic written language, SSDs convert images to sound based on visuospatial properties, with the right cerebral hemisphere potentially having a role in processing such visuospatial data. Here we investigated whether there is a hemispheric bias in the processing of visual-to-auditory sensory substitution information and whether that varies as a function of experience and visual ability. We assessed the lateralization of auditory processing with two tests: a standard dichotic listening test and a novel dichotic listening test created using the auditory information produced by an SSD, The vOICE. Participants were tested either in the lab or online with the same stimuli. We did not find a hemispheric bias in the processing of visual-to-auditory information in visually impaired, experienced vOICE users. Further, we did not find any difference between visually impaired, experienced vOICE users and sighted novices in the hemispheric lateralization of visual-to-auditory information processing. Although standard dichotic listening is lateralised to the left hemisphere, the auditory processing of images in SSDs is bilateral, possibly due to the increased influence of right hemisphere processing. Auditory SSDs might therefore be equally effective with presentation to either ear if a monaural, rather than binaural, presentation were necessary.

- **Keywords:** Dichotic listening; Blindness; Sensory substitution; Audiovisual; Ergonomics; Hemispheric lateralization

Eunsik Kim, Faisal Aqlan, Andris Freivalds. Development of an ergonomic four-finger-push manual pipette design.

The purpose of this study was to develop a new pipette design in which the pipette is operated by four fingers, taking into account the anatomy and anthropometry of the hand. The proposed new pipette designs were compared with a traditional thumb-push pipette based on muscle activity, wrist posture, subjective discomfort ratings for upper extremities, and user preference. The results of the study revealed that the four-finger, ergonomic pipette design reduced muscle exertion (25% reduction for aspiration and 35% reduction for dispensing), awkward wrist posture (33% reduction in wrist flexion, radial and ulnar deviation), and perceived discomfort in the wrist, hand and lower arm. Furthermore, most participants (9 of 10) who used a pipette in their daily work preferred the new pipette designs to a traditional thumb-push pipette design. Thus, we expect that this study will contribute to the reduction of WMSDs risk factors and pain.

- **Keywords:** Pipette design; Musculoskeletal injuries; Four-finger-push pipette; EMG; Wrist posture; Borg CR-10 scale

Elizabeth M. Argyle, Jonathan J. Gourley, Ziho Kang, Randa L. Shehab. *Investigating the relationship between eye movements and situation awareness in weather forecasting.*

Physiological indicators, including eye tracking measures, may provide insight into human decision making and cognition in many domains, including weather forecasting. Situation awareness (SA), a critical component of forecast decision making, is commonly conceptualized as the degree to which information is perceived, understood, and projected into a future context. Drawing upon recent applications of eye tracking in the study of forecaster decision making, we investigate the relationship among eye movement measures, automation, and SA assessed through a freeze probe assessment method. In addition, we explore the relationship between an automated forecasting decision aid use and information seeking behavior. In this study, a sample of professional weather forecasters completed a series of tasks, informed by a set of forecasting decision aids, and with variable access to an experimental automated tool, while an eye tracking system captured data related to eye movements and information usage. At the end of each forecasting task, participants responded to a set of questions related to the environmental situation in the framework of a survey-based assessment technique in order to assess their level of situation awareness. Regression analysis revealed a moderate relationship between the SA measure and eye tracking metrics, supporting the hypothesis that eye tracking may have utility in assessing SA. The results support the use of eye tracking in the assessment of specific and measurable attributes of the decision-making process in weather forecasting. The findings are discussed in light of potential benefits that eye tracking could bring to human performance assessment as well as decision-making research in the forecasting domain.

- **Keywords:** Situation awareness; Human factors; Assessment; Eye tracking; Weather forecasting

Luis CR. Oliveira, Stewart Birrell, Rebecca Cain. *Journey mapping from a crew's perspective: Understanding rail experiences.*

Technological developments present diverse opportunities to modernise services for the rail industry. Systems can be implemented to improve passengers' experiences, but these may also affect the experiences of crew working on board trains. This first-of-a-kind research extends the concept of customer journey mapping as a design tool to understand the experiences of train crew. To produce these crew journey maps, interviews and user observation methods were adopted (N = 22). Results show that two main negative touchpoints for the crew occur at the platform-train interface and during revenue protection activities. This paper presents an innovative methodological contribution around journey mapping to better understand rail experiences, but revolving around the crew rather than the expected consumer experience. We conclude this paper

proposing requirements for technological systems and indicate opportunities for the design of systems to generate human-centred improvements for the working practices and experiences of train crew.

- **Keywords:** Customer journey map; Qualitative study; Shadowing; Work satisfaction; User experience

Alida Esmail, Frédérique Poncet, Claudine Auger, Annie Rochette, Noémi Dahan-Oliel, Delphine Labbé, Eva Kehayia, Christophe Billebaud, Éline de Guise, Isabelle Lessard, Isabelle Ducharme, Olivier Vermeersch, Bonnie Swaine. *The role of clothing on participation of persons with a physical disability: A scoping review.*

Determining ways to facilitate participation of persons with a physical disability is crucial and clothing may play a central role. This review aims to synthesize and examine the role of clothing on participation of persons with a physical disability. Six research databases and grey literature were searched following Arksey & O'Malley's six steps, including multiple expert consultations. English and French articles contributing to how clothing affects participation were included and tabulated based on the International Classification of Functioning, Disability and Health. Fifty-seven articles and 88 websites were included. A variety of stakeholder perspectives, diagnoses, and types of clothing were represented. Clothing mostly influences mobility and self-care, as well as various personal factors. Forty-nine percent of articles reported essential clothing design features to consider. Clothing is an important and complex environmental factor that interacts with all health domains, including participation. Future research should consider intersectoral initiatives.

- **Keywords:** Fashion; Rehabilitation; Inclusion

Damee Choi, Toshihisa Sato, Takafumi Ando, Takashi Abe, Motoyuki Akamatsu, Satoshi Kitazaki. *Effects of cognitive and visual loads on driving performance after take-over request (TOR) in automated driving.*

The present study investigated effects of cognitive and visual loads on driving performance after take-over request (TOR) in an automated driving task. Participants completed automated driving in a driving simulator without a non-driving related task, with an easy non-driving related task, and with a difficult non-driving related task. The primary task was to monitor the environment and the system state. An N-back task and a Surrogate Reference Task (SuRT) were adapted to induce cognitive and visual loads respectively. The system followed a front vehicle automatically. Driving performance was measured by responses to a critical event (appearance of a broken-down car) after the automated system issued TOR and then terminated. High subjective difficulty of the N-back task was related to increased time and increased steering angle variance in the time course from onset of steering control to lane change, while high subjective difficulty of SuRT was related to increased steering angle variance in the time course after lane change. This suggests that both cognitive and visual loads affect driving performance after TOR in automated driving, but the effects appear in different time courses.

- **Keywords:** Automated driving; Visual load; Cognitive load; Driving performance; Take-over request

Siao Hui Toh, Pieter Coenen, Erin K. Howie, Anne J. Smith, Swarup Mukherjee, David A. Mackey, Leon M. Straker. *A prospective longitudinal study of mobile touch screen device use and musculoskeletal symptoms and visual health in adolescents.*

This study aimed to examine prospective associations of mobile touch screen device (i.e. smartphone, tablet) use and patterns of use with musculoskeletal symptoms and visual health among adolescents. A representative sample of 1691 adolescents in Singapore (51% girls; 10–19 years) completed an online questionnaire at baseline and one-year follow-up. After adjusting for potential confounders, prospective associations were found between baseline smartphone use and follow-up neck/shoulder (OR = 1.61(95%CI = 1.06–2.44)) and low back (OR = 1.86(1.10–3.14)) symptoms; tablet use was also associated with neck/shoulder, low back and arms symptoms (OR = 1.33(1.04–1.71)to1.52(1.18–1.95)). No associations were observed between the duration of smartphone/tablet use and symptoms. Baseline patterns of use (bout length, certain types of activities, multitasking) were associated with follow-up musculoskeletal symptoms. Smartphone/tablet use was not related to visual outcomes (visual symptoms, wearing glasses/contact lenses, myopia) at follow-up. These findings suggest that patterns of smartphone/tablet use (though not the duration of use) can pose a prospective risk for musculoskeletal symptoms.

- **Keywords:** Smartphone; Tablet; Pain

Wonjoon Kim, Nayoung Kim, Joseph B. Lyons, Chang S. Nam. *Factors affecting trust in high-vulnerability human-robot interaction contexts: A structural equation modelling approach.*

The current research proposed and tested a structural equation model (SEM) that describes hypothesized relationships among factors affecting trust in human-robot interaction (HRI) such as trustworthiness, human-likeness, intelligence, perfect automation schema (PAS), and affect. A video stimulus depicting an autonomous guard robot interacting with humans was employed as a stimulus via Amazon's Mechanical Turk to recruit 233 participants. Human-related and robot-related metrics were found to affect trustworthiness that subsequently affected trust. In particular, ability (as a trustworthiness facet) was a dominant factor affecting trust in HRI. Integrity was found to mediate the relationships between robot- and human-related metrics and trustworthiness. This study also showed a correlation between intelligence and trustworthiness, as well as between PAS and trustworthiness. The findings of the present study have significant implications for both theory and practice on factors and levels that affect trust in HRI.

- **Keywords:** Trustworthiness; Human-robot interaction; Structural equation modelling; Amazon's mechanical turk; Autonomous guard robot

Kirsten M.A. Revell, Joy Richardson, Pat Langdon, Mike Bradley, Ioannis Politis, Simon Thompson, Lee Skrypchuck, Jim O'Donoghue, Alex Mouzakitis, Neville A. Stanton. *Breaking the cycle of frustration: Applying Neisser's Perceptual Cycle Model to drivers of semi-autonomous vehicles.*

Semi-autonomous cars are already on the road and highly autonomous cars will soon be with us. Little is understood about how drivers will adapt to the changing relationship with their vehicle, but to ensure safety and consumer acceptance, this insight is vital. To this end, an on-road study in a semi-autonomous vehicle was undertaken with six UK drivers. The 'think aloud' technique was employed and video and audio footage of their interaction with the vehicle was captured. Neisser's (1976) Perceptual Cycle Model (PCM) was used to analyse the data and three case studies are presented to highlight how poor synergy between driver and semi-autonomous vehicles can occur from the lens of Schema, Action or World information. Seven key design considerations are proposed to ensure a more positive and safer interaction between driver and autonomous vehicle to guide focus by manufacturers. Further evidence for the existence of a 'counter cycle'

(Plant and Stanton, 2015) within the PCM is found and how this relates to the challenges of using verbal protocols expressed during a fast moving dynamic task is discussed.

- **Keywords:** Perceptual cycle model; Semi-autonomous vehicles; Interaction design; Usability

Ouren X. Kuiper, Jelte E. Bos, Cyriel Diels, Eike A. Schmidt. *Knowing what's coming: Anticipatory audio cues can mitigate motion sickness.*

Being able to anticipate upcoming motion is known to potentially mitigate sickness resulting from provocative motion. We investigated whether auditory cues could increase anticipation and subsequently reduce motion sickness. Participants (N = 20) were exposed on a sled on a rail track to two 15-min conditions. Both were identical in terms of motion, being composed of the same repeated 9 m fore-aft displacements, with a semi-random timing of pauses and direction. The auditory cues were either 1) informative on the timing and direction of the upcoming motion, or 2) non-informative. Illness ratings were recorded at 1-min intervals using a 11-point scale. After exposure, average illness ratings were significantly lower for the condition that contained informative auditory cues, as compared to the condition without informative cues. This knowledge, i.e. that auditory signals can improve anticipation to motion, could be of importance in reducing carsickness in domains such as that of autonomous vehicles.

- **Keywords:** Motion sickness; Autonomous driving; Multisensory integration; Anticipation; Carsickness; Countermeasures; Unpredictable motion

Gemma S. Milligan, Joseph O'Halloran, Michael J. Tipton. *An ergonomics assessment of three simulated 120 m ladder ascents: A comparison of novice and experienced climbers.*

This study investigated the ergonomics of three simulated 120 m vertical ladder ascents and differences between novice (NC) and experienced climbers (EC). Seven EC and 10 NC undertook three 120 m climbs; comprising of four 30 m climbs. Ascending 120 m was reported as a high physical demand, supported by high peak HRs (~ 173 b.min⁻¹ across the three climbs) and $\dot{V} \text{ O}_2$ (~ 3.1 L.min⁻¹ across the three climbs). Grip strength and endurance were significantly ($p < 0.05$) impaired by ascents. With multiple ascents, toe clearance was reduced (Climb 1 - 0.0515 m; Climb 3 - 0.046 m), and participants reached higher with their arms (shoulder angle: Climb 1 - 117°; Climb 3 - 136°). NC demonstrated less range of movement through the hips (NC - 46°; EC - 58°), and higher muscle activation in the upper body (NC - 60%; EC - 49%). Experience reduced cumulative climbing times (exercise + rest), whilst maintaining the same physiological demand as NC and maintained optimised movement patterns for longer.

- **Keywords:** Wind turbine; Ladder climbing; Offshore Wind Industry

Kiana Kia, Stephanie M. Fitch, Sean A. Newsom, Jeong Ho Kim. *Effect of whole-body vibration exposures on physiological stresses: Mining heavy equipment applications.*

The aim of this study was to employ validated biological markers to quantify the physiologic consequences of exposure to whole-body vibration (WBV) and evaluate the relative impact of mining vehicle operator vibration exposure on physiological responses as compared to vertical-axial dominant WBV. In a laboratory-based study with a repeated-measures design, we played actual field-measured floor vibration profiles into a 6-degree-of-freedom motion platform to create different realistic WBV exposures: 1) vertical-dominant vibration collected from long-haul trucks, 2) multi-axial vibration collected from mining heavy equipment vehicles, and 3) no vibration (control condition).

Circulating biomarkers of interest were cortisol and catecholamines (epinephrine and norepinephrine) to assess physiological stress, interleukin-6 (IL-6) and tumor necrosis factor- α (TNF α) to test for inflammation, thiobarbituric acid reactive substances (TBARS) to measure oxidative stress, and myoglobin and plasma creatine kinase to assess muscle damage. We collected blood samples at pre-exposure (0 h), during-exposure (2 and 4 h), and 2 h into recovery after the WBV exposure (6 h) in all four exposure conditions. The results showed that a single, 4-h acute exposure to WBV may not be sufficient to induce skeletal muscle damage, inflammation or physiologic stress measurable in the blood. No significant differences were observed between conditions for any of the biomarkers that could be attributed to the exposure contrast between vertical-dominant and multi-axial WBV exposures. These findings further indicate known complications of WBV exposure likely arise secondary to chronic, repeated exposures that give rise to subclinical stresses that were not captured here.

- **Keywords:** Biomarkers; Off-road vehicles; Muscle damage; Oxidative stress; Musculoskeletal disorders; Professional drivers

Siddarth Ponnala, Laura Block, Aloysius J. Lingg, Amy J. Kind, Nicole E. Werner. *Conceptualizing caregiving activities for persons with dementia (PwD) through a patient work lens.*

Informal caregivers are an integral part of care delivery for persons with dementia (PwD). Informal caregivers take part in a wide range of care activities both individually and collaboratively with other caregivers. Caregiving often involves high demands in the face of limited resources, which can lead to stress, burden, and burnout. To support caregivers, we need to conceptualize caregiving activities they perform, and the networks and roles through which they perform work. We performed a directed content analysis on interview data from twenty caregivers and applied a human factors approach to characterize informal caregiving work. Our results revealed 1) nuances in caregiving roles, 2) differences in caregiving networks, and 3) 13 categories of caregiving activities characterized by time commitments; physical, cognitive and socio-behavioral demands; and varying network dependencies. These findings can be applied in future studies to evaluate the needs of caregiving networks and how to better support them.

- **Keywords:** Patient work; Dementia caregiving; Human factors engineering

Marina Machado Cid, Leticia Bergamin Januario, Roberta de Fátima Carreira Moreira, Julie N. Côté, Pascal Madeleine, Ana Beatriz Oliveira. *Does sEMG normalization change results on sex differences in the activation of the shoulder girdle muscles during a simulated work task?*

The aim was to investigate if the method of normalizing surface electromyography (sEMG) can change results on sex differences in the muscular activation of the shoulder girdle muscles during a simulated work task. sEMG was recorded in 36 asymptomatic participants (17 females, 19 males) from four parts of trapezius and from serratus anterior muscles during a simulated work task. Four normalization methods, one involving maximal voluntary contractions (MVCs) and three involving submaximal voluntary contractions were applied. Sex differences in absolute and normalized amplitude of sEMG were analyzed. The normalization method had a significant influence on the observed sex differences. Females only showed higher sEMG amplitude than males when the sEMGs were normalized to MVC and to a submaximal contraction based on 20% of MVC for the upper trapezius (acromial fibers). Researchers and practitioners should be aware of the impact of the sEMG normalization method in sex differences investigation.

- **Keywords:** Neck/shoulder; Gender differences; Repetitive task

Julie Bodin, Ronan Garlandézec, Nathalie Costet, Alexis Descatha, Jean-François Viel, Yves Roquelaure. *Shoulder pain among male industrial workers: Validation of a conceptual model in two independent French working populations.*

This study aims to validate a conceptual model for shoulder pain risk factors in two independent samples of male industrial workers: the Cosali cohort (n = 334) and one pharmaceutical company (n = 487). Direct and indirect relationships between work organization factors (automatic speed of a machine or movement of a product and work pace dependent on customers' demand), psychosocial factors (Job strain model), biomechanical factors (working with abducted arms, working with arms at or above shoulder level, and perceived physical exertion), perceived stress, and shoulder pain were explored using structural equation models. Shoulder pain was positively associated with biomechanical exposure in both samples, and with perceived stress only in the pharmaceutical preparation manufacturer, while factors related to work organization and psychosocial factors had indirect impacts on the risk of chronic shoulder pain in both samples. The results provide a deeper understanding of the complex relationships between workplace risk factors and shoulder pain.

- **Keywords:** Shoulder pain; Occupational exposure; Structural equation model

SPECIAL SECTION ON CARE TRANSITIONS IN HEALTHCARE: A HUMAN FACTORS PERSPECTIVE; EDITED BY DR. MIKE FRAY, DR. PATRICK WATERSON, PROFESSOR AYSE P. GURSES AND DR. EVI- MARIA CARMAN

Jane K. O'Hara, Ruth Baxter, Natasha Hardicre. *Handing over to the patient: A FRAM analysis of transitional care combining multiple stakeholder perspectives.*

Introduction: The period following discharge can present risks for older adults. Most research has focused on hospital discharge with less attention paid to on-going care needs. Despite evidence that patients undertake 'invisible work' to improve care safety, their reported willingness to be involved in care, and the consensus that successful transitions interventions include patient involvement, in reality, this is variable. Further, little research has viewed transitional care as a 'system', with gaps, interdependencies and variability across settings, nor the role of patients and families in supporting the system resilience. **Research objectives:** 1) model transitional care from multiple perspectives using the Functional Resonance Analysis Method (FRAM); 2) use the model to develop a theory of change to support intervention development. **Method:** We drew data from two studies: i) exploring the perspective of older adults across transitional care, and ii) exploring how health services experience transitional care. We employed the FRAM to develop a model of transitional care, with a system boundary spanning an older patient's admission to hospital, through to thirty days post-discharge. **Findings:** Modelling transitional care from multiple perspectives was challenging. 27 functions were identified with interdependencies between hospital-based functions and patient-led functions once home, the success of which may impact on transitions 'outcomes' (e.g. safety events, readmissions). The model supported development of a theory of change, to guide future intervention development. **Conclusions:** Supporting certain patient-facing upstream hospital functions (e.g. encouraging mobility, supporting a better understanding of medication and condition), may lead to improved outcomes for patients following hospital discharge.

- **Keywords:** Functional Resonance Analysis Method; Transitional care; Transitions; Resilience engineering; Safety II; Patient involvement; Hospital discharge

Abigail R. Wooldridge, Pascale Carayon, Peter Hoonakker, Bat-Zion Hose, Benjamin Eithun, Thomas Brazelton, Joshua Ross, Jonathan E. Kohler, Michelle M. Kelly, Shannon M. Dean, Deborah Rusy, Ayse P. Gurses. *Work system barriers and facilitators in inpatient care transitions of pediatric trauma patients.*

Hospital-based care of pediatric trauma patients includes transitions between units that are critical for quality of care and patient safety. Using a macroergonomics approach, we identify work system barriers and facilitators in care transitions. We interviewed eighteen healthcare professionals involved in transitions from emergency department (ED) to operating room (OR), OR to pediatric intensive care unit (PICU) and ED to PICU. We applied the Systems Engineering Initiative for Patient Safety (SEIPS) process modeling method and identified nine dimensions of barriers and facilitators – anticipation, ED decision making, interacting with family, physical environment, role ambiguity, staffing/resources, team cognition, technology and characteristic of trauma care. For example, handoffs involving all healthcare professionals in the OR to PICU transition created a shared understanding of the patient, but sometimes included distractions. Understanding barriers and facilitators can guide future improvements, e.g., designing a team display to support team cognition of healthcare professionals in the care transitions.

- **Keywords:** Macroergonomics; Pediatric trauma care transitions; SEIPS

SPECIAL SECTION ON ADVANCING THEORY AND METHODS IN HUMAN FACTORS/ERGONOMICS FOR HEALTH AND HEALTHCARE: A TRIBUTE TO PROFESSOR BEN-TZION (BENTZI) KARSH EDITED BY ASSIST. PROF. RUPA VALDEZ, DR. A. JOY RIVERA AND DR. RICHARD J. HOLDEN

Ji-Eun Kim, Larry Kessler, Zach McCauley, Itsumi Niiyama, Linda Ng Boyle. *Human factors considerations in designing a personalized mobile dialysis device: An interview study.*

Recent technical advances have enabled the creation of mobile dialysis device prototypes. These prototypes have been tested for their ability to allow an individual to be dialyzed continuously rather than sporadically. The most recent prototype of a mobile dialysis device aims at increased functionality, which suggests that human factors issues (e.g., efficiency, bulkiness, and weight) are now considered carefully. This study describes advances in the design of an Ambulatory Kidney to Improve Vitality (AKTIV), using an interview protocol during the early stages of product development to capture patients' and caregivers' reactions. The AKTIV has the potential to improve patients' quality of life and decrease mortality rates. The goal of our study is to examine patients' and caregivers' design preferences and feature considerations for an AKTIV. We interviewed 22 participants (age M = 57.50, SD = 13.30), of whom 12 were female and 16 were patients. A pre-interview survey was distributed to the participants, and semi-structured interviews were subsequently held. The pre-interview results show that the belt and backpack designs were preferred over the shoulder bag and distributed designs. The participants also indicated on their pre-interview forms that safety and accuracy were more important to them than attachment ease, comfort, compactness, or operational simplicity. Invisibility and mobility were frequently mentioned when determining the strengths of each of the five design types during the interviews. Finally, individual differences in preferences for the various design types and attributes were identified. The results from our study have important implications for improving efficiency, effectiveness, and user satisfaction in relation to AKTIV prototypes and products. The findings from this interview study will help to ensure engineers and clinicians have target parameters for redesigning the AKTIV.

- **Keywords:** Human factors; Mobile dialysis devices; Interviewing; ESRD; Wearable medical devices

Theresa E. Fuller, Pamela M. Garabedian, Demetri P. Lemonias, Erin Joyce, Jeffrey L. Schnipper, Elizabeth M. Harry, David W. Bates, Anuj K. Dalal, James C. Benneyan. *Assessing the cognitive and work load of an inpatient safety dashboard in the context of opioid management.*

For health information technology to realize its potential to improve flow, care, and patient safety, applications should be intuitive to use and burden neutral for frontline clinicians. We assessed the impact of a patient safety dashboard on clinician cognitive and work load within a simulated information-seeking task for safe inpatient opioid medication management. Compared to use of an electronic health record for the same task, the dashboard was associated with significantly reduced time on task, mouse clicks, and mouse movement (each $p < 0.001$), with no significant increases in cognitive load nor task inaccuracy. Cognitive burden was higher for users with less experience, possibly partly attributable to usability issues identified during this study. Findings underscore the importance of assessing the usability, cognitive, and work load analysis during the design and implementation of health information technology applications.

- **Keywords:** Patient safety; Healthcare; Cognitive load; NASA TLX

John W. Beasley, Richard J. Holden, Erkin Ötles, Lee A. Green, Linsey M. Steege, Tasha B. Wetterneck. *It's time to bring human factors to primary care policy and practice.*

Primary health care is a complex, highly personal, and non-linear process. Care is often sub-optimal and professional burnout is high. Interventions intended to improve the situation have largely failed. This is due to a lack of a deep understanding of primary health care. Human Factors approaches and methods will aid in understanding the cognitive, social and technical needs of these specialties, and in designing and testing proposed innovations. In 2012, Ben-Tzion Karsh, Ph.D., conceived a transdisciplinary conference to frame the opportunities for research human factors and industrial engineering in primary care. In 2013, this conference brought together experts in primary care and human factors to outline areas where human factors methods can be applied. The results of this expert consensus panel highlighted four major research areas: Cognitive and social needs, patient engagement, care of community, and integration of care. Work in these areas can inform the design, implementation, and evaluation of innovations in Primary Care. We provide descriptions of these research areas, highlight examples and give suggestions for future research.

- **Keywords:** Primary care; Human factors; Health information technology

SPECIAL SECTION: CONSIDERING SEX AND GENDER IN ERGONOMICS: EXPLORING THE "HOWS" AND "WHYS"; EDITED BY DR. MARIE LABERGE, DR. SANDRINE CAROLY AND DR. JESSICA RIEL

Marie Laberge, Sandrine Caroly, Jessica Riel, Karen Messing. *Considering sex and gender in ergonomics: Exploring the hows and whys.*

At the 2018 IEA conference, the Gender and Work Technical Committee organized three symposia with over 20 presentations. Overall, these contributions positioned ergonomics as a theoretical and pragmatic approach developing innovative methods to integrate sex/gender analysis into the construction and evaluation of interventions. This special

issue of Applied Ergonomics includes diverse approaches to the consideration of sex and gender in ergonomics, including methods in accident analysis, musculoskeletal disorders, work-family interactions, work schedule analysis, prevention programs and evaluation of interventions. The contents are summarized in this introduction.

- **Keywords:** Sex; Gender; Ergonomic intervention; Evaluation of interventions; Occupational health

SPECIAL SECTION: 50 YEARS OF APPLIED ERGONOMICS; EDITED BY PATRICK DEMPSEY, JIA-HUA LIN AND SARAH SHARPLES

Ruoyu Chen, Jincheng Huang, Jia Zhou. *Skeuomorphic or flat icons for an efficient visual search by younger and older adults?*

The debate around skeuomorphic and flat designs has been long lasting and inconclusive, in part because of the lack of empirical evidence supporting the superiority of one or the other icon style from the perspectives of function and aesthetics. Therefore, this study investigated whether older and younger users perceive the aesthetics of icon styles in the same manner as designers and which style results in the most efficient visual search. Using an experimental system that we developed, 24 older and 24 younger participants rated and searched application icons belonging to the two styles. The results indicated that there was generally a notable difference between participants' and designers' perceptions of icon design styles, even after training, and that the perceived icon design styles further influenced the visual search time and accuracy of the participants as well as their evaluation of the icons' beauty. The results imply that the younger participants could use the skeuomorphic icons more efficiently than they could use the flat icons and that they had an advantage over older participants in terms of this ability; however, aesthetically they appreciated flat icons more. In contrast, older participants searched skeuomorphic icons more quickly and accurately than they did flat icons, and aesthetically they appreciated skeuomorphic icons more.

- **Keywords:** Skeuomorphic design; Flat design; Smartphone; Older adults; App icons; Visual search

John A. Rey-Galindo, Libertad Rizo-Corona, Elvia Luz González-Muñoz, Carlos Aceves-González. *Environmental information for people with visual impairment in Mexico - or what they need and how they use it.*

From an ergonomics perspective, the environmental characteristics should facilitate user activities. Matching user capabilities to demands of the environment is essential. However, about some users such as those with visual impairments, there is little information available for use in designing products and spaces. There is also a gap in information regarding the commutes and needs of the visually impaired, making it even more difficult to establish how environments should be designed to include this population. This study aimed to identify the information needs of people with visual impairment in terms of: 1) Daily life activities, 2) Wayfinding in the complex built environments, 3) Use of the signals provided by the environment 4) Characteristics of the environment which reduce the usability of a space and may put the user in danger, and 5) Safety perception. Data were obtained through a semi-structured interview to which eighteen adults responded. All had either complete blindness or severe visual impairment. For orientation, the most common references were texture or changes in ground level/surface, along with such ambient elements as noise or smells. Information presented in Braille was reported as little used, due to difficulty in finding such information. Regarding safety, participants reported feeling unsafe; most mentioned crossing the street as a major risk. Using auditory, tactile or even olfactory signals may

provide important information while commuting: thus, designing signals which consider and highlight these senses is paramount. Assessing features and location of existing tactile signals is also required, to identify opportunities for improving the safety and independence of people with visual impairment.

- **Keywords:** Visual impairment; Information resources; Information design; Environmental ergonomics