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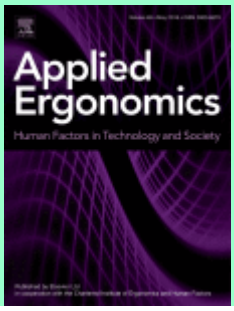

Chao-Hung Wang, Chih-Yu Hsiao, An-Ting Tai, Mao-Jiun J. Wang. *Usability evaluation of augmented reality visualizations on an optical see-through head-mounted display for assisting machine operations*. 104112.

This study explores the effect of using different visual information overlays and guiding arrows on a machine operation task with an optical see-through head-mounted display (OST-HMD). Thirty-four participants were recruited in the experiment. The independent variables included visual information mode (text, animation, and mixed text and animation) and the use of guiding arrows (with and without arrows). In addition, gender difference was also an objective of this study. The task performance indicators were determined based on task completion time and error counts as well as subjective measures (system usability scale, NASA task load index, and immersion scale). This study used the mixed analysis of variance design to evaluate the main and interaction effects. The results showed that males performed better when using the mixed text and animation mode. Females performed better when using the text mode. In addition, using the mixed text and animation mode demonstrated the best outcome in system usability scale and NASA task load index. For the use of guiding arrows, the task completion time was reduced and the system usability scale, NASA task load index, and immersion scale showed positive effects.

- **Keywords:** Augmented reality; Optical see-through head-mounted display; Visual information

Eve Floriane Fabre, Bertille Somon, Valeria Baragona, Quentin Uhl, Mickaël Causse. *Fast & scrupulous: Gesture-based alarms improve accuracy and reaction times under various mental workload levels: An ERSP study*. 104082.

In high-risk environments, fast and accurate responses to warning systems are essential to efficiently handle emergency situations. The aim of the present study was twofold: 1) investigating whether hand action videos (i.e., gesture alarms) trigger faster and more accurate responses than text alarm messages (i.e., written alarms), especially when mental workload (MWL) is high; and 2) investigating the brain activity in response to both types of alarms as a function of MWL. Regardless of MWL, participants (N = 28) were found to be both faster and more accurate when responding to gesture alarms than to written alarms. Brain electrophysiological results suggest that this greater efficiency might be due to a facilitation of the action execution, reflected by the decrease in mu and

beta power observed around the response time window observed at C3 and C4 electrodes. These results suggest that gesture alarms may improve operators' performances in emergency situations.

- **Keywords:** Gesture alarms; Emergency situations; Operators; Safety; EEG; Time-frequency analysis

Kiana Kia, Jaejin Hwang, Jeong Ho Kim. *Effects of error rates and target sizes on neck and shoulder biomechanical loads during augmented reality interactions*. 104107.

Augmented reality (AR) interactions have been associated with increased biomechanical loads on the neck and shoulders. To provide a better understanding of the factors that may impact such biomechanical loads, this repeated-measures laboratory study evaluated the effects of error rates and target sizes on neck and shoulder biomechanical loads during two standardized AR tasks (omni-directional pointing and cube placing). Twenty participants performed the two AR tasks with different error rates and target sizes. During the tasks, angles, moments, and muscle activity in the neck and shoulders were measured. The results showed that the target sizes and error rates significantly affected angles, moments, and muscle activity in the neck and shoulder regions. Specifically, the presence of errors increased neck extension, shoulder flexion angles and associated moments. Muscle activity in the neck (splenius capitis) and shoulder (anterior and medial deltoids) also increased when the errors were introduced. Moreover, interacting with larger targets resulted in greater neck extension moments and shoulder abduction angles along with higher muscle activity in the splenius capitis and upper trapezius muscles. These findings indicate the importance of reducing errors and incorporating appropriate target sizes in the AR interfaces to minimize risks of musculoskeletal discomfort and injuries in the neck and shoulders.

- **Keywords:** Human-computer interaction; Head-mounted display; Wearable device; Biomechanics; Musculoskeletal problems

Geoffrey N. Ertel, Guillaume Mornieux, Frédéric R. Simon, Gérome C. Gauchard. *Characterizing the effects of an ergonomic handle on upper limbs kinematics and neuromuscular activity, comfort, and performance during ergometer rowing*. 104093.

Articular stress and discomfort during repetitive movements may impact the risk of injuries of the upper limbs during ergometer rowing, especially when using a regular circular handle. Therefore, the purpose of the study was to propose and evaluate the influence of an ergonomic handle on upper limbs biomechanics, comfort and performance during ergometer rowing. An ergonomic irregular hexagon handle, with a 1:1.25 width/length diameters ratio, has been developed. Left upper limb kinematics and neuromuscular activity, perceived comfort and power production were monitored for 29 expert rowers. The ergonomic handle increased the perceived comfort while maintaining the overall articular stress and performance as the same level compared to the regular handle. We recommend using irregular hexagon handles with 1:1.25 ratio for ergometer rowing. Further improvements of the ergonomic handle such as an individualization based on the user's hand length may further enhance comfort and achieve better performance.

- **Keywords:** Ergonomics; Handle; Rowing; Upper limb; Pattern

Michael W.B. Watterworth, Ryuta Dharmaputra, Ryan Porto, Joel A. Cort, Nicholas J. La Delfa. *Equations for estimating the static supportive torque provided by upper-limb exoskeletons*. 104092.

Upper-limb exoskeletons are gaining traction in industrial work environments. However, other than advertised general specifications (e.g., peak support angle), the support torque provided throughout the reach envelope is largely unknown to end users. As such, this paper describes a methodology for measuring the specific supportive torque provided by upper-limb exoskeletons. The support of four commercially available passive upper-limb exoskeletons was quantified using an isokinetic dynamometer for all support ranges and levels (n = 68). Tests were repeated four times to determine between-session reliability. Intraclass correlation coefficients demonstrated 'Good' to 'Excellent' reliability, except for one condition. Polynomial regression equations were developed for each condition to predict exoskeleton support for any upper-limb elevation angle between 10° and 180°. These equations can be used to approximate upper-limb exoskeleton support in digital human modeling assessments, or to aid selection of exoskeleton settings specific to a worker's anthropometry and work task location.

- **Keywords:** Exoskeleton; Dynamometry; Reliability

Junho Park, Maryam Zahabi, Skylar Blanchard, Xi Zheng, Marcia Ory, Mark Benden. *A novel autonomous vehicle interface for older adults with cognitive impairment*. 104080.

The population of older Americans with cognitive impairments, especially memory loss, is growing. Autonomous vehicles (AVs) have the potential to improve the mobility of older adults with cognitive impairment; however, there are still concerns regarding AVs' usability and accessibility in this population. Study objectives were to (1) better understand the needs and requirements of older adults with mild and moderate cognitive impairments regarding AVs, and (2) create a prototype for a holistic, user-friendly interface for AV interactions. An initial (Generation 1) prototype was designed based on the literature and usability principles. Based on the findings of phone interviews and focus group meetings with older adults and caregivers (n = 23), an enhanced interface (Generation 2) was developed. This generation 2 prototype has the potential to reduce the mental workload and anxiety of older adults in their interactions with AVs and can inform the design of future in-vehicle information systems for older adults.

- **Keywords:** In-vehicle display; Autonomous vehicle; Older adults; Cognitive impairment; Interface design

Mackenzie Warner, Jeff A. Nessler, Davide Filingeri, Sean C. Newcomer. *The characterization of thermal perception in recreational surfers wearing wetsuits*. 104108.

The purpose of this study was to characterize the perception of heat loss, comfort, and wetness in recreational surfers wearing wetsuits, to compare these data with changes in skin temperature reported in prior studies, and to examine the impact of wetsuit thickness, zipper location, and accessory use on thermal sensation and comfort. Following their surf session, nine-hundred and three male (n = 735) and female (n = 168) recreational surfers responded to a series of questions regarding thermal comfort/sensation, wetsuit characteristics, and surfing history. Average whole body thermal sensation rating was 0.8 ± 3.6 on a scale of −10 to +10 and average whole body thermal comfort rating was 1.5 ± 1.2, midway between "just comfortable" and "comfortable." Overall, surfers felt coldest in their feet, hands, and head. Under their wetsuits, surfers felt the coldest, wettest, and least comfortable in their chest, lower legs, lower arms, and upper back. Wetsuit accessory use had the greatest impact on regions

identified as coldest, least comfortable, and wettest. These data suggest that wetsuit design should focus on optimizing water access points and improving accessories for the feet, hands, and head.

- **Keywords:** Wetsuit; Surfing; Thermal sensation; Thermal perception; Thermal comfort

Somang Nam, Maria Karam, Christie Christelis, Hemanshu Bhargav, Deborah I. Fels. *Assessing subjective workload for live captioners*. 104094.

Live captioning is a challenging task that requires intense concentration to convert audio to text in real-time. Despite the importance of live captioning for accessibility, little is known about the subjective workload of captioners in this context. This study aimed to measure the subjective workload of live captioners using the NASA-TLX and to explore the factors that contribute to their mental workload. Thirty live captioners participated in the study, completing questionnaires and interviews. Results showed that the subjective mental workload of live captioners is high, similar to that of neurosurgeons. The mental workload was found to be associated with caption paraphrasing and employment status. The challenges of the job, such as the speed of speaking in live content, cognitive tasks involved in paraphrasing, the concern about poor performance, the impact on audiences, and the lack of control over job scheduling contribute to this high workload. These findings suggest the need for modulating the scheduling of the workers, having longer breaks, and working in teams rather than independently. Introducing paradigm changes for live captioning workflow, such as reducing the human effort of typing by adopting auto-generated captions, so that captioners become decision-makers or managers of generational AI systems should also be considered. By addressing these issues, we can help improve the well-being of live captioners and the quality of captions, ultimately enhancing accessibility for all.

- **Keywords:** Mental workload; Cognition; Cognitive work analysis; Fatigue

Maria K. Talarico, Frank Morelli, Jingzhen Yang, Ajit Chaudhari, James A. Onate. *Estimating marksmanship performance during walking while maintaining weapon aim*. 104096.

Marksmanship performance while moving is a critical skill among tactical athletes due to the high demands of their occupational duties. Qualifications for dynamic marksmanship performance are not standardized across tactical athlete groups, which may limit comprehensive assessment of tactical athlete performance for situational awareness and adaptability to an unpredictable environment. Although static marksmanship performance provides foundational information on skills and level of ability, research is lacking on factors that influence dynamic marksmanship performance to best prepare tactical athletes for duties. The purpose of this study was to identify whether static marksmanship performance, speed of movement, load carriage, and biomechanical factors while 'shooting on the move' influenced dynamic marksmanship performance. Twenty-four male tactical athletes (22 active-duty Army Soldiers, two civilian SWAT operators; age: 23.83 ± 5.47 years; height: 1.80 ± 0.08 m; weight: 81.04 ± 7.87 kg) participated; final analyses did not include data from the two civilian operators to maintain sample homogeneity. Tactical athletes completed static and dynamic ('shoot on the move') marksmanship tasks under three load conditions: (1) no load (NL), (2) half kit (HK) of 11.34 kg, and (3) full kit (KIT) of 22.68 kg. Dynamic marksmanship was completed under three speed conditions: (1) self-selected slow speed, (2) standard speed, and (3) self-selected fast speed. Hip, knee, and ankle kinematics were collected via wireless inertial measurement units. Spatiotemporal parameters were collected via optical detection system. Marksmanship performance (accuracy) was collected via open-air acoustic target scoring and mean radial error (MRE) was calculated for both static and

dynamic marksmanship tasks. Linear mixed-effects models were fit with dynamic MRE as the outcome variable with fixed effects of static MRE, load condition, speed condition, kinematics, and spatiotemporal parameters, adjusting for body mass. Alpha level was set a priori at $p \leq 0.10$. The final statistical model included fixed effects of static MRE, load condition, speed condition, and time spent in double limb support. Static MRE ($p < 0.01$) and time spent in double limb support ($p = 0.01$) were significant factors. For each 1 cm increase in static MRE there was a 0.66 cm increase in dynamic MRE. For every 1% increase in time spent in double limb support while 'shooting on the move' there was a 0.13 cm increase in dynamic MRE. Findings from this study highlight that tactical athletes who have larger static stance MRE and spend a longer time in double limb support during a gait cycle exhibit an increase in MRE during 'shoot on the move' trials. Overall, dynamic shooting accuracy is not affected by lower extremity joint angles, load carriage, or speed of movement. Although strong relationships are known between gait speed, load, and lower extremity kinematics, the differences in tactical gait compared to normal gait and multi-task paradigm that likely favors marksmanship accuracy seem to present novel movement characteristics unique to occupational gait. Further investigation is warranted to identify other potential factors that may improve or worsen dynamic marksmanship performance.

- **Keywords:** Tactical athlete; Target engagement; Biomechanics

Yifan Ding, Zhaohua Zhang, Zhirui Chen. *Effect of local ventilation temperature and speed under garments on the thermal response of humans at different metabolic rates*. 104102.

Ventilation under garments is one of the effective solutions to alleviate heat stress in the human body, but ventilation preferences and cooling effects in different body segments at different metabolic rates are not thoroughly studied. Eighteen participants performed three metabolic intensities of cycling exercise at 30 °C, RH 35%, where five body segments underwent adjustable ventilation. The ventilation preferences, psychological and physiological responses, and energy consumption were analyzed. The preferred ventilation temperature was approximately 24.5 ± 1.9 °C and the preferred ventilation speed was 1.56 ± 0.29–1.68 ± 0.27 m s-1. At low and moderate metabolic intensities, the five body segments preferred similar ventilation temperatures. At high metabolic intensity, the back preferred lower ventilation temperatures and higher ventilation speeds than the lower limbs. Additionally, the lower back and chest are considered optimal ventilation body segments to achieve higher overall thermal comfort. This study contributes to the optimization of personal ventilated cooling garments for different metabolism scenarios.

- **Keywords:** Local ventilation; Metabolic rate; Human thermal responses

Yincheng Wang, Junyu Huo, Di Wu, Tong Lin, Xinrui Li, Jibo He. *Usability of curved keyboard design on the large smartphone: An empirical study*. 104013.

The curved design is ubiquitous, with a vast user base due to its similarity with in shape to human physiological structure. The curved QWERTY keyboard layout was proposed for one-handed usage on smartphones with ambiguous effects. This study evaluated whether the curved QWERTY could optimize the user experience and input performance on large smartphones better than the traditional straight QWERTY layout. Eight measurements were used to evaluate the usability of each design, six suggesting curved QWERTY failed to achieve outstanding typing performance or subjective user experience, while the other two indicators showed that curved QWERTY had advantages in touch dispersion and touching offset, indicating the possible higher usability it could reach. The results also investigated the potential application of curved designs and provided insights into the optimization methods.

- **Keywords:** Curved design; Keyboard input; One-handed use; Smartphone; QWERTY

Chandler Shannon, Ed Havey, Rajal G. Cohen, Anita N. Vasavada. *Effect of sit-stand workstation position and computer task on head and trunk postural sway and discomfort*. 104098.

Adjustable-height desks may provide musculoskeletal health benefits to offset the effects of prolonged sitting. One mechanism may be increased postural variability, here characterized by head and trunk postural sway. Linear acceleration of the head and trunk were measured while participants used computer workstations in seated and standing positions during keyboard and mouse tasks; secondary measures were discomfort and proprioception (head and neck repositioning error). Median accelerations of the head and trunk were 20–26% lower in mouse tasks compared to keyboard tasks ($p < 0.01$). There were no significant differences in sway parameters between seated and standing positions. Discomfort and proprioception were correlated; subjects who experienced increased neck discomfort after 1.5 h of computer work had almost twice the head and neck repositioning error. The results suggest that postural sway is more affected by different tasks (keyboard vs. mouse) than by different workstation configurations and that low proprioception acuity may relate to the development of discomfort.

- **Keywords:** Adjustable-height workstations; Motor variability; Proprioception

Lasse Schrøder Jakobsen, Mark de Zee, Afshin Samani, Kévin Desbrosses, Pascal Madeleine. *Biomechanical changes, acceptance, and usability of a passive shoulder exoskeleton in manual material handling. A field study*. 104104.

Occupational exoskeletons contribute to diminish the biomechanical load during manual work. However, familiarization to the use of exoskeletons is rarely considered, which may lead to failure of acceptance and implementation. In this study, ten logistic workers underwent a 5-week progressive familiarization to a passive shoulder exoskeleton, while ten workers acted as controls. Tests pre and post the familiarization applied measurements of muscle activity and kinematics of back, neck, and shoulder, perceived effort, and usability-ratings of the exoskeleton. Exoskeleton use resulted in lower muscle activity of anterior deltoid (13–39%) and upper trapezius (16–60%) and reduced perceived effort. Additionally, it induced an offset in shoulder flexion and abduction during resting position (8–10°). No conclusions on familiarization could be drawn due to low adherence to the protocol. However, the emotions of the workers towards using the exoskeleton decreased making it questionable whether the shoulder exoskeleton is suitable for use in the logistics sector.

- **Keywords:** Occupational exoskeletons; Passive assistive device; Workload; Work-related musculoskeletal disorders; Human factors; Logistics

Xinyi Yuan, Zijian Wang, Feng Feng, Yuanyuan Bu, Zhijun Fan, Heshan Liu, Puhong Li, Luan Zhang, Xiao Li, Zhiwei Hu. *Measurement of pressure discomfort threshold in auricular concha for in-ear wearables design*. 104078.

In an effort to mitigate the homogenization of in-ear wearables, designers have been focusing on finding new solutions to enhance user comfort. While the concept of pressure discomfort thresholds (PDT) in humans has been applied to product design, research on the auricular concha remains scarce. In this study, we conducted an experiment to measure the PDT at six points in the auricular concha of 80 participants. Our results showed that the tragus was the most sensitive area and that gender, symmetry, and

Body Mass Index (BMI)had no significant effect on PDT. Based on these findings, we generated pressure sensitivity maps of the auricular concha to aid in the optimization of in-ear wearable design.

- **Keywords:** Pressure discomfort threshold; Pressure sensitivity map; In-ear wearables

Tiejun Ma, Yanxin Zhang, Sang D. Choi, Shuping Xiong. *Modelling for design and evaluation of industrial exoskeletons: A systematic review*. 104100.

Industrial exoskeletons are developed to relieve workers' physical demands in the workplace and to alleviate ergonomic issues associated with work-related musculoskeletal disorders. As a safe and economical alternative to empirical/experimental methods, modelling is considered as a powerful tool for design and evaluation of industrial exoskeletons. This systematic review aims to provide a comprehensive understanding of the current literature on the design and evaluation of industrial exoskeletons through modelling. A systematic study was conducted by general keyword searches of five electronic databases over the last two decades (2003–2022). Out of the 701 records initially retrieved, 33 eligible articles were included and analyzed in the final review, presenting a variety of model inputs, model development, and model outputs used in the modelling. This systematic review study revealed that existing modelling methods can evaluate the biomechanical and physiological effects of industrial exoskeletons and provide some design parameters. However, the modelling method is currently unable to cover some of the main evaluation metrics supported by experimental assessments, such as task performance, user experience/discomfort, change in metabolic costs etc. Standard guidelines for model construction and implementation, as well as validation of human-exoskeleton interactions, remain to be established.

- **Keywords:** Musculoskeletal disorders; Industrial exoskeleton; Modelling; Design and evaluation; Literature review

Bat-Zion Hose, Pascale Carayon, Peter L.T. Hoonakker, Thomas B. Brazelton, Shannon M. Dean, Benjamin L. Eithun, Michelle M. Kelly, Jonathan E. Kohler, Joshua C. Ross, Deborah A. Rusy. *Work system barriers and facilitators of a team health information technology*. 104105.

Designing health IT aimed at supporting team-based care and improving patient safety is difficult. This requires a work system (i.e., SEIPS) evaluation of the technology by care team members. This study aimed to identify work system barriers and facilitators to the use of a team health IT that supports care transitions for pediatric trauma patients. We conducted an analysis on 36 interviews – representing 12 roles – collected from a scenario-based evaluation of T3. We identified eight dimensions with both barriers and facilitators in all five work system elements: person (experience), task (task performance, workload/efficiency), technology (usability, specific features of T3), environment (space, location), and organization (communication/coordination). Designing technology that meets every role's needs is challenging; in particular, when trade-offs need to be managed, e.g., additional workload for one role or divergent perspectives regarding specific features. Our results confirm the usefulness of a continuous work system approach to technology design and implementation.

- **Keywords:** Team health information technology; SEIPS; Pediatric trauma care

Lei Huang, Yiting Hou, Yuxuan Chen, Xuqun You, Robert W. Proctor, Gregory Francis, Ming Chang. *How the black hole illusion environment affects operational performance at different flight phases in aviation*. 104048.

The black hole illusion (BHI) is a subtype of spatial disorientation that can result in fatal consequences in aviation. Research on the BHI has generally focused on altitude deviation, and few studies have examined the effect across different flight phases. In a simulation-based experiment, 18 participants performed 12 simulated approach and landing tasks in normal and BHI environments. Flight performance was analyzed with 14 flight parameters and was compared across five points and three phases, which were referenced from a National Transportation Safety Board report and other previous studies. Results showed that multiple flight parameters were significantly impaired and that their influences varied from the initial approach to the final touchdown. In the BHI environment, participants tended to descend aggressively during the approach phase and flew a lower but similar glidepath during the last approach phase. They might have realized the abnormal situation induced by the BHI but usually were unable to recover from the dangerous maneuver in time. Additionally, the result of glide path error, one of the most commonly used variables in previous BHI research, was only significant during the last approach phase. Flight stability was also impaired in the BHI environment. This is the first study to systematically analyze the BHI effects on multiple flight parameters at different flight phases. The use of this experimental paradigm could facilitate future research to evaluate and prevent the BHI in a more comprehensive way.

- **Keywords:** Black hole illusion; Flight phases; Spatial disorientation; Flight simulation; Aviation accidents

Yuval Steinman, Eric Groen, Monique H.W. Frings- Dresen. *Hypoxia impairs reaction time but not response accuracy in a visual choice reaction task.* 104079.

We investigated the effect of hypoxia on the reaction time (RT) and response accuracy of pilots performing a visual choice reaction task that corresponded to the scanning of helmet mounted display (HMD) symbology. Eighteen male military pilots performed the task in a hypobaric chamber at two simulated altitudes (92 m and 4572 m) in a single-blinded repeated measures and counter-balanced design. The visual stimuli were displayed in low and high contrast and at a 30- and 50-degree field of view (FoV). We measured the pilots' RT and response accuracy. Using an eye tracker, we measured the pilot's glance time at each stimulus location. Finally, we collected subjective ratings of alertness. The results show that hypoxia increased the RT and glance time. Lowering the stimulus contrast and increasing the FoV further increased the RT, independent of hypoxia. These findings provide no evidence for hypoxia-induced changes in visual contrast sensitivity or visual field. Instead, hypoxia seemed to affect RT and glance time by reducing alertness. Despite the increased RT, the pilots maintained their accuracy on the visual task, suggesting that visual scanning of HMD symbology may be resistant to the effects of acute hypoxia.

- **Keywords:** Hypoxia; Reaction time; Response accuracy; Glance time; Alertness; Visual contrast sensitivity; Visual field

Yuhao Chen, Hao-Yu Liao, Sara Behdad, Boyi Hu. Human activity recognition in an end-of-life consumer electronics disassembly task. 104090.

The production of electronic waste, also known as e-waste, has risen with the growing reliance on electronic products. To reduce negative environmental impact and achieve

sustainable industrial processes, recovering and reusing products is crucial. Advances in AI and robotics can help in this effort by reducing workload for human workers and allowing them to stay away from hazardous materials. However, autonomous human motion/intention perception is a primary barrier in e-waste remanufacturing. To address the research gap, this study combined experimental data collection with deep learning models for accurate disassembly task recognition. Over 570,000 frames of motion data were collected from inertial measurement units (IMU) worn by 22 participants. A novel sequence-based correction (SBC) algorithm was also proposed to further improve the accuracy of the overall pipeline. Results showed that models (CNN, LSTM, and GoogLeNet) had an overall accuracy of 88–92%. The proposed SBC algorithm improved accuracy to 95%.

- **Keywords:** e-waste disassembly; Task recognition; Deep learning methods

M. Ryan Kealey, Jacqueline Urakami, Kailyn Henderson, Mark Chignell, Sharon E. Straus. *In what ways does user experience design improve printed educational materials?* 104081.

We report on a series of four studies that investigated how user experience design (UXD) can improve printed educational materials (PEMs). We examined the perceived usability of an existing PEM for breast cancer screening and observed the usability problems associated with it (Study 1). We then compared a breast cancer screening PEM created by user experience designers with two other breast cancer screening PEMS, finding that the PEM based on UXD had higher perceived usability, and lower mentions of usability problems, than the other two PEMs (Study 2). We next examined the impact of individual differences in design expertise on perceived usability, this time including a PEM on cervical cancer screening as well as one on breast cancer screening (Study 3). Our concluding study (Study 4) then examined the impacts of UXD on learnability of PEM content as defined by answers to a knowledge questionnaire about screening administered before and after reading the PEM, and by intention to screen for cancer after reading the PEM. The first three studies showed that the involvement of UXD improved the perceived usability of PEMs, and Study 3 showed that designers differ in their ability to create useable PEMs. Study 4 failed to find a corresponding improvement in learnability or intention to screen when UXD was used to improve perceived usability. We conclude that a user experience design approach that incorporates graphic design can improve the perceived usability of PEMs in some situations (e.g., when the PEM material is not too lengthy or complex, and when the graphic designer is sufficiently skilled). However, we found no evidence that lack of perceived usability accounted for the failure of PEMS (found in previous research) to improve knowledge or intention to screen.

- **Keywords:** Printed educational materials; User study; Usability testing; Human factors; Cancer screening

Angela Bearth, Gioia Köppel, Nicole Schöni, Sandro Ropelato, Michael Siegrist. *Protecting the children: a virtual reality experiment on consumers' risk perceptions of household chemicals*. 104095.

Warnings on the labels of hazardous household chemicals (e.g. warning pictograms and use instructions) should create risk awareness and thus encourage safe storage, handling and disposal. However, scientific findings have called into question the effectiveness of warnings to prevent accidents, albeit mostly based on consumers' self-reports. This study aimed to contribute to existing data on household chemicals and consumer safety by applying a novel observational method using virtual reality (VR). The study participants (N = 119) were observed after receiving a task to childproof a virtual apartment from various interactable neutral and hazardous objects (i.e. knives, lighters and household chemicals with and without warnings) that were placed in the virtual apartment. For the analysis, the object placement (i.e. accessible or inaccessible to the children) and the

level of interaction with the objects were coded, and the observational data were supplemented with data gathered through a questionnaire. The results showed that most hazardous household chemicals were moved to spots that were inaccessible to the children without any interactions of the participants with the warnings. Instead, they used their pre-existing knowledge and intuitive strategies to judge the objects' risks. These potentially misleading intuitive strategies should be increasingly considered in the regulation of hazardous household chemicals. This study also discussed the use and limitations of VR for the observation of human behaviour and decision making under uncertainty.

- **Keywords:** Risk perceptions; Household chemicals; Virtual reality; Accident prevention

Maddison M. Kirk, Joshua P.M. Mattock, Celeste E. Coltman, Julie R. Steele. *What do male netball players want in their footwear? Design recommendations for netball-specific shoes for men*. 104075.

With the increasing professionalisation of men's netball and the high prevalence of foot-related problems and pain, manufacturers must develop shoes with the correct ergonomic design to meet the unique needs of male netball players. This study aimed to determine what factors men consider when selecting a netball-specific shoe and what design features they want in an ideal netball-specific shoe. 279 amateur, sub-elite and elite male netball players completed a 38-question online survey about their footwear habits and preferences. Support was the most influential factor when men selected a netball-specific shoe. A wider toe-box, more durable upper and outsole, and added cushioning and support in the midsole and insole were preferred fit, form and function features for an ideal netball-specific shoe. We recommend that manufacturers develop a range of netball-specific shoes based on the foot dimensions, playing demands and preferences of male netball players to meet men's fit and functionality requirements.

- **Keywords:** Men's netball; Footwear design; Ideal shoe; Consumer product; User requirements

Mincong Huang, Samuel Chabot, Carla Leitão, Ted Krueger, Jonas Braasch. *Spatially-aware group interaction design framework for collaborative room-oriented immersive systems*. 104076.

Room-oriented immersive systems are human-scale built environments that enable collective multi-sensory immersion in virtual space. Although such systems are currently seeing increasing applications in public realms, limited understanding remains regarding how humans interact with the virtual environments displayed within. Synthesizing virtual reality ergonomics and human-building interaction (HBI) knowledge allows us to investigate these systems meaningfully. In this work, we develop a model of content analysis based on hardware components of the Collaborative-Research Augmented Immersive Virtual Environment Laboratory (CRAIVE-Lab) and the Cognitive Immersive Room (CIR) at Rensselaer Polytechnic Institute. Situating ROIS as a joint cognitive system, this model consists of five categories of qualitative factors: 1) general design approach; 2) topological relationships; 3) features of tasks; 4) hardware-specific design modalities; and 5) interactive qualities. We probe the comprehensiveness of this model using existing design scenarios at the CRAIVE-Lab and the CIR featuring both application-based and experience-based designs. Through these case studies, the robustness of this model in its representation of design intention is observed, with limitations on temporal constraints. In creating this model, we establish foundations for more detailed assessments of the interactive qualities of systems alike.

- **Keywords:** Room-oriented immersive virtual environment; Group interaction; Human-building interaction

Oshin Tyagi, Tiash Rana Mukherjee, Ranjana K. Mehta. *Neurophysiological, muscular, and perceptual adaptations of exoskeleton use over days during overhead work with competing cognitive demands*. 104097.

This study captured neurophysiological, muscular, and perceptual adaptations to shoulder exoskeleton use during overhead work with competing physical-cognitive demands. Twenty-four males and females, randomly divided into control and exoskeleton groups, performed an overhead reaching and pointing task over three days without (single task) and with (dual task) a working memory task. Task performance, electromyography (EMG), neural activity, heart rate, and subjective responses were collected. While task completion time reduced for both groups at the same rate over days, EMG activity of shoulder muscles was lower for the exoskeleton group for both tasks, specifically for females during the dual task. Dual task reduced the physiological benefits of exoskeletons and neuromotor strategies to adapt to the dual task demands differed between the groups. Neuromuscular benefits of exoskeleton use were immediately realized irrespective of cognitive demand, however the perceptual, physiological, and neural adaptations with exoskeleton use were task- and sex-specific.

- **Keywords:** Passive shoulder exoskeleton; Human-exoskeleton interaction; Brain activity; Motor adaptation; Neuroergonomics

Ali Golabchi, Negar Riahi, Mackenzie Fix, Linda Miller, Hossein Rouhani, Mahdi Tavakoli. *A framework for evaluation and adoption of industrial exoskeletons*. 104103.

Work-related Musculoskeletal Disorders (WMSDs) account for a significant portion of worker illnesses and injuries, resulting in high costs and productivity losses to employers globally. In recent years, there has been an increased interest in the use of exoskeleton technology to reduce rates of WMSDs in industrial worksites. Despite the potential of exoskeletons to mitigate the risks of WMSDs, the required steps to properly assess and implement the technology for industrial applications are not clear. This paper proposes a framework that can help organizations successfully evaluate and adopt industrial exoskeletons. Through a focus group of industry professionals, researchers, and exoskeleton experts, and by building on existing literature, an overarching adoption framework is developed. The identified stages and tasks within the framework enable an organization to evaluate and adopt exoskeletons through a systematic approach and to identify the existing gaps in their technology adoption process. The findings also highlight the areas where further studies are needed to promote the adoption of industrial exoskeletons, including large-scale field studies and long-term monitoring.

- **Keywords:** Exoskeleton; Technology adoption; Framework; Industrial exoskeleton; Work-related musculoskeletal disorders

Megan N. Sax van der Weyden, James W. Kearney, Nelson Cortes, Orlando Fernandes, Joel R. Martin. *Common law enforcement load carriage systems have limited acute effects on postural stability and muscle activity*. 104091.

Law enforcement officers are inherently at a high risk of injury and the loads they must carry during their occupational duties further increase their injury risk. It is unknown how different methods of carrying a law enforcement officer's load influence factors related to injury risk. This study assessed the effects of common law enforcement load carriage systems on muscular activity and postural stability while standing. Twenty-four participants performed single and dual-task (i.e. concurrent performance of cognitive tasks) standing while wearing a duty belt, tactical vest, and no load. The postural

stability and muscle activity were measured and effects of condition and task examined. Dual task standing decreased postural stability and increased muscular activity. The belt and vest (7.2 kg each) increased muscle activity compared to control for the right abdominals, low back, right thigh. The duty belt resulted in less muscle activity in the right abdominals but more muscle activity in the left multifidus compared to the control. The findings indicate that common law enforcement load carriage systems increase muscular activity but do not affect postural stability. However, the lack of differences between the duty belt and tactical vest did not provide clear support for one load carriage system versus the other.

- **Keywords:** Work performance; Risk factors; Police

Rongjuan Zhu, Xiaoliang Ma, Xuqun You. *The effect of working memory load on inattentional deafness during aeronautical decision-making*. 104099.

Operating an aircraft requires pilots to handle a significant amount of multi-modal information, which creates a high working memory load. Detecting auditory alarms in this high-load scenario is crucial for aviation safety. According to cognitive control load theory, an increase in working memory load may enhance distractor interference, resulting in improved detection sensitivity for task-irrelevant stimuli. Therefore, understanding the effect of working memory load on auditory alarm detection is of particular interest in aviation safety research. The studies were designed to investigate the effect of storage load and executive function load of working memory on auditory alarm detection during aeronautical decision-making through three experiments. In Experiment 1 and 2, participants performed an aeronautical decision-making task while also detecting an auditory alarm during the retention interval of a working memory task (visual-spatial, visual-verbal and auditory-verbal). In Experiment 3, participants were required to detect an auditory alarm while performing the 2-back and 3-back aeronautical decision-making tasks. Experiment 1 found that the auditory alarm sensitivity was higher in conditions of low visual-spatial working memory storage load compare to high load conditions. Experiment 2 found that a high storage load of visual-verbal working memory reduced auditory alarm sensitivity but auditory-verbal working memory load did not. Experiment 3 found that, unlike storage load, auditory alarm sensitivity was stronger under high executive function load relative to low executive function load. These findings show that working memory storage load and executive function load have different effects on auditory alarm sensitivity. The relationship between executive function and auditory alarm sensitivity supports cognitive control load theory, while the impact of the storage function on auditory alarm sensitivity does not adhere to this theory.

- **Keywords:** Auditory alarm deafness; Aeronautical decision-making; Cognitive control theory; Working memory load

Michael A. Bromfield, Thomas Milward, Samuel B. Everett, Alex Stedmon. *Pilot performance and workload whilst using an angle of attack system*. 104101.

Loss of control in flight is the primary category of fatal accidents within all sectors of aviation and failure to maintain adequate airspeed – leading to a stall - is often cited as a causal factor. Stalls occur when the critical angle of the aircraft is exceeded for a given airspeed. Using airspeed as an indicator of the potential to stall is an unreliable proxy. Systems that measure the angle of attack have been routinely used by military aircraft for over 50 years however rigorous academic research with respect to their effectiveness has been limited. Using a fixed-base flight simulator fitted with a simulated, commercially available angle of attack system, 20 pilots performed normal and emergency procedures during the circuit/pattern in a light aircraft. Experimental results have shown that pilot

performance was improved when angle of attack was displayed in the cockpit for normal and emergency procedures during the approach phase of flight in the pattern/circuit. In relation to pilot workload, results indicated that during the approach phase of flight, there was a moderate but tolerable increase in pilot workload. The use of such a display may assist pilots to maintain the aircraft within the optimum range and hence reduce occurrences of unstable approaches. Overall, fewer stall events were observed when angle of attack was displayed and appropriate pilot decisions made during emergencies. These results provide a new perspective on pilot workload and aviation safety.

- **Keywords:** Pilot performance; Workload; Angle of attack management; Airspeed management; Loss of control in flight