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AGING

Hamid Allahverdipour, Iman Dianat, Galavizh Mameh, Mohammad Asghari Jafarabadi. *Effects of Cognitive and Physical Loads on Dynamic and Static Balance Performance of Healthy Older Adults Under Single-, Dual-, and Multi-task Conditions*. pp. 1133–1140.

Objective: The aim of this study is to examine the effects of cognitive and physical loads on dynamic and static balance performance of healthy older adults under single-, dual-, and multi-task conditions. **Background:** Previous studies on postural control in older adults have generally used dual-task methodology, whereas less attention has been paid to multi-task performance, despite its importance in many daily and occupational activities. **Method:** The effects of single versus combined (dual-task and multi-task) cognitive (to speak out the name of the weekdays in a reverse order) and physical (with three levels including handling weights of 1, 2, and 3 kg in each hand) loads on dynamic and static balance performance of 42 older adults (21 males and 21 females) aged ≥60 years were examined. Dynamic and static balance measures were evaluated using the Timed Up and Go (TUG) and stabilometer (sway index) tests, respectively. **Results:** The TUG speed of female participants was generally slower than that of male participants. Age had no effect on balance performance measures. Under dual-task conditions, cognitive load decreased the dynamic balance performance, while the physical task levels had no effect. The dual-task conditions had no impact on the static balance performance. The effects of cognitive and physical loads on dynamic balance performance varied under dual- and multi-task conditions. **Conclusion:** The findings highlight differences between dual- and multi-task protocols and add to the understanding of balance performance in older adults under cognitive and physical loads. **Application:** The present study highlights differences between dual- and multi-task methodologies that need to be considered in future studies of balance and control in older adults.

- **Keywords:** cognitive load, dual task, multiple tasks, physical load, postural sway

COGNITION

Kara J. Blacker, Kyle A. Pettijohn, Grant Roush, Adam T. Biggs. *Measuring Lethal Force Performance in the Lab: The Effects of Simulator Realism and Participant Experience*. pp. 1141–1155.

Objective: The goal of the current study was to compare two types of shooting simulators to determine which is best suited for assessing different aspects of lethal force performance. **Background:** Military and law enforcement personnel are often required to make decisions regarding the use of lethal force. A critical goal of both training and research endeavors surrounding lethal force is to find ways to simulate lethal force encounters to better understand behavior in those scenarios. **Method:** Participants of varying degrees of experience completed both marksmanship and shoot/don't shoot scenarios on both a video game and a military-grade shooting simulator. Using signal detection theory, we assessed sensitivity as a measure of lethal force performance overall. We used hit rate to assess shooting accuracy and false alarm rate to assess decision making. **Results:** Results demonstrated that performance was correlated across simulators. Results supported the notion that shooting accuracy and decision making are independent components of performance. Individuals with firearms expertise outperformed novices on the military-grade simulator, but only with respect to shooting accuracy, not unintended casualties. Individuals with video game experience outperformed novices in the video game simulator, but again only on shooting accuracy. **Conclusion:** Experience played a crucial role in the assessment of shooting accuracy on a given simulator platform; decision-making performance remained unaffected by experience level or type of simulator. **Application:** We recommend that in expert populations or when assessing shooting accuracy, a military-grade shooting simulator be used. However, with a novice population and/or when interested in decision making in lethal force, a video game simulator is appropriate.

- **Keywords:** decision making, shooting simulator, signal detection theory, shooting accuracy

DISPLAYS AND CONTROLS

Yke Bauke Eisma, Clark Borst, René van Paassen, Joost de Winter. *Augmented Visual Feedback: Cure or Distraction?* pp. 1156–1168.

Objective: The aim of the study was to investigate the effect of augmented feedback on participants' workload, performance, and distribution of visual attention. **Background:** An important question in human–machine interface design is whether the operator should be provided with direct solutions. We focused on the solution space diagram (SSD), a type of augmented feedback that shows directly whether two aircraft are on conflicting trajectories. **Method:** One group of novices (n = 13) completed conflict detection tasks with SSD, whereas a second group (n = 11) performed the same tasks without SSD. Eye-tracking was used to measure visual attention distribution. **Results:** The mean self-reported task difficulty was substantially lower for the SSD group compared to the No-SSD group. The SSD group had a better conflict detection rate than the No-SSD group, whereas false-positive rates were equivalent. High false-positive rates for some scenarios were attributed to participants who misunderstood the SSD. Compared to the No-SSD group, the SSD group spent a large proportion of their time looking at the SSD aircraft while looking less at other areas of interest. **Conclusion:** Augmented feedback makes the task subjectively easier but has side effects related to visual tunneling and misunderstanding. **Application:** Caution should be exercised when

human operators are expected to reproduce task solutions that are provided by augmented visual feedback.

- **Keywords:** visual attention, eye-tracking, human–machine interfaces

HEALTH CARE/HEALTH SYSTEMS

Yifan Li, Mitchell D. Wolf, Amol D. Kulkarni, James Bell, Jonathan S. Chang, Amit Nimunkar, Robert G. Radwin. *In Situ Tremor in Vitreoretinal Surgery*. pp. 1169–1181.

Objective: Surgeon tremor was measured during vitreoretinal microscopic surgeries under different hand support conditions. **Background:** While the ophthalmic surgeon's forearm is supported using a standard symmetric wrist rest when operating on the patient's same side as the dominant hand (SSD), the surgeon's hand is placed directly on the patient's forehead when operating on the contralateral side of the dominant hand (CSD). It was hypothesized that more tremor is associated with CSD surgeries than SSD surgeries and that, using an experimental asymmetric wrist rest where the contralateral wrist bar gradually rises and curves toward the patient's operative eye, there is no difference in tremor associated with CSD and SSD surgeries. **Methods:** Seventy-six microscope videos, recorded from three surgeons performing macular membrane peeling operations, were analyzed using marker-less motion tracking, and movement data (instrument path length and acceleration) were recorded. Tremor acceleration frequency and magnitude were measured using spectral analysis. Following 47 surgeries using a conventional symmetric wrist support, surgeons incorporated the experimental asymmetric wrist rest into their surgical routine. **Results:** There was 0.11 mm/s2 (22%) greater ($p = .05$) average tremor acceleration magnitude for CSD surgeries (0.62 mm/s2, SD = 0.08) than SSD surgeries (0.51 mm/s2, SD = 0.09) for the symmetric wrist rest, while no significant ($p > .05$) differences were observed (0.57 mm, SD = 0.13 for SSD and 0.58 mm, SD = 0.11 for CSD surgeries) for the experimental asymmetric wrist rest. **Conclusion:** The asymmetric wrist support reduced the difference in tremor acceleration between CSD and SSD surgeries.

- **Keywords:** hand tremor, microscopic surgery, ophthalmology, wrist rest

HUMAN-COMPUTER INTERACTION, COMPUTER SYSTEMS

Gyouhyung Kyung, Sungryul Park. *Curved Versus Flat Monitors: Interactive Effects of Display Curvature Radius and Display Size on Visual Search Performance and Visual Fatigue*. pp. 1182–1195.

Objective: The aim of this study is to examine the interactive effects of display curvature radius and display size on visual search accuracy, visual search speed, and visual fatigue. **Background:** Although the advantages of curved displays have been reported, little is known about the interactive effects of display curvature radius and size. **Method:** Twenty-seven individuals performed visual search tasks at a viewing distance of 50 cm using eight configurations involving four display curvature radii (400R, 600R, 1200R, and flat) and two display sizes (33″ and 50″). To simulate curved screens, five flat display panels were horizontally arranged with their centers concentrically repositioned following each display curvature radius. **Results:** For accuracy, speed, and fatigue, 33″–600R and 50″–600R provided the best or comparable-to-best results, whereas 50″–flat provided the worst results. For accuracy and fatigue, 33″–flat was the

second worst. The changes in the horizontal field of view and viewing angle due to display curvature as well as the association between effective display curvature radii and empirical horopter (loci of perceived equidistance) can explain these results **Conclusion:** The interactive effects of display curvature radius and size were evident for visual search performance and fatigue. Beneficial effects of curved displays were maintained across 33″ and 50″, whereas increasing flat display size from 33″ to 50″ was detrimental. **Application:** For visual search tasks at a viewing distance of 50 cm, 33″–600R and 50″ 600R displays are recommended, as opposed to 33″ and 50″ flat displays. Wide flat displays must be carefully considered for visual display terminal tasks.

- **Keywords:** display design principles, visual, pictorial, object displays, workspace, workstation, built environment, design, industrial/workplace ergonomics, usability testing and evaluation, vision

HUMAN-ROBOT INTERACTION

P. A. Hancock, Theresa T. Kessler, Alexandra D. Kaplan, John C. Brill, James L. Szalma. *Evolving Trust in Robots: Specification Through Sequential and Comparative Meta-Analyses*. pp. 1196–1229.

Objective: The objectives of this meta-analysis are to explore the presently available empirical findings on the antecedents of trust in robots and use this information to expand upon a previous meta-analytic review of the area. **Background:** Human–robot interaction (HRI) represents an increasingly important dimension of our everyday existence. Currently, the most important element of these interactions is proposed to be whether the human trusts the robot or not. We have identified three overarching categories that exert effects on the expression of trust. These consist of factors associated with (a) the human, (b) the robot, and (c) the context in which any specific HRI event occurs. **Method:** The current body of literature was examined and all qualifying articles pertaining to trust in robots were included in the meta-analysis. A previous meta-analysis on HRI trust was used as the basis for this extended, updated, and evolving analysis. **Results:** Multiple additional factors, which have now been demonstrated to significantly influence trust, were identified. The present results, expressed as points of difference and points of commonality between the current and previous analyses, are identified, explained, and cast in the setting of the emerging wave of HRI. **Conclusion:** The present meta-analysis expands upon previous work and validates the overarching categories of trust antecedent (human-related, robot-related, and contextual), as well as identifying the significant individual precursors to trust within each category. A new and updated model of these complex interactions is offered. **Application:** The identified trust factors can be used in order to promote appropriate levels of trust in robots.

- **Keywords:** robotics, trust, human–robot interaction, meta-analysis

NEUROERGONOMICS

Emad Alyan, Naufal M. Saad, Nidal Kamel. *Effects of Workstation Type on Mental Stress: FNIRS Study*. pp. 1230–1255.

Objective: The purpose of this study is to examine the effect of the workstation type on the severity of mental stress by means of measuring prefrontal cortex (PFC) activation using functional near-infrared spectroscopy. **Background:** Workstation type is known to influence worker's health and performance. Despite the practical implications of

ergonomic workstations, limited information is available regarding their impact on brain activity and executive functions. **Method:** Ten healthy participants performed a Montreal imaging stress task (MIST) in ergonomic and nonergonomic workstations to investigate their effects on the severity of the induced mental stress. **Results:** Cortical hemodynamic changes in the PFC were observed during the MIST in both the ergonomic and nonergonomic workstations. However, the ergonomic workstation exhibited improved MIST performance, which was positively correlated with the cortical activation on the right ventrolateral and the left dorsolateral PFC, as well as a marked decrease in salivary alpha-amylase activity compared with that of the nonergonomic workstation. Further analysis using the NASA Task Load Index revealed a higher weighted workload score in the nonergonomic workstation than that in the ergonomic workstation. **Conclusion:** The findings suggest that ergonomic workstations could significantly improve cognitive functioning and human capabilities at work compared to a nonergonomic workstation. **Application:** Such a study could provide critical information on workstation design and development of mental stress that can be overlooked during traditional workstation design and mental stress assessments.

- **Keywords:** neuroergonomics, prefrontal cortex, cerebral oxygenation, ergonomic, near-infrared spectroscopy

Eric T. Greenlee, Tiffany G. Lui, Emily L. Maw. *Is Physiobehavioral Monitoring Nonintrusive? An Examination of Transcranial Doppler Sonography in a Vigilance Task*. pp. 1256–1270.

Objective: The current study was designed to determine whether continuous, physiobehavioral monitoring via transcranial Doppler sonography (TCD) has negative effects on human performance or user state in a vigilance task. **Background:** Physiobehavioral measures have been identified as a promising method of user state assessment, in part because they are thought to be relatively nonintrusive. The notion that physiobehavioral measures are nonintrusive should not be taken for granted and needs to be tested empirically. It is possible that, even though physiobehavioral measures do not require input from a user, they may still hinder performance by causing discomfort, distraction, or interfering with physical activities required for task performance. **Method:** The current study employed TCD, a common method of monitoring user vigilance. Participants completed a 40-min vigilance task. During the task, 50% wore TCD apparatus, while 50% did not. Intrusiveness was measured in terms of vigilance performance as well as workload, stress, and simulator sickness. **Results:** Analyses revealed results that mirrored prototypical vigilance findings: performance declined over time, workload was high, distress and reported simulator sickness symptomology increased during the task, while engagement decreased. The presence or absence of TCD monitoring had no direct or interactive effects on performance or user state. **Conclusion:** TCD monitoring of user vigilance appears to be nonintrusive. **Application:** Findings support the recommendation that TCD should be used in research and operational settings where user vigilance is of paramount importance. More broadly, when developing and fielding physiobehavioral state measurement systems, intrusiveness should be considered and evaluated.

- **Keywords:** neuroergonomics, physiological measurement, vigilance, workload, stress

Kathryn A. Feltman, Kyle A. Bernhardt, Amanda M. Kelley. *Measuring the Domain Specificity of Workload Using EEG: Auditory and Visual Domains in Rotary-Wing Simulated Flight*. pp. 1271–1283.

Objective: The overarching objective was to evaluate whether workload sensory-domain specificity could be identified through electroencephalogram (EEG) recordings during simulated rotary-wing operations. **Background:** Rotary-wing aviators experience

workload from different sensory domains, although predominantly through auditory and visual domains. Development of real-time monitoring tools using psychophysiological indices, such as EEG recordings, could enable identification of aviator overload in real time. **Method:** Two studies were completed, both of which recorded EEG, task performance, and self-report data. In Study 1, 16 individuals completed a basic auditory and a basic visual laboratory task where workload was manipulated. In Study 2, 23 Army aviators completed simulated aviation flights where workload was manipulated within auditory and visual sensory domains. **Results:** Results from Study 1 found differences in frontal alpha activity during the auditory task, and that alpha and beta activities were associated with perceived workload. Frontal theta activity was found to differ during the visual task while frontal alpha was associated with perceived workload. Study 2 found support for frontal beta activity and the ratio of beta to alpha + theta to differentiate level of workload within the auditory domain. **Conclusion:** There is likely a role of frontal alpha and beta activities in response to workload manipulations within the auditory domain; however, this role becomes more equivocal when examined in a multifaceted flight scenario. **Application:** Results from this study provide a basis for understanding changes in EEG activity when workload is manipulated in sensory domains that can be used in furthering the development of real-time monitoring tools.

- **Keywords:** neuroergonomics, physiological measurement, mental workload, multiple resource model, pilot behavior

METHODS AND SKILLS

Colin D. McKinnon, Samantha Ehmke, Aaron M. Kociolek, Jack P. Callaghan, Peter J. Keir. *Wrist Posture Estimation Differences and Reliability Between Video Analysis and Electrogoniometer Methods*. pp. 1284–1294.

Objective: The aim of this study was to determine the inter- and intrarater agreement of estimated wrist angles using video and to compare wrist angles from video analysis to electrogoniometers. **Background:** Video analysis is used frequently in ergonomic assessments, but factors including parallax and complex angles may influence wrist angle estimates. Electrogoniometers are an alternative to video, but may not be reliable in complex postures. Given the limitations of each method, there is a need to determine the suitability of the measurement methods for field use. **Method:** Ten participants performed frame-by-frame wrist (flexion–extension, radioulnar deviation) and forearm (pronation–supination) posture estimation for worker tasks from three camera views (top, side, and oblique). Workers were equipped with electrogoniometers to record wrist posture during the tasks. The video estimate data was compared between 2 days and to sensor data. **Results:** Percent agreement between participants ranged from 53% to 81% across all ratings. Agreement was highest from the side view (66%, $\kappa = 0.56$) for flexion–extension and top view for radioulnar deviation (77%, $\kappa = 0.52$) and pronation–supination (69%, $\kappa = 0.58$). Video–electrogoniometer agreement was lower, with peak agreement from the top view for flexion–extension (57%, $\kappa = 0.49$) and radioulnar deviation (68%, $\kappa = 0.30$) and the oblique view for pronation–supination (53%, $\kappa = -0.1$). **Conclusion:** Participant estimate agreement was moderate-substantial overall and aligns with previous reports. Disagreement between video and electrogoniometers may be attributed to camera angle and parallax effects and the small magnitude of wrist motions compared to other joints.

- **Keywords:** wrist, video analysis, posture estimate, electrogoniometer, physical ergonomics

SURFACE TRANSPORTATION

Husam Muslim, Makoto Itoh. *Long-Term Evaluation of Drivers' Behavioral Adaptation to an Adaptive Collision Avoidance System*. pp. 1295–1315

Objective: Taking human factors approach in which the human is involved as a part of the system design and evaluation process, this paper aims to improve driving performance and safety impact of driver support systems in the long view of human–automation interaction. **Background:** Adaptive automation in which the system implements the level of automation based on the situation, user capacity, and risk has proven effective in dynamic environments with wide variations of human workload over time. However, research has indicated that drivers may not efficiently deal with dynamically changing system configurations. Little effort has been made to support drivers' understanding of and behavioral adaptation to adaptive automation. **Method:** Using a within-subjects design, 42 participants completed a four-stage driving simulation experiment during which they had to gradually interact with an adaptive collision avoidance system while exposed to hazardous lane-change scenarios over 1 month. **Results:** Compared to unsupported driving (stage i), although collisions have been significantly reduced when first experienced driving with the system (stage ii), improvements in drivers' trust in and understanding of the system and driving behavior have been achieved with more driver–system interaction and driver training during stages iii and iv. **Conclusion:** While designing systems that take into account human skills and abilities can go some way to improving their effectiveness, this alone is not sufficient. To maximize safety and system usability, it is also essential to ensure appropriate users' understanding and acceptance of the system. **Application:** These findings have important implications for the development of active safety systems and automated driving.

- **Keywords:** behavioral adaptation, adaptive automation, human–automation interaction, training, trust in automation, reaction time