

# Human Factors – rok 2019, roč. 61

## Číslo 2 (March)



### CRITIQUE AND REBUTTAL

**Sara Lu Riggs and Nadine Sarter. *Tactile, Visual, and Crossmodal Visual-Tactile Change Blindness: The Effect of Transient Type and Task Demands*. S. 5-24.**

**Objective:** The present study examined whether tactile change blindness and crossmodal visual-tactile change blindness occur in the presence of two transient types and whether their incidence is affected by the addition of a concurrent task.

**Background:** Multimodal and tactile displays have been proposed as a promising means to overcome data overload and support attention management. To ensure the effectiveness of these displays, researchers must examine possible limitations of human information processing, such as tactile and crossmodal change blindness.

**Method:** Twenty participants performed a unmanned aerial vehicle (UAV) monitoring task that included visual and tactile cues. They completed four blocks of 70 trials each, one involving visual transients, the other tactile transients. A search task was added to determine whether increased workload leads to a higher risk of change blindness.

**Results:** The findings confirm that tactile change detection suffers in terms of response accuracy, sensitivity, and response bias in the presence of a tactile transient. Crossmodal visual-tactile change blindness was not observed. Also, change detection was not affected by the addition of the search task and helped reduce response bias.

**Conclusion:** Tactile displays can help support multitasking and attention management, but their design needs to account for tactile change blindness. Simultaneous presentation of multiple tactile indications should be avoided as it adversely affects change detection.

**Application:** The findings from this research will help inform the design of multimodal and tactile interfaces in data-rich domains, such as military operations, aviation, and healthcare.

### AUTOMATION, EXPERT SYSTEMS

**Megan L. Bartlett and Jason S. McCarley. *No Effect of Cue Format on Automation Dependence in an Aided Signal Detection Task*. S. 169-190.**

**Objective:** To investigate whether manipulating the format of an automated decision aid's cues can improve participants' information integration strategies in a signal detection task. **Background:** Automation-aided decision making is often suboptimal, falling well short of statistically ideal levels. The choice of format in which the cues from the aid are displayed may help users to better understand and integrate the aid's judgments with their own. **Method:** Participants performed a signal detection task that asked them to classify random dot images as either blue or orange dominant. They made their judgments either unaided or with assistance from a 93% reliable automated decision aid. The aid provided a binary judgment, along with an estimate of signal strength in the form of either a raw value, a likelihood ratio, or a confidence rating (Experiments 1 and 2) or a binary judgment along with either a verbal or verbal-visuospatial expression of confidence (Experiment 3). Aided sensitivity was benchmarked to the predictions of various statistical models of collaborative decision making. **Results and Conclusion:** Aided performance was suboptimal, matching the predictions of some of the least efficient models. Most importantly, performance was similar across cue formats. **Application:** Results indicate that changes to the format in which cues from a signal detection aid are rendered are unlikely to dramatically improve the efficiency of automation-aided decision making.

## **BIOMECHANICS, ANTHROPOMETRY, AND WORK PHYSIOLOGY**

**Mohamad Behjati and Navid Arjmand. *Biomechanical Assessment of the NIOSH Lifting Equation in Asymmetric Load-Handling Activities Using a Detailed Musculoskeletal Model.* S. 191-202.**

**Objective:** To assess adequacy of the National Institute for Occupational Safety and Health (NIOSH) Lifting Equation (NLE) in controlling lumbar spine loads below their recommended action limits during asymmetric load-handling activities using a detailed musculoskeletal model, that is, the AnyBody Modeling System. **Background:** The NIOSH committee employed simplistic biomechanical models for the calculation of the spine compressive loads with no estimates of the shear loads. It is therefore unknown whether the NLE would adequately control lumbar compression and shear loads below their recommended action limits during asymmetric load-handling activities. **Method:** Twenty-four static stoop lifting tasks at different load asymmetry angles, heights, and horizontal distances were performed by one normal-weight (70 kg) and one obese (93 kg) individual. For each task, the recommended weight limit computed by the NLE and body segment angles measured by a video-camera system (VICON) were prescribed in the participant-specific models developed in the AnyBody Modeling System that estimated spinal loads. **Results:** For both individuals, the NLE adequately controlled L5-S1 loads below their recommended action limits for all activities performed in upright postures. Both individuals, however, experienced compressive and/or shear L5-S1 loads beyond the recommended action limits when lifting was performed near the floor with large load asymmetry. **Conclusion:** The NLE failed to control spinal loads below the recommended limits during asymmetric lifting tasks performed near the floor. **Application:** The NLE should be used with caution for extreme tasks involving load handling near the floor with large load asymmetry.

**Simon S. W. Li, Otto H. T. Chan, T. Y. Ng, L. H. Kam, C. Y. Ng, W. C. Chung, and Daniel H. K. Chow. *Gender Differences in Energy Expenditure During Walking With Backpack and Double-Pack Loads.* S. 203-213.**

**Objective:** To investigate gender differences in energy expenditure during walking with backpack and double-pack loads. **Background:** Studies have reported that energy expenditure during walking with double-pack loads is lower compared with backpack

carriage. However, the effect of gender on energy expenditure while walking with these two load distribution systems has not been investigated. **Method:** Thirty healthy young adults (15 female and 15 male participants) walked on a treadmill with backpack and double-pack loads weighing 30% of their body weight at a speed of 0.89 m/s for 10 min. The energy expenditure in terms of oxygen consumption ( $VO_2$ ) and respiratory exchange ratio (RER) were continuously monitored using a portable gas analyzer throughout each walking exercise. A mixed-design analysis of variance model was adopted to test the effects of gender, pack, and time on  $VO_2$  and RER. **Results:** No time effect was observed on  $VO_2$ . However, significant gender, pack, and interaction effects were observed. The lowest  $VO_2$  was found in female participants under double-pack carriage. No significant gender or pack differences existed in RER. However, RER significantly and incrementally increased in time from the 4th through 6th, 8th, and 10th min. **Conclusion:** This study revealed that heavy double-pack load carriage for healthy young female participants had significantly lower energy expenditure (normalized by the entire system weight, i.e., the participant's weight plus the weight of the pack) than that of the male participants in a 10-min walking exercise. **Application:** The findings of this study indicated that healthy young female participants carried a heavy double-pack with less energy cost (normalized by the entire system weight, i.e., the participant's weight plus the weight of the pack) compared with their male counterparts during a 10-min walking exercise.

**Frédéric Noé, Xavier García-Massó, Damien Ledez, and Thierry Paillard. *Ski Boots Do Not Impair Standing Balance by Restricting Ankle-Joint Mobility*. S. 214-224.**

**Objective:** This study was undertaken in order to provide new insight into sensorimotor control of posture when wearing high-shaft (HS) boots as ski boots. **Background:** Previous studies into the effects of HS boots on postural control have produced controversial results. Some studies reported postural control impairments with ski boots in bipedal postural tasks due to ankle movement restrictions without quantifying the actual restrictive effect of these boots and specifying the adaptations of the postural control system. **Method:** Eighteen young healthy subjects took part in the experiment. Bilateral postural control was assessed on stable and unstable surfaces, while standing barefoot or wearing ski boots. Center of pressure (COP) parameters, ankle, knee, and hip joints movements were calculated and EMG activity from main postural muscles was recorded. **Results:** Ski boots did not restrict the amplitude of ankle angular movements and largely impacted COP parameters and EMG activity on stable ground. In conditions of mediolateral instability, COP data illustrated an enhanced postural control in the frontal plane when wearing ski boots. **Conclusions:** Ski boots do not affect bipedal postural balance by restricting the ankle angular motions but induce complex adaptations of the postural control system which combine factors of a mechanical, motor, and sensorial nature. They impede postural control mainly when standing on stable ground without producing similar deleterious effects on unstable surfaces. **Application:** Our results show that HS boots as ski boots can improve lateral balance on unstable surfaces, which can contribute to prevent fall risk and ankle sprain.

## **COGNITION**

**Michael B. Dillard, Joel S. Warm, Gregory J. Funke, W. Todd Nelson, Victor S. Finomore, Christopher K. McClernon, F. Thomas Eggemeier, Lloyd D. Tripp, and Matthew E. Funke. *Vigilance Tasks: Unpleasant, Mentally Demanding, and Stressful Even When Time Flies*. S. 225-242.**

**Objective:** To determine whether perceived time progression (PTP) moderates participants' negative reactions to vigilance tasks. **Background:** Vigilance tasks are

rated by participants to be unenjoyable and as having high levels of workload and stress. Based on the adage, "You are having fun when time flies," we tested the possibility that accelerating PTP might reduce these negative experiences. **Method:** Two studies were performed, involving a long 30-min and a short 12-min vigil. We manipulated participants' PTP by creating a mismatch between their expectations about how long they would perform the task and the actual time that they were engaged. **Results:** PTP was *significantly faster* for participants who were led to expect that the vigilance task would last longer than it did relative to those led to expect that task duration would be shorter than it actually was and for controls for whom task duration was equal to the expected duration. However, accelerating PTP had no effect in either experiment on undesirable reactions to the vigilance tasks. Participants uniformly rated both tasks as unenjoyable, as having a high level of workload, and as stressful. Apparently, vigilance isn't fun even when time flies. **Conclusion:** Our findings greatly underscore the depth to which negative subjective reactions are embedded in the nature of vigilance tasks and therefore that these tasks can have potentially serious costs to participants in terms of health, safety, and productivity. **Application:** These costs must be considered at the operational level.

**Patrick P. Weis and Eva Wiese. *Using Tools to Help Us Think: Actual but Also Believed Reliability Modulates Cognitive Offloading.* S. 243-254.**

**Objective:** A *distributed cognitive system* is a system in which cognitive processes are distributed between brain-based internal and environment-based external resources. In the current experiment, we examined the influence of metacognitive processes on external resource use (i.e., *cognitive offloading*) in such systems. **Background:** High-tech working environments oftentimes represent distributed cognitive systems. Because cognitive offloading can both support and harm performance, depending on the specific circumstances, it is essential to understand when and why people offload their cognition. **Method:** We used an extension of the mental rotation paradigm. It allowed participants to rotate stimuli either internally as in the original paradigm or with a rotation knob that afforded rotating stimuli externally on a computer screen. Two parameters were manipulated: the knob's actual reliability (AR) and an instruction altering participants' beliefs about the knob's reliability (believed reliability; BR). We measured cognitive offloading proportion and perceived knob utility. **Results:** Participants were able to quickly and dynamically adjust their cognitive offloading proportion and subjective utility assessments in response to AR, suggesting a high level of offloading proficiency. However, when BR instructions were presented that falsely described the knob's reliability to be lower than it actually was, participants reduced cognitive offloading substantially. **Conclusion:** The extent to which people offload their cognition is not based solely on utility maximization; it is additionally affected by possibly erroneous preexisting beliefs. **Application:** To support users in efficiently operating in a distributed cognitive system, an external resource's utility should be made transparent, and preexisting beliefs should be adjusted prior to interaction.

**Nathan Herdener, Benjamin A. Clegg, Christopher D. Wickens, and C. A. P. Smith. *Anchoring and Adjustment in Uncertain Spatial Trajectory Prediction.* S. 255-272.**

**Objective:** The aim of this study was to explore the impact of prior information on spatial prediction and understanding of variability. **Background:** In uncertain spatial prediction tasks, such as hurricane forecasting or planning search-and-rescue operations, decision makers must consider the most likely case and the distribution of possible outcomes. Base performance on these tasks is varied (and in the case of understanding the distribution, often poor). Humans must update mental models and predictions with new information, sometimes under cognitive workload. **Method:** In a spatial-trajectory prediction task, participants were anchored on accurate or inaccurate information, or not anchored, regarding the future behavior of an object (both average behavior and the

variability). Subsequently, they predicted an object's future location and estimated its likelihood at multiple locations. In a second experiment, participants repeated the process under varying levels of external cognitive workload. **Results:** Anchoring influenced understanding of most likely predicted location, with fairly rapid adjustment following inaccurate anchors. Increasing workload resulted in decreased overall performance and an impact on the adjustment component of the task. Overconfidence was present in all conditions. **Conclusion:** Prior information exerted short-term influence on spatial predictions. Cognitive load impaired users' ability to effectively adjust to new information. Accurate graphical anchors did not improve user understanding of variability. **Application:** Prior briefings or forecasts about spatiotemporal trajectories affect decisions even in the face of initial contradictory information. To best support spatial prediction tasks, efforts also need to be made to separate extraneous load-causing tasks from the process of integrating new information. Implications are discussed.

## DISPLAYS AND CONTROLS

**Donghee Choi, Gyouhyung Kyung, Kyunghyun Nam, and Sungryul Park. *Effects of Display Curvature, Presbyopia, and Task Duration on Visual Fatigue, Task Performance, and User Satisfaction. S. 273-287.***

**Objective:** This study examined the effects of display curvature, presbyopia, and task duration on visual fatigue, task performance, and user satisfaction. **Background:** Although curved displays have been applied to diverse display products, and some studies reported their benefits, it is still unknown whether the effects of display curvature are presbyopia-specific. **Method:** Each of 64 individuals (eight nonpresbyopes and eight presbyopes per display curvature) performed four 15-min proofreading tasks at one display curvature radius setting (600R, 1140R, 4000R, and flat; mm). Diverse measurements were obtained to assess visual fatigue, task performance, and user satisfaction. **Results:** The mean pupil diameter was the largest with 1140R, indicating this curvature radius was associated with the least development of visual fatigue; 600R was comparable with 1140R in terms of pupil diameter. The presbyopic group showed a 28.5% slower proofreading speed compared with the nonpresbyopic group, whereas their proofreading accuracy was comparable. For both groups, the mean visual fatigue increased significantly during the first 15 min of proofreading, as indicated by a decrease of 0.11 mm in the mean pupil diameter, an increase of 3.8 in the mean bulbar conjunctival redness, and an increase of 9.13 in the mean eye complaint questionnaire score. **Conclusion:** The effect of display curvature was not presbyopia-specific. Low visual fatigue was observed with 1140R and 600R. **Application:** Display curvature radii near or in the range of 600R and 1140R and frequent breaks are recommended for both presbyopic and nonpresbyopic groups to reduce their visual fatigue due to visual display terminal tasks.

## HEALTH CARE/HEALTH SYSTEMS

**Simon Y. W. Li, Man-Kei Tse, Birgit Brecknell, and Penelope M. Sanderson. *Spearcon Sequences for Monitoring Multiple Patients: Laboratory Investigation Comparing Two Auditory Display Designs. S. 288-304.***

**Objective:** The aim was to compare the effectiveness of two auditory displays, implemented with spearcons (time-compressed speech), for monitoring multiple patients.

**Background:** Sequences of sounds can convey information about patients' vital signs, such as oxygen saturation (SpO<sub>2</sub>) and heart rate (HR). We tested whether participants could monitor five patients using spearcon-based sound sequences. **Method:** A 2 × 3 within-subjects design was used. The first factor was interface, with two levels: the ALL interface used spearcons to convey vital signs for all five patients, whereas the ABN (abnormal) interface represented patients who had normal vital signs with a low-pitched single-tone sound and patients who had at least one abnormal vital sign with spearcons. The second factor was the number of patients who had at least one abnormal vital sign: there were one, two, or three such patients in each monitoring sequence. Participants were 40 nonclinicians. **Results:** Participants identified abnormal patients' SpO<sub>2</sub> and HR levels and located abnormal patients in the sound sequence more accurately with the ABN interface than the ALL interface. Accuracy declined as the number of abnormal patients increased. Participants associated ABN with easier identification of vital signs, resulting in higher ratings of confidence and pleasantness compared with ALL. **Conclusion:** Sequences of spearcons may support effective eyes-free monitoring of multiple patients. **Application:** Sequences of spearcons may be useful in monitoring multiple patients and the underlying design principles may extend to monitoring in other domains such as industrial process control or control of multiple autonomous vehicles.

## HUMAN-COMPUTER INTERACTION, COMPUTER SYSTEMS

**Nicole Hättenschwiler, Marcia Mendes, and Adrian Schwaninger. *Detecting Bombs in X-Ray Images of Hold Baggage: 2D Versus 3D Imaging*. S. 305-321.**

**Objective:** This study compared the visual inspection performance of airport security officers (screeners) when screening hold baggage with state-of-the-art 3D versus older 2D imaging. **Background:** 3D imaging based on computer tomography features better automated detection of explosives and higher baggage throughput than older 2D X-ray imaging technology. Nonetheless, some countries and airports hesitate to implement 3D systems due to their lower image quality and the concern that screeners will need extensive and specific training before they can be allowed to work with 3D imaging. **Method:** Screeners working with 2D imaging (2D screeners) and screeners working with 3D imaging (3D screeners) conducted a simulated hold baggage screening task with both types of imaging. Differences in image quality of the imaging systems were assessed with the standard procedure for 2D imaging. **Results:** Despite lower image quality, screeners' detection performance with 3D imaging was similar to that with 2D imaging. 3D screeners revealed higher detection performance with both types of imaging than 2D screeners. **Conclusion:** Features of 3D imaging systems (3D image rotation and slicing) seem to compensate for lower image quality. Visual inspection competency acquired with one type of imaging seems to transfer to visual inspection with the other type of imaging. **Application:** Replacing older 2D with newer 3D imaging systems can be recommended. 2D screeners do not need extensive and specific training to achieve comparable detection performance with 3D imaging. Current image quality standards for 2D imaging need revision before they can be applied to 3D imaging.

## SIMULATION AND VIRTUAL REALITY

**Justin Maximilian Mittelstädt, Jan Wacker, and Dirk Stelling. *Emotional and Cognitive Modulation of Cybersickness: The Role of Pain Catastrophizing and Body Awareness*. S. 322-336.**

**Objective:** The goal was to investigate the influence of the tendency to catastrophize somatic symptoms and body awareness on motion-related sickness. **Background:** Influences of emotional and cognitive-evaluative processes on the genesis of motion sickness or cybersickness have rarely been investigated. Brain imaging studies showed activation during cybersickness, resembling the pattern found for pain processing. Two aspects often investigated in this context are pain catastrophizing and body awareness. The present two studies investigated the relationship of motion-related sickness to two tendencies involved in pain processing: pain catastrophizing and body awareness. **Method:** In the first study, 115 participants reported their motion sickness history, pain catastrophizing, and body awareness. In the second study, 40 participants were exposed to a virtual reality and reported their experience of cybersickness as well as their pain catastrophizing and body awareness. **Results:** Pain catastrophizing was positively correlated to motion sickness history and cybersickness. Body awareness did not show a linear effect on motion sickness history or cybersickness. However, the interaction effect of pain catastrophizing and body awareness was significant in both studies. **Conclusion:** Pain catastrophizing seems to have a detrimental effect on cybersickness symptoms. Body awareness moderated the relationship in the sense that the combination of high pain catastrophizing and low body awareness lead to the highest sickness levels. **Application:** Affective and cognitive modulation of cybersickness symptoms should be considered when exposing risk groups to motion-related adverse stimuli.

## **SURFACE TRANSPORTATION**

**Kristen L. Macuga. *Multisensory Influences on Driver Steering During Curve Navigation*. S. 337-347.**

**Objective:** The effects of inertial (vestibular and somatosensory) information on driver steering during curve navigation were investigated, using an electric four-wheel mobility vehicle outfitted with a steering wheel and a portable virtual reality system. **Background:** When driving, multiple sources of perceptual information are available. Researchers have focused on visual information, which plays a critical role in steering control. However, it is not yet well established how inertial information might contribute. **Methods:** I biased inertial cues by varying visual/inertial gains (doubled, halved, reversed), as drivers negotiated curving paths, and measured steering accuracy and efficiency. I also assessed whether being exposed to inertial biases had an impact on postbias steering by comparing pre- and posttest session performance measures. **Results:** Doubling or halving inertial cues had little effect on steering performance. Inertial information only disrupted steering when it was reversed with respect to visual information. Over time, the influence of this extreme inertial bias was reduced though not eliminated. Postbias curve navigation performance was not impacted, likely because participants had learned to disregard, rather than integrate, biased inertial cues. **Conclusion:** Results suggest that biased inertial information has little influence on curve navigation performance when visual information is available. **Application:** Though inertial cues may be important for open-loop steering, when visual cues are unavailable, their role in closed-loop steering seems less influential. This has implications for driving simulation and suggests that inertial discrepancies due to limitations in motion-cuing capabilities may not be all that problematic for the simulation of closed-loop curve steering tasks.

## **TEAMS AND GROUPS**

**Eric T. Greenlee, Gregory J. Funke, and Lindsay Rice. *Evaluation of the Team Workload Questionnaire (TWLQ) in a Team-Choice Task*. S. 348-359.**

**Objective:** The present study was designed to evaluate the team workload questionnaire (TWLQ) in a task that was distinct from the task used to create it. **Background:** The TWLQ was created from workload ratings generated by members of athletic sports teams. Given that such teams represent only a portion of the diversity of operational teams, we aimed to assess the generalizability of the TWLQ. **Method:** The present study applied the TWLQ in a collaborative choice task (hiring decision) to determine whether the factor structure reported in the initial publication of the scale would generalize from the execution tasks it was developed from to a disparate team task focused on consensus building. **Results:** Confirmatory factor analysis indicated that the present data ( $N = 144$ ) were a poor fit for the three-factor structure of the TWLQ. Subsequent exploratory factor analysis revealed a much more interrelated model of team workload with no clear division between the three conceptual factors described in the original validation of the TWLQ. **Conclusion:** The factor structure of the TWLQ did not generalize to the present team-choice task. **Application:** Given that the duties of operational teams vary, it is critical that future research examine how the conceptual structure of team workload may be altered by task type.