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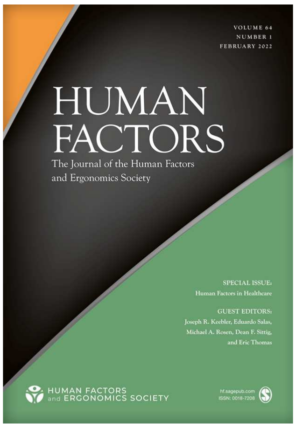

AUTOMATION, EXPERT SYSTEMS

Tobias Rieger, Dietrich Manzey. *Human Performance Consequences of Automated Decision Aids: The Impact of Time Pressure*. pp. 617–634

Objective: The study addresses the impact of time pressure on human interactions with automated decision support systems (DSSs) and related performance consequences. **Background:** When humans interact with DSSs, this often results in worse performance than could be expected from the automation alone. Previous research has suggested that time pressure might make a difference by leading humans to rely more on a DSS. **Method:** In two laboratory experiments, participants performed a luggage screening task either manually, supported by a highly reliable DSS, or by a low reliable DSS. Time provided for inspecting the X-rays was 4.5 s versus 9 s varied within-subjects as the time pressure manipulation. Participants in the automation conditions were either shown the automation's advice prior (Experiment 1) or following (Experiment 2) their own inspection, before they made their final decision. **Results:** In Experiment 1, time pressure compromised performance independent of whether the task was performed manually or with automation support. In Experiment 2, the negative impact of time pressure was only found in the manual but not in the two automation conditions. However, neither experiment revealed any positive impact of time pressure on overall performance, and the joint performance of human and automation was mostly worse than the performance of the automation alone. **Conclusion:** Time pressure compromises the quality of decision-making. Providing a DSS can reduce this effect, but only if the automation's advice follows the assessment of the human. **Application:** The study provides suggestions for the effective implementation of DSSs in addition to supporting concerns that highly reliable DSSs are not used optimally by human operators.

BIOMECHANICS, ANTHROPOMETRY, WORK PHYSIOLOGY

Benjamin Steinhilber, Robert Seibt, Monika A. Rieger, Tessy Luger. *Postural Control When Using an Industrial Lower Limb Exoskeleton: Impact of Reaching for a Working Tool and External Perturbation*. pp. 649–661.

Objective: To investigate postural control related to a lower limb exoskeleton (Chairless Chair) when (a) reaching for a working tool, and (b) an external perturbation occurs. **Background:** Lower limb exoskeletons aiming to reduce physical load associated with prolonged standing may impair workers' postural control and increase the risk of falling. **Method:** Forty-five males were reaching for an object (3-kg dumbbell) at the lateral end of their reaching area without the exoskeleton in upright standing (STAND) and with the exoskeleton at a high ($EXO_{HIGH.SEAT}$) and low sitting position ($EXO_{LOW.SEAT}$). The task was performed with the object placed in three different angles (120°, 150°, and 180°) in the transversal plane. The minimum absolute static postural stability ($SS_{ABS.MIN}$) as the shortest distance (mm) of the center of pressure to the base of support border was measured (zero indicates risk of falling). Additionally, eight subjects were standing without the exoskeleton or sitting on it ($EXO_{HIGH.SEAT}$ and $EXO_{LOW.SEAT}$) while being pulled backward. The tilting moment when subjects lost their balance was assessed. **Results:** $SS_{ABS.MIN}$ was lower when using the exoskeleton ($p < .05$) but still about 17 mm. The location of the object to be reached had no influence. Tilting moments of less than 30 nm were sufficient to let people fall backward when sitting on the exoskeleton (50 nm for STAND). **Conclusion:** Impairments in postural control by the exoskeleton may not be relevant when reaching laterally for objects up to 3 kg. When an external perturbation occurs, the risk of falling may be much higher; irrespective of factors like uneven or slippery flooring. **Application:** The risk of falling using the exoskeleton seems to be low when reaching laterally for an object of up to 3 kg. In situations where, for example, a collision with coworkers is likely, this exoskeleton is not recommended.

Linh Q. Vu, Han Kim, Lawrence J. H. SchulzeSudhakar L. Rajulu. *Evaluating Lumbar Shape Deformation With Fabric Strain Sensors*. pp. 649–661.

Objective: To better study human motion inside the space suit and suit-related contact, a multifactor statistical model was developed to predict torso body shape changes and lumbar motion during suited movement by using fabric strain sensors that are placed on the body. **Background:** Physical interactions within pressurized space suits can pose an injury risk for astronauts during extravehicular activity (EVA). In particular, poor suit fit can result in an injury due to reduced performance capabilities and excessive body contact within the suit during movement. A wearable solution is needed to measure body motion inside the space suit. **Methods:** An array of flexible strain sensors was attached to the body of 12 male study participants. The participants performed specific static lumbar postures while 3D body scans and sensor measurements were collected. A model was created to predict the body shape as a function of sensor signal and the accuracy was evaluated using holdout cross-validation. **Results:** Predictions from the torso shape model had an average root mean square error (RMSE) of 2.02 cm. Subtle soft tissue deformations such as skin folding and bulges were accurately replicated in the shape prediction. Differences in posture type did not affect the prediction error. **Conclusion:** This method provides a useful tool for suited testing and the information gained will drive the development of injury countermeasures and improve suit fit assessments. **Application:** In addition to space suit design applications, this technique can provide a lightweight and wearable system to perform ergonomic evaluations in field assessments.

COGNITION

Richard Clewley, Jim Nixon. *Penguins, Birds, and Pilot Knowledge: Can an Overlooked Attribute of Human Cognition Explain Our Most Puzzling Aircraft Accidents?* pp. 662–674

Objective: We extend the theory of conceptual categories to flight safety events, to understand variations in pilot event knowledge. **Background:** Experienced, highly trained pilots sometimes fail to recognize events, resulting in procedures not being followed, damaging safety. Recognition is supported by typical, representative members of a concept. Variations in typicality ("gradients") could explain variations in pilot knowledge, and hence recognition. The role of simulations and everyday flight operations in the acquisition of useful, flexible concepts is poorly understood. We illustrate uses of the theory in understanding the industry-wide problem of nontypical events. **Method:** One hundred and eighteen airline pilots responded to scenario descriptions, rating them for typicality and indicating the source of their knowledge about each scenario. **Results:** Significant variations in typicality in flight safety event concepts were found, along with key gradients that may influence pilot behavior. Some concepts were linked to knowledge gained in simulator encounters, while others were linked to real flight experience. **Conclusion:** Explicit training of safety event concepts may be an important adjunct to what pilots may variably glean from simulator or operational flying experiences, and may result in more flexible recognition and improved response. **Application:** Regulators, manufacturers, and training providers can apply these principles to develop new approaches to pilot training that better prepare pilots for event diversity.

HUMAN-COMPUTER INTERACTION, COMPUTER SYSTEMS

Sean W. Kortschot, Greg A. Jamieson, Amrit Prasad. *Detecting and Responding to Information Overload With an Adaptive User Interface*. pp. 675–693.

Objective: The objective of this study was to develop and evaluate an adaptive user interface that could detect states of operator information overload and calibrate the amount of information on the screen. **Background:** Machine learning can detect changes in operating context and trigger adaptive user interfaces (AUIs) to accommodate those changes. Operator attentional state represents a promising aspect of operating context for triggering AUIs. Behavioral rather than physiological indices can be used to infer operator attentional state. **Method:** In Experiment 1, a network analysis task sought to induce states of information overload relative to a baseline. Streams of interaction data were taken from these two states and used to train machine learning classifiers. We implemented these classifiers in Experiment 2 to drive an AUI that automatically calibrated the amount of information displayed to operators. **Results:** Experiment 1 successfully induced information overload in participants, resulting in lower accuracy, slower completion time, and higher workload. A series of machine learning classifiers detected states of information overload significantly above chance level. Experiment 2 identified four clusters of users who responded significantly differently to the AUIs. The AUIs benefited performance, completion time, and workload in three clusters. **Conclusion:** Behavioral indices can successfully detect states of information overload and be used to effectively drive an AUI for some user groups. The success of AUIs may be contingent on characteristics of the user group. **Application:** This research applies to domains seeking real-time assessments of user attentional or psychological state.

SENSORY AND PERCEPTUAL PROCESSES

Benjamin Wolfe, Ben D. Sawyer, Ruth Rosenholtz. *Toward a Theory of Visual Information Acquisition in Driving*. pp. 694–713.

Objective: The aim of this study is to describe information acquisition theory, explaining how drivers acquire and represent the information they need. **Background:** While questions of what drivers are aware of underlie many questions in driver behavior, existing theories do not directly address how drivers in particular and observers in general acquire visual information. Understanding the mechanisms of information acquisition is necessary to build predictive models of drivers' representation of the world and can be applied beyond driving to a wide variety of visual tasks. **Method** We describe our theory of information acquisition, looking to questions in driver behavior and results from vision science research that speak to its constituent elements. We focus on the intersection of peripheral vision, visual attention, and eye movement planning and identify how an understanding of these visual mechanisms and processes in the context of information acquisition can inform more complete models of driver knowledge and state. **Results:** We set forth our theory of information acquisition, describing the gap in understanding that it fills and how existing questions in this space can be better understood using it. **Conclusion:** Information acquisition theory provides a new and powerful way to study, model, and predict what drivers know about the world, reflecting our current understanding of visual mechanisms and enabling new theories, models, and applications. **Application:** Using information acquisition theory to understand how drivers acquire, lose, and update their representation of the environment will aid development of driver assistance systems, semiautonomous vehicles, and road safety overall.

Jork Stapel, Mounir El Hassnaoui, Riender Happee. *Measuring Driver Perception: Combining Eye-Tracking and Automated Road Scene Perception*. pp. 714–731.

Objective: To investigate how well gaze behavior can indicate driver awareness of individual road users when related to the vehicle's road scene perception. **Background:** An appropriate method is required to identify how driver gaze reveals awareness of other road users. **Method:** We developed a recognition-based method for labeling of driver situation awareness (SA) in a vehicle with road-scene perception and eye tracking. Thirteen drivers performed 91 left turns on complex urban intersections and identified images of encountered road users among distractor images. **Results:** Drivers fixated within 2° for 72.8% of relevant and 27.8% of irrelevant road users and were able to recognize 36.1% of the relevant and 19.4% of irrelevant road users one min after leaving the intersection. Gaze behavior could predict road user relevance but not the outcome of the recognition task. Unexpectedly, 18% of road users observed beyond 10° were recognized. **Conclusions:** Despite suboptimal psychometric properties leading to low recognition rates, our recognition task could identify awareness of individual road users during left turn maneuvers. Perception occurred at gaze angles well beyond 2°, which means that fixation locations are insufficient for awareness monitoring. **Application:** Findings can be used in driver attention and awareness modelling, and design of gaze-based driver support systems.

Patricia R. DeLucia, Eric T. Greenlee. *Tactile Vigilance Is Stressful and Demanding*. pp. 732–745.

Objective: The primary aims of the study were to replicate the vigilance decrement in the tactile modality, examine whether a decrease in sensitivity is associated with the decrement, and determine whether tactile vigilance is stressful and demanding. **Background:** When people monitor occasional and unpredictable signals for sustained durations, they experience a decline in performance known as the vigilance decrement, which has important practical consequences. Prior studies of the vigilance decrement focused primarily on visual vigilance and, to a lesser degree, on auditory vigilance. There are relatively few studies of tactile vigilance. **Method:** Participants monitored vibrotactile stimuli that were created from a tactor, for 40 min. **Results:** Sensitivity declined, self-report ratings of distress increased, and ratings of task engagement decreased, during the vigil, and perceived workload was moderately high. **Conclusion:** Monitoring tactile signals is demanding and stressful and results in a decrement in signal detection. **Application:** Monitoring tactile signals may result in a decrement in tasks requiring discrimination, such as monitoring lane position with the use of rumble strips; these require discrimination between current road vibration and increased vibration when the car drifts out of its lane and crosses over the strip.

SURFACE TRANSPORTATION

Shiyan Yang, Kyle M. Wilson, Trey Roady, Jonny Kuo, Michael G. Lenné. *Evaluating Driver Features for Cognitive Distraction Detection and Validation in Manual and Level 2 Automated Driving*. pp. 746–759.

Objective: This study aimed to investigate the impacts of feature selection on driver cognitive distraction (CD) detection and validation in real-world nonautomated and Level 2 automated driving scenarios. **Background:** Real-time driver state monitoring is critical to promote road user safety. **Method:** Twenty-four participants were recruited to drive a Tesla Model S in manual and Autopilot modes on the highway while engaging in the N-back task. In each driving mode, CD was classified by the random forest algorithm built on three "hand-crafted" glance features (i.e., percent road center [PRC], the standard deviation of gaze pitch, and yaw angles), or through a large number of features that were transformed from the output of a driver monitoring system (DMS) and other sensing systems. **Results:** In manual driving, the small set of glance features was as effective as the large set of machine-generated features in terms of classification accuracy. Whereas in Level 2 automated driving, both glance and vehicle features were less sensitive to CD. The glance features also revealed that the misclassified driver state was the result of the dynamic fluctuations and individual differences of cognitive loads under CD. **Conclusion:** Glance metrics are critical for the detection and validation of CD in on-road driving. **Applications:** The paper suggests the practical value of human factors domain knowledge in feature selection and ground truth validation for the development of driver monitoring technologies.

TRAINING, EDUCATION, INSTRUCTIONAL SYSTEMS

Gonzalo J. Muñoz, Diego A. Cortéz, Constanza B. Álvarez, Juan A. Raggio, Antonia Concha, Francisca I. Rojas, Winfred Arthur, Bastián M. Fischer, Sebastián Rodriguez. *After-Action Reviews and Long-Term Performance: An Experimental Examination in the Context of an Emergency Simulation*. pp. 760–778.

Objective: The present study examined the effectiveness of after-action reviews (AARs; also known as debriefing) in mitigating skill decay. **Background:** Research on the long-term effectiveness of AARs is meager. To address this gap in the literature, we conducted an experimental study that also overcomes some research design issues that characterize the limited extant research. **Method:** Eighty-four participants were randomly assigned to an AAR or non-AAR condition and trained to operate a PC-based

fire emergency simulator. During the initial acquisition phase, individuals in the AAR condition were allowed to review their performance after each practice session, whereas individuals in the non-AAR condition completed a filler task. About 12 weeks later, participants returned to the lab to complete four additional practice sessions using a similar scenario (i.e., the retention and reacquisition phase). **Results:** The performance of participants in the AAR condition degraded more after nonuse but also recovered faster than the performance of participants in the non-AAR condition, although these effects were fairly small and not statistically significant. **Conclusion:** Consistent with the limited research on the long-term effectiveness of AARs, our findings failed to support their effectiveness as a decay-prevention intervention. Because the present study was conducted in a laboratory setting using a relatively small sample of undergraduate students, additional research is warranted. **Application:** Based on the results of the present study, we suggest some additional strategies that trainers might consider to support long-term skill retention when using AARs.