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ACCIDENTS, HUMAN ERROR

Chloe Jade Robbins, Peter Chapman. *Drivers' Visual Search Behavior Toward Vulnerable Road Users at Junctions as a Function of Cycling Experience*. pp. 889–901.

Objectives: The current study investigated the behavior and visual attention of two groups of drivers with differing pedal cycling experience (pedal cyclists and nonpedal cyclists) towards vulnerable road users at junctions in a driving simulator. **Background:** Pedal cyclists and motorcyclists are involved in a disproportionate number of crashes given the distance they travel, with a high proportion of these crashes occurring at junctions. Many studies have found that car drivers who also hold a motorcycle license have increased awareness towards motorcycles. **Methods:** The task involved approaching a T-junction and turning right when it was deemed to be safe. In Study 1, the junction was controlled by a give way sign, and in Study 2, the junction was controlled by a stop sign. Each T-junction contained a target vehicle (car, motorcycle, or pedal cycle), approaching from a near, medium, or far distance from the junction. **Results:** Participants did not look at pedal cycles approaching from a far distance for as long as they looked at approaching motorcycles and cars, despite all vehicles travelling at identical speeds. No differences were found between pedal cyclists and nonpedal cyclists on any visual attention measures, indicating that pedal cycling experience was not associated with differences in drivers' attention toward pedal cycles. **Conclusions:** Findings have implications for road safety, demonstrating subtle differences in drivers' everyday visual attention toward differing vehicle types. **Applications:** This research has the potential to inform the development of in-car technical assistive systems, improving the safety of vulnerable road users at junctions.

- **Keywords:** attentional processes, visual search, simulation, bicycle safety, eye tracking

AUTOMATION, EXPERT SYSTEMS

Dietlind Helene Cymek. *Redundant Automation Monitoring: Four Eyes Don't See More Than Two, if Everyone Turns a Blind Eye*. pp. 902–921.

Background: In safety-critical and highly automated environments, more than one person typically monitors the system in order to increase reliability. **Objective:** We investigate whether the anticipated advantage of redundant automation monitoring is lost due to social loafing and whether individual performance feedback can mitigate this effect. **Method:** In two experiments, participants worked on a multitasking paradigm in which one task was the monitoring and cross-checking of an automation. Participants worked either alone or with a team partner on this task. The redundant group was further subdivided. One subgroup was instructed that only team performance would be evaluated, whereas the other subgroup expected to receive individual performance feedback after the experiment. **Results:** Compared to participants working alone, those who worked collectively but did not expect individual feedback performed significantly less cross-checks and found 25% fewer automation failures. Due to this social loafing effect, even the combined team performance did not surpass the performance of participants working alone. However, when participants expected individual performance feedback, their monitoring behavior and failure detection performance was similar to participants working alone and a team advantage became apparent. **Conclusion:** Social loafing in redundant automation monitoring can negate the expected gain, if individual performance feedback is not provided. **Application:** These findings may motivate safety experts to evaluate whether their implementation of human redundancy is vulnerable to social loafing effects.

- **Keywords:** group processes, human-automation interaction, supervisory control, motivation, reliability issues, process control

AVIATION AND AEROSPACE

Sébastien Scannella, Vsevolod Peysakhovich, Florian Ehrig, Evelyne Lepron, Frédéric Dehais. *Assessment of Ocular and Physiological Metrics to Discriminate Flight Phases in Real Light Aircraft*. pp. 922–935.

Objective: The purpose of the present study was to find psychophysiological proxies that are straightforward to use and could be implemented in actual flight conditions to accurately discriminate pilots' workload levels. **Background:** Piloting an aircraft is a complex activity where cognitive limitations may jeopardize flight safety. There is a need to implement solutions to monitor pilots' workload level to improve flight safety. There has been recent interest in combining psychophysiological measurements. Most of these studies were conducted in flight simulators at the group level, limiting the interpretation of the results. **Methods:** We conducted an experiment with 11 pilots performing two standard traffic patterns in a light aircraft. Five metrics were derived from their ocular and cardiac activities and were evaluated through three flight phases: takeoff, downwind, and landing. **Results:** Statistical analyses showed that the saccadic rate was the most efficient metric to distinguish between the three flight phases. In addition, a classifier trained on the ocular data collected from the first run predicted the flight phase within a second run with an accuracy of 75%. No gain in the classifier accuracy has been found by combining cardiac and ocular metrics. **Conclusions:** Ocular-based metrics may be more suitable than cardiac ones to provide relevant information on pilots' flying activity in operational settings. **Applications:** Electrocardiographic and eye-tracking devices could be implemented in future cockpits as additional flight data for accident analysis, an objective pilot's state evaluation for training, and proxies for human-machine interactions to improve flight safety.

- **Keywords:** workload, aircraft pilots, eye-tracker, ECG, classification

Grégory Froger, Colin Blättler, Emilien Dubois, Cyril Camachon, Nathalie Bonnardel. *Time-Interval Emphasis in an Aeronautical Dual-Task Context: A Countermeasure to Task Absorption*. pp. 936–946.

Objective: We tested a training method intended to prevent unsafe aeronautical behavior (i.e., too much time spent gazing inside the cockpit) induced by the modern cockpit, by teaching individuals to perform a task complementing the see-and-avoid mandatory safety task within a limited time interval. **Background:** Aeronautical activities led crews to perform several tasks simultaneously in an ergonomic environment under constant change. *See and avoid* remains one of the main safety tasks during visual flight. However, modern cockpits induce absorption and impair performance of this safety task. Many laboratory studies showed the relevance of training methods for managing dual-task situations and estimating time intervals. **Method:** A specific virtual environment was developed to expose participants to a dual-task situation in which time-interval emphasis was provided in real time. Two types of emphasis training were tested: a permissive one that allowed participants to pursue the inside-cockpit task beyond the time limit and a nonpermissive one that did not. **Results:** The best time-interval acquisition, with retention up to 24 hr later, was observed in the nonpermissive condition, but task performances immediately after the training sessions were equivalent across conditions. **Conclusion:** Time-emphasis training appears to be an efficient means of promoting absorption resistance while preserving task performance. Transferability of time-interval estimation skills has yet to be tested. **Application:** Most areas of application for absorption resistance (aviation, shipping, rail, road, etc.) could benefit from this type of training to manage multitask situations.

- **Keywords:** dual task, learning, interval timing, simulation-based skill acquisition, absorption

BIOMECHANICS, ANTHROPOMETRY, WORK PHYSIOLOGY

Richelle Baker, Pieter Coenen, Erin Howie, Jeremy Lee, Ann Williamson, Leon Straker. *Musculoskeletal and Cognitive Effects of a Movement Intervention During Prolonged Standing for Office Work*. pp. 947–961.

Objective: To investigate whether use of a movement intervention when undertaking prolonged standing affected discomfort and cognitive function. **Background:** Alternate work positions to break up prolonged sitting for office workers are being trialed, such as standing. Prolonged standing has potential negative health implications, including low back and lower limb discomfort, and may influence cognitive function. Introducing movement during standing may provide a healthy and productive alternative work posture. **Method:** Twenty adult participants undertook a laboratory study of 2 hr of standing and standing with movement (using a footrest) while performing computer work. Changes in discomfort and cognitive function, with muscle fatigue, low back angle, pelvis movement, lower limb swelling, and mental state, were investigated. **Results:** Discomfort increased significantly over time across all body regions. Ankle/foot differed between conditions (incident rate ratio [95% confidence interval]: 1.89 [1.10–3.23]), with higher discomfort during standing with movement. Creative problem-solving errors increased during standing with movement and decreased during standing (Time × Condition: $\beta = 0.64$ [0.10–1.18]), with no other cognitive function measure differences. Mental state deteriorated over time for both conditions, greater during standing with movement (Time × Condition: $\beta = 2.44$ [0.23–4.66]). No significant interaction effects were found for the other outcome variables. **Conclusion:** Standing with movement provided no advantage in discomfort or cognitive function. There were some negative effects for ankle/foot discomfort and creative problem solving. An alternate footrest design and protocol for use may yield more favorable results. **Application:** Based on the results from this study, footrest use to raise alternative foot for forced 5-min intervals would not be recommended to assist with managing discomfort while prolonged standing in workplaces.

- **Keywords:** musculoskeletal system, biomechanics, interventions, problem solving, vigilance

COGNITION

Sean W. Kortschot, Dusan Sovilj, Greg A. Jamieson, Scott Sanner, Chelsea Carrasco, Harold Soh. *Measuring and Mitigating the Costs of Attentional Switches in Active Network Monitoring for Cybersecurity*. pp. 962–977.

Objective: The authors seek to characterize the behavioral costs of attentional switches between points in a network map and assess the efficacy of interventions intended to reduce those costs. **Background:** Cybersecurity network operators are tasked with determining an appropriate attentional allocation scheme given the state of the network, which requires repeated attentional switches. These attentional switches may result in temporal performance decrements, during which operators disengage from one attentional fixation point and engage with another. **Method:** We ran two experiments where participants identified a chain of malicious emails within a network. All interactions with the system were logged and analyzed to determine if users experienced disengagement and engagement delays. **Results:** Both experiments revealed significant costs from attentional switches before (i.e., disengagement) and after (i.e., engagement) participants navigated to a new area in the network. In our second experiment, we found that interventions aimed at contextualizing navigation actions lessened both disengagement and engagement delays. **Conclusion:** Attentional switches are detrimental to operator performance. Their costs can be reduced by design features that contextualize navigations through an interface. **Application:** This research can be applied to the identification and mitigation of attentional switching costs in a variety of visual search tasks. Furthermore, it demonstrates the efficacy of noninvasive behavioral monitoring for inferring cognitive events.

- **Keywords:** attentional processes, cybersecurity, adaptive automation, visual search, interface evaluation

Shayne Loft, Lisa Jooste, Yanqi Ryan Li, Timothy Ballard, Samuel Huf, Ottmar V. Lipp, Troy A. W. Visser. *Using Situation Awareness and Workload to Predict Performance in Submarine Track Management: A Multilevel Approach*. pp. 978–991.

Objective: Examine the extent to which subjective workload and situation awareness (SA) can predict variance in performance at the between- and within-person levels of analysis in a simulated submarine track management task. **Background:** SA and workload are crucial constructs in human factors that are conceptualized as states that change within individuals over time. Thus, a change in an individual's subjective workload or SA over the course of performing a task should be predictive of their subsequent performance (within-person effects). However, there is little empirical evidence for this. **Method:** Participants monitored displays to track the behaviors of contacts in relationship to their own ship (Ownship) and landmarks. The Situational Awareness Global Assessment Technique measured SA, and the Air Traffic Workload Input Technique measured subjective workload. **Results:** When a participant's subjective workload rating increased, their subsequent performance decreased, but there was no evidence for within-person effects of SA on performance. We replicated prior between-person level effects of SA; participants with higher SA performed better than those with lower SA. **Conclusion:** Change in an individual's subjective workload rating (but not SA) was predictive of their subsequent performance. Because an increase in SA should increase the extent to which operators hold the knowledge required to perform subsequent tasks, further research is required to examine SA effects on performance at the within-person level. **Application:** Adapting automation is more likely to produce optimal outcomes if based on measurement of operator states that predict future task performance, such as workload.

- **Keywords:** situation awareness, workload, submarine track management, multilevel modeling

HEALTH CARE/HEALTH SYSTEMS

Katherina A. Jurewicz, David M. Neyens, Ken Catchpole, Scott T. Reeves. *Developing a 3D Gestural Interface for Anesthesia-Related Human-Computer Interaction Tasks Using Both Experts and Novices*. pp. 992–1007.

Objective: The purpose of this research was to compare gesture-function mappings for experts and novices using a 3D, vision-based, gestural input system when exposed to the same context of anesthesia tasks in the operating room (OR). **Background:** 3D, vision-based, gestural input systems can serve as a natural way to interact with computers and are potentially useful in sterile environments (e.g., ORs) to limit the spread of bacteria. Anesthesia providers' hands have been linked to bacterial transfer in the OR, but a gestural input system for anesthetic tasks has not been investigated. **Methods:** A repeated-measures study was conducted with two cohorts: anesthesia providers (i.e., experts) (N = 16) and students (i.e., novices) (N = 30). Participants chose gestures for 10 anesthetic functions across three blocks to determine intuitive gesture-function mappings. Reaction time was collected as a complementary measure for understanding the mappings. **Results:** The two gesture-function mapping sets showed some similarities and differences. The gesture mappings of the anesthesia providers showed a relationship to physical components in the anesthesia environment that were not seen in the students' gestures. The students also exhibited evidence related to longer reaction times compared to the anesthesia providers. **Conclusion:** Domain expertise is influential when creating gesture-function mappings. However, both experts and novices should be able to use a gesture system intuitively, so development methods need to be refined for considering the needs of different user groups. **Application:** The development of a touchless interface for perioperative anesthesia may reduce bacterial contamination and eventually offer a reduced risk of infection to patients.

- **Keywords:** gestures, human-computer interaction, expertise, anesthesiology and perioperative care

HUMAN-COMPUTER INTERACTION, COMPUTER SYSTEMS

David Lyell, Farah Magrabi, Enrico Coiera. *The Effect of Cognitive Load and Task Complexity on Automation Bias in Electronic Prescribing*. pp. 1008–1021.

Objective: Determine the relationship between cognitive load (CL) and automation bias (AB). **Background:** Clinical decision support (CDS) for electronic prescribing can improve safety but introduces the risk of AB, where reliance on CDS replaces vigilance in information seeking and processing. We hypothesized high CL generated by high task complexity would increase AB errors. **Method:** One hundred twenty medical students prescribed medicines for clinical scenarios using a simulated e-prescribing system in a randomized controlled experiment. Quality of CDS (correct, incorrect, and no CDS) and task complexity (low and high) were varied. CL, omission errors (failure to detect prescribing errors), and commission errors (acceptance of false positive alerts) were measured. **Results:** Increasing complexity from low to high significantly increased CL, $F(1, 118) = 71.6$, $p < .001$. CDS reduced CL in high-complexity conditions compared to no CDS, $F(2, 117) = 4.72$, $p = .015$. Participants who made omission errors in incorrect and no CDS conditions exhibited lower CL compared to those who did not, $F(1, 636.49) = 3.79$, $p = .023$. **Conclusion:** Results challenge the notion that AB is triggered by increasing task complexity and associated increases in CL. Omission errors were

associated with lower CL, suggesting errors may stem from an insufficient allocation of cognitive resources. **Application:** This is the first research to examine the relationship between CL and AB. Findings suggest designers and users of CDS systems need to be aware of the risks of AB. Interventions that increase user vigilance and engagement may be beneficial and deserve further investigation.

- **Keywords:** automation bias, cognitive load, task complexity, human-computer interaction, working memory, health information technology, medication management and safety, patient safety, medication alerts, compliance, reliance

NEUROERGONOMICS

Ronald H. Stevens, Trysha L. Galloway, Ann Willemsen-Dunlap. *Neuroergonomics: Quantitative Modeling of Individual, Shared, and Team Neurodynamic Information*. pp. 1022–1034.

Objective: The aim of this study was to use the same quantitative measure and scale to directly compare the neurodynamic information/organizations of individual team members with those of the team. **Background:** Team processes are difficult to separate from those of individual team members due to the lack of quantitative measures that can be applied to both process sets. **Method:** Second-by-second symbolic representations were created of each team member's electroencephalographic power, and quantitative estimates of their neurodynamic organizations were calculated from the Shannon entropy of the symbolic data streams. The information in the neurodynamic data streams of health care (n = 24), submarine navigation (n = 12), and high school problem-solving (n = 13) dyads was separated into the information of each team member, the information shared by team members, and the overall team information. **Results:** Most of the team information was the sum of each individual's neurodynamic information. The remaining team information was shared among the team members. This shared information averaged ~15% of the individual information, with momentary levels of 1% to 80%. **Conclusion:** Continuous quantitative estimates can be made from the shared, individual, and team neurodynamic information about the contributions of different team members to the overall neurodynamic organization of a team and the neurodynamic interdependencies among the team members. **Application:** Information models provide a generalizable quantitative method for separating a team's neurodynamic organization into that of individual team members and that shared among team members.

- **Keywords:** teamwork, entropy information, EEG, neurodynamics

PYSIOLOGICAL AND PSYCHOLOGICAL CONDITIONS ("INTERNAL ENVIRONMENT")

Hugo F. Posada-Quintero, Jeffrey B. Bolkhovsky, Michael Qin, Ki H. Chon. *Human Performance Deterioration Due to Prolonged Wakefulness Can Be Accurately Detected Using Time-Varying Spectral Analysis of Electrodermal Activity*. pp. 1035–1047.

Objective: The aim was to determine if indices of the autonomic nervous system (ANS), derived from the electrodermal activity (EDA) and electrocardiogram (ECG), could be used to detect deterioration in human cognitive performance on healthy participants during 24-hour sleep deprivation. **Background:** The ANS is highly sensitive to sleep deprivation. **Methods:** Twenty-five participants performed a desktop-computer-based version of the psychomotor vigilance task (PVT) every 2 hours. Simultaneously with reaction time (RT) and false starts from PVT, we measured EDA and ECG. We derived heart rate variability (HRV) measures from ECG recordings to assess dynamics of the ANS. Based on RT values, average reaction time (avRT), minor lapses (RT > 500 ms),

and major lapses (RT > 1 s) were computed as indices of performance, along with the total number of false starts. **Results:** Performance measurement results were consistent with the literature. The skin conductance level, the power spectral index, and the high-frequency components of HRV were not significantly correlated to the indices of performance. The nonspecific skin conductance responses, the time-varying index of EDA (TVSymp), and normalized low-frequency components of HRV were significantly correlated to indices of performance ($p < 0.05$). TVSymp exhibited the highest correlation to avRT (−0.92), major lapses (−0.85), and minor lapses (−0.83). **Conclusion:** We conclude that indices that account for high-frequency dynamics in the EDA, specifically the time-varying approach, constitute a valuable tool for understanding the changes in the autonomic nervous system. **Application:** This can be used to detect the adverse effects of prolonged wakefulness on human performance.

- **Keywords:** electrodermal activity, heart rate variability, autonomic nervous system, prolonged wakefulness, performance

SURFACE TRANSPORTATION

Hongwei Hsiao, Joonho Chang, Peter Simeonov. *Preventing Emergency Vehicle Crashes: Status and Challenges of Human Factors Issues*. pp. 1048–1072.

Objective: This study reports current status of knowledge and challenges associated with the emergency vehicle (police car, fire truck, and ambulance) crashes, with respect to the major contributing risk factors. **Background:** Emergency vehicle crashes are a serious nationwide problem, causing injury and death to emergency responders and citizens. Understanding the underlying causes of these crashes is critical for establishing effective strategies for reducing the occurrence of similar incidents. **Method:** We reviewed the broader literature associated with the contributing factors for emergency vehicle crashes: peer-reviewed journal papers; and reports, policies, and manuals published by government agencies, universities, and research institutes. **Results:** Major risk factors for emergency vehicle crashes identified in this study were organized into four categories: driver, task, vehicle, and environmental factors. Also, current countermeasures and interventions to mitigate the hazards of emergency vehicle crashes were discussed, and new ideas for future studies were suggested. **Conclusion:** Risk factors, control measures, and knowledge gaps relevant to emergency vehicle crashes were presented. Six research concepts are offered for the human factors community to address. Among the topics are emergency vehicle driver risky behavior carryover between emergency response and return from a call, distraction in emergency vehicle driving, in-vehicle driver assistance technologies, vehicle red light running, and pedestrian crash control. **Application:** This information is helpful for emergency vehicle drivers, safety practitioners, public safety agencies, and research communities to mitigate crash risks. It also offers ideas for researchers to advance technologies and strategies to further emergency vehicle safety on the road.

- **Keywords:** police vehicle, ambulance, fire truck, intersection, roadway design, driver assistance systems