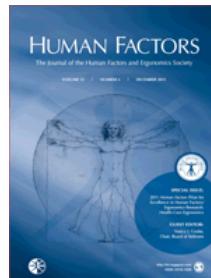


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ACCIDENTS, SAFETY AND HUMAN ERROR

Leo Gugerty, Scott E. McIntyre, Drew Link, Karl Zimmerman, Devendra Tolani, Peter Huang, Robert A. Pokorny. *Effects of Intelligent Advanced Warnings on Drivers Negotiating the Dilemma Zone.* S. 1021-1035.

Objective: We investigated whether intelligent advanced warnings of the end of green traffic signals help drivers negotiate the dilemma zone (DZ) at signalized intersections and sought to identify behavioral mechanisms for any warning-related benefits.

Background: Prior research suggested that warnings of end of green can increase slowing and stopping frequency given the DZ, but drivers may sometimes respond to warnings by speeding up. **Method:** In two simulator studies, we compared six types of roadway or in-vehicle warnings with a no-warning control condition.

Using multilevel modeling, we tested mediation models of the behavioral mechanisms underlying the effects of warnings. **Results:** In both studies, warnings led to more stopping at DZ intersections and milder decelerations when stopping compared with no warning. Drivers' predominant response to warnings was anticipatory slowing on approaching the intersection, not speeding up. The increased stopping with warning was mediated by increased slowing. In Study 1, anticipatory slowing given warnings generalized to green-light intersections where no warning was given. In Study 2, we found that lane-specific warnings (e.g., LED lights embedded in each lane) sometimes led to fewer unsafe emergency stops than did non-lane-specific roadside warnings. **Conclusion:** End-of-green warnings led to safer behavior in the DZ and on the early approach to intersections. The main mechanism for the benefits of warnings was drivers' increased anticipatory slowing on approaching an intersection. Lane-specific warnings may have some benefits over roadside warnings. **Application:** Applications include performance models of how drivers use end-of-green warnings, control algorithms and warning displays for intelligent intersections, and statistical methodology in human factors research.

- **Keywords:** driving simulator, human factors

AUTOMATION, EXPERT SYSTEMS

Ericka Rovira, Austin Cross, Evan Leitch, Craig Bonaceto. *Displaying Contextual Information Reduces the Costs of Imperfect Decision Automation in Rapid Retasking of ISR Assets.* S. 1136-1049.

Objective: The impact of a decision support tool designed to embed contextual mission factors was investigated. Contextual information may enable operators to infer the

appropriateness of data underlying the automation's algorithm. **Background:** Research has shown the costs of imperfect automation are more detrimental than perfectly reliable automation when operators are provided with decision support tools. Operators may trust and rely on the automation more appropriately if they understand the automation's algorithm. The need to develop decision support tools that are understandable to the operator provides the rationale for the current experiment. **Method:** A total of 17 participants performed a simulated rapid retasking of intelligence, surveillance, and reconnaissance (ISR) assets task with manual, decision automation, or contextual decision automation differing in two levels of task demand: low or high. Automation reliability was set at 80%, resulting in participants experiencing a mixture of reliable and automation failure trials. Dependent variables included ISR coverage and response time of replanning routes. **Results:** Reliable automation significantly improved ISR coverage when compared with manual performance. Although performance suffered under imperfect automation, contextual decision automation helped to reduce some of the decrements in performance. **Conclusion:** Contextual information helps overcome the costs of imperfect decision automation. **Application:** Designers may mitigate some of the performance decrements experienced with imperfect automation by providing operators with interfaces that display contextual information, that is, the state of factors that affect the reliability of the automation's recommendation.

- **Keywords:** automation reliability, human–automation interaction, ISR assets, contextual information, automation imperfection

Huiyang Li, Christopher D. Wickens, Nadine Sarter, Angelia Sebok.
Stages and Levels of Automation in Support of Space Teleoperations. S. **1050-1061.**

Objective: This study examined the impact of stage of automation on the performance and perceived workload during simulated robotic arm control tasks in routine and off-nominal scenarios. **Background:** Automation varies with respect to the stage of information processing it supports and its assigned level of automation. Making appropriate choices in terms of stages and levels of automation is critical to ensure robust joint system performance. To date, this issue has been empirically studied in domains such as aviation and medicine but not extensively in the context of space operations. **Method:** A total of 36 participants played the role of a payload specialist and controlled a simulated robotic arm. Participants performed fly-to tasks with two types of automation (camera recommendation and trajectory control automation) of varying stage. Tasks were performed during routine scenarios and in scenarios in which either the trajectory control automation or a hazard avoidance automation failed. **Results:** Increasing the stage of automation progressively improved performance and lowered workload when the automation was reliable, but incurred severe performance costs when the system failed. **Conclusion:** The results from this study support concerns about automation-induced complacency and automation bias when later stages of automation are introduced. The benefits of such automation are offset by the risk of catastrophic outcomes when system failures go unnoticed or become difficult to recover from. **Application:** A medium stage of automation seems preferable as it provides sufficient support during routine operations and helps avoid potentially catastrophic outcomes in circumstances when the automation fails.

- **Keywords:** human–automation interaction, stages and levels of automation, function allocation, teleoperation, robotics, space operations

COGNITIVE PROCESSES

Peter Tikuisis, Oshin Vartanian, David R. Mandel. *Effect of Feedback Mode and Task Difficulty on Quality of Timing Decisions in a Zero-Sum Game.* S. 1062-1076.

Objective: The objective was to investigate the interaction between the mode of performance outcome feedback and task difficulty on timing decisions (i.e., when to act).

Background: Feedback is widely acknowledged to affect task performance. However, the extent to which feedback display mode and its impact on timing decisions is moderated by task difficulty remains largely unknown. **Method:** Participants repeatedly engaged a zero-sum game involving silent duels with a computerized opponent and were given visual performance feedback after each engagement. They were sequentially tested on three different levels of task difficulty (low, intermediate, and high) in counterbalanced order. Half received relatively simple "inside view" binary outcome feedback, and the other half received complex "outside view" hit rate probability feedback. The key dependent variables were response time (i.e., time taken to make a decision) and survival outcome. **Results:** When task difficulty was low to moderate, participants were more likely to learn and perform better from hit rate probability feedback than binary outcome feedback. However, better performance with hit rate feedback exacted a higher cognitive cost manifested by higher decision response time. **Conclusion:** The beneficial effect of hit rate probability feedback on timing decisions is partially moderated by task difficulty. **Application:** Performance feedback mode should be judiciously chosen in relation to task difficulty for optimal performance in tasks involving timing decisions.

- **Keywords:** gaming, uncertainty, probability, outcome, display

Adam Heenan, Chris M. Herdman, Matthew S. Brown, Nicole Robert. *Effects of Conversation on Situation Awareness and Working Memory in Simulated Driving.* S. 1077-1092.

Objective: In the present research, we investigated the hypothesis that working memory mediates conversation-induced impairment of situation awareness (SA) while driving. **Background:** Although there is empirical evidence that conversation impairs driving performance, the cognitive mechanisms that mediate this relationship remain underspecified. Researchers have reported that a phonological working memory task decreased drivers' SA for vehicles located behind them whereas a visuospatial working memory task impaired SA for vehicles ahead. Conversation, therefore, might impair SA for vehicles behind the driver by preferentially taxing the phonological loop. **Method:** A 20-questions task was used as a proxy for natural conversation. In Experiment 1, driving performance was measured across three within-subjects conversation conditions (i.e., no conversation, driver asks questions, driver answers questions) with the use of a driving simulator. In Experiment 2, participants drove in the same simulator while either conversing (20-questions task) or not. Participants estimated the positions of other vehicles after the screens were blanked at the end of each trial. **Results:** Speed monitoring and responses to visual probes were impaired by the 20-questions conversation task (Experiment 1). As predicted, conversation impaired SA for the location of other vehicles more for vehicles located behind the driver than for those in front (Experiment 2). **Conclusion:** Conversation impairs drivers' SA of vehicles behind them by taxing working memory's phonological loop and impairs SA generally by taxing working memory's central executive. **Application:** Provides a theoretical framework that links driver SA to working memory and a mechanism for understanding why conversation impairs driving performance.

- **Keywords:** driving performance, phonological loop, visuospatial sketchpad

Samuel D. Hannah, Andrew Neal. *On-the-Fly Scheduling as a Manifestation of Partial-Order Planning and Dynamic Task Values.* S. 1093-1112.

Objective: The aim of this study was to develop a computational account of the spontaneous task ordering that occurs within jobs as work unfolds ("on-the-fly task scheduling"). **Background:** Air traffic control is an example of work in which operators have to schedule their tasks as a partially predictable work flow emerges. To date, little attention has been paid to such on-the-fly scheduling situations. **Method:** We present a series of discrete-event models fit to conflict resolution decision data collected from experienced controllers operating in a high-fidelity simulation. **Results:** Our simulations reveal air traffic controllers' scheduling decisions as examples of the partial-order planning approach of Hayes-Roth and Hayes-Roth. The most successful model uses opportunistic first-come-first-served scheduling to select tasks from a queue. Tasks with short deadlines are executed immediately. Tasks with long deadlines are evaluated to assess whether they need to be executed immediately or deferred. **Conclusion:** On-the-fly task scheduling is computationally tractable despite its surface complexity and understandable as an example of both the partial-order planning strategy and the dynamic-value approach to prioritization.

- **Keywords:** decision making, scheduling, planning, air traffic control, temporal discounting

Harris R. Lieberman, J. Philip Karl, Philip J. Niro, Kelly W. Williams, Emily K. Farina, Sonya J. Cable, James P. McClung. *Positive Effects of Basic Training on Cognitive Performance and Mood of Adult Females.* S. 1113-1123.

Objective: This study investigated whether a stressful military training program, the 9-to 10-week U.S. Army basic combat training (BCT) course, alters the cognitive performance and mood of healthy young adult females. **Background:** Structured training programs including adolescent boot camps, sports training camps, learning enrichment programs, and military basic training are accepted methods for improving academic and social functioning. However, limited research is available on the behavioral effects of structured training programs in regard to cognitive performance and mood. **Method:** Two separate, within-subject studies were conducted with different BCT classes; in total 212 female volunteers were assessed before and after BCT. In Study 1, Four-Choice Reaction Time, Match-to-Sample, and Grammatical Reasoning tests were administered. The Psychomotor Vigilance Test (PVT) was administered in Study 2. The Profile of Mood States (POMS) was administered in both studies. **Results:** In Study 1, reaction time to correct responses on all three of the performance tests improved from pre- to post-BCT. In Study 2, PVT reaction time significantly improved. All POMS subscales improved over time in the second study, whereas POMS subscales in the first study failed to meet criteria for statistically significant differences over time. **Conclusion:** Cognition and mood substantially improved over military basic training. These changes may be a result of structured physical and mental training experienced during basic training or other factors not as yet identified. **Application:** Properly structured training may have extensive, beneficial effects on cognitive performance and mood; however, additional research is needed to determine what factors are responsible for such changes.

- **Keywords:** army, stress fatigue, depression, reaction time, vigilance, learning, boot camp, structured training, soldiers

Panagiotis Matsangas, Michael E. McCauley, William Becker. The Effect of Mild Motion Sickness and Sopite Syndrome on Multitasking Cognitive Performance. S. 1124-1135.

Objective: In this study, we investigated the effects of mild motion sickness and sopite syndrome on multitasking cognitive performance. **Background:** Despite knowledge on general motion sickness, little is known about the effect of motion sickness and sopite syndrome on multitasking cognitive performance. Specifically, there is a gap in existing knowledge in the gray area of mild motion sickness. **Method:** Fifty-one healthy individuals performed a multitasking battery. Three independent groups of participants were exposed to two experimental sessions. Two groups received motion only in the first or the second session, whereas the control group did not receive motion. Measurements of motion sickness, sopite syndrome, alertness, and performance were collected during the experiment. **Results:** Only during the second session, motion sickness and sopite syndrome had a significant negative association with cognitive performance. Significant performance differences between symptomatic and asymptomatic participants in the second session were identified in composite (9.43%), memory (31.7%), and arithmetic (14.7%) task scores. The results suggest that performance retention between sessions was not affected by mild motion sickness. **Conclusion:** Multitasking cognitive performance declined even when motion sickness and soporific symptoms were mild. The results also show an order effect. We postulate that the differential effect of session on the association between symptomatology and multitasking performance may be related to the attentional resources allocated to performing the multiple tasks. Results suggest an inverse relationship between motion sickness effects on performance and the cognitive effort focused on performing a task. **Application:** Even mild motion sickness has potential implications for multitasking operational performance.

- **Keywords:** cognitive multitasking performance, motion sickness, sopite syndrome, stress, cognitive resources

NEUROERGONOMICS

Altynkul T. Kamzanova, Almira M. Kustubayeva, Gerald Matthews. Use of EEG Workload Indices for Diagnostic Monitoring of Vigilance Decrement. S. 1136-1149.

Objective: A study was run to test which of five electroencephalographic (EEG) indices was most diagnostic of loss of vigilance at two levels of workload. **Background:** EEG indices of alertness include conventional spectral power measures as well as indices combining measures from multiple frequency bands, such as the Task Load Index (TLI) and the Engagement Index (EI). However, it is unclear which indices are optimal for early detection of loss of vigilance. **Method:** Ninety-two participants were assigned to one of two experimental conditions, cued (lower workload) and uncued (higher workload), and then performed a 40-min visual vigilance task. Performance on this task is believed to be limited by attentional resource availability. EEG was recorded continuously. Performance, subjective state, and workload were also assessed. **Results:** The task showed a vigilance decrement in performance; cuing improved performance and reduced subjective workload. Lower-frequency alpha (8 to 10.9 Hz) and TLI were most sensitive to the task parameters. The magnitude of temporal change was larger for lower-frequency alpha. Surprisingly, higher TLI was associated with superior performance. Frontal theta and EI were influenced by task workload only in the final period of work. Correlational data also suggested that the indices are distinct from one another. **Conclusions:** Lower-frequency alpha appears to be the optimal index for monitoring vigilance on the task used here, but further work is needed to test how diagnosticity of EEG indices varies with task demands. **Application:** Lower-frequency alpha may be used to diagnose loss of operator alertness on tasks requiring vigilance.

- **Keywords:** attentional processes, vigilance (sustained attention), monitoring, supervisory control, mental workload

SENSORY AND PERCEPTUAL PROCESSES

Ziho Kang, Steven J. Landry. *Using Scanpaths as a Learning Method for a Conflict Detection Task of Multiple Target Tracking.* S. 1150-1162.

Objective: The objective was to determine whether the scanpaths of air traffic controllers (ATCs) could be used to improve the performance of novices in a conflict detection task. **Background:** Studies in other domains show that novice performance can be improved by exposure to experts' scanpaths. Whether this effect can be found for an aircraft conflict detection task is unknown. **Method:** Scanpaths of 25 professional ATCs ("experts") were recorded using a medium-fidelity air traffic control simulation with realistic scripted traffic that included aircraft pairs that would lose separation. A total of 20 novices were exposed to experts' scanpaths ("treatment"), and their performance (for both loss of separation detection rates and false alarm rates) was compared to that of 20 novices given no treatment or instructions ("control") and 20 novices who were verbally instructed to attend to altitude ("instruction-only"). Interviews were held about the helpfulness of the exposure. The scanpaths were analyzed to find pattern differences among the three groups. **Results:** Chi-square tests showed significant differences for false alarm rates across the three groups ($p = .001$). Pairwise Mann-Whitney tests showed that the number of false alarms for the treatment group was significantly lower than that for the control group ($p = .005$), and trended lower than the instruction-only group ($p = .08$). Treatment group participants responded that experts' scanpaths helped. Analysis of scanpaths showed an increased tendency of the scanpath treatment group to follow the experts' scanpath. **Conclusion:** The scanpath training intervention improved novice performance by reducing false alarms. **Application:** Implementing experts' scanpaths into novices' active learning process shows promise in enhancing training effectiveness and reducing training time.

- **Keywords:** eye tracking, conflict detection task, aerospace systems, expert-novice differences, training

SIMULATION AND VIRTUAL REALITY

Karen B. Chen, Ryan A. Kimmel, Aaron Bartholomew, Kevin Ponto, Michael L. Gleicher, Robert G. Radwin. *Manually Locating Physical and Virtual Reality Objects.* S. 1163-1176.

Objective: In this study, we compared how users locate physical and equivalent three-dimensional images of virtual objects in a cave automatic virtual environment (CAVE) using the hand to examine how human performance (accuracy, time, and approach) is affected by object size, location, and distance. **Background:** Virtual reality (VR) offers the promise to flexibly simulate arbitrary environments for studying human performance. Previously, VR researchers primarily considered differences between virtual and physical distance estimation rather than reaching for close-up objects. **Method:** Fourteen participants completed manual targeting tasks that involved reaching for corners on equivalent physical and virtual boxes of three different sizes. Predicted errors were calculated from a geometric model based on user interpupillary distance, eye location, distance from the eyes to the projector screen, and object. **Results:** Users were 1.64 times less accurate ($p < .001$) and spent 1.49 times more time ($p = .01$) targeting virtual versus physical box corners using the hands. Predicted virtual targeting errors were on average 1.53 times ($p < .05$) greater than the observed errors for farther virtual targets but not significantly different for close-up virtual targets. **Conclusion:** Target size, location, and distance, in addition to binocular disparity, affected virtual object targeting inaccuracy. Observed virtual box inaccuracy was less than predicted for farther

locations, suggesting possible influence of cues other than binocular vision. **Application:** Human physical interaction with objects in VR for simulation, training, and prototyping involving reaching and manually handling virtual objects in a CAVE are more accurate than predicted when locating farther objects.

- **Keywords:** virtual reality, physical interface, simulation, CAVE

SURFACE TRANSPORTATION SYSTEMS

Steven Cloete, Christine Zupanc, Robin Burgess-Limerick, Guy Wallis.
Control Order and Visuomotor Strategy Development for Joystick-Steered Underground Shuttle Cars. S. 1177-1188.

Objective: In this simulator-based study, we aimed to quantify performance differences between joystick steering systems using first-order and second-order control, which are used in underground coal mining shuttle cars. In addition, we conducted an exploratory analysis of how users of the more difficult, second-order system changed their behavior over time. **Background:** Evidence from the visuomotor control literature suggests that higher-order control devices are not intuitive, which could pose a significant risk to underground mine personnel, equipment, and infrastructure. **Method:** Thirty-six naive participants were randomly assigned to first- and second-order conditions and completed three experimental trials comprising sequences of 90° turns in a virtual underground mine environment, with velocity held constant at 9 km/h⁻¹. Performance measures were lateral deviation, steering angle variability, high-frequency steering content, joystick activity, and cumulative time in collision with the virtual mine wall. **Results:** The second-order control group exhibited significantly poorer performance for all outcome measures. In addition, a series of correlation analyses revealed that changes in strategy were evident in the second-order group but not the first-order group. **Conclusion:** Results were consistent with previous literature indicating poorer performance with higher-order control devices and caution against the adoption of the second-order joystick system for underground shuttle cars. **Application:** Low-cost, portable simulation platforms may provide an effective basis for operator training and recruitment.

- **Keywords:** steering, visuomotor control, vehicles, mining

Mahtab Ghazizadeh, Anthony D. McDonald, John D. Lee. *Text Mining to Decipher Free-Response Consumer Complaints : Insights From the NHTSA Vehicle Owner's Complaint Database.* S. 1189-1203.

Objective: This study applies text mining to extract clusters of vehicle problems and associated trends from free-response data in the National Highway Traffic Safety Administration's vehicle owner's complaint database. **Background:** As the automotive industry adopts new technologies, it is important to systematically assess the effect of these changes on traffic safety. Driving simulators, naturalistic driving data, and crash databases all contribute to a better understanding of how drivers respond to changing vehicle technology, but other approaches, such as automated analysis of incident reports, are needed. **Method:** Free-response data from incidents representing two severity levels (fatal incidents and incidents involving injury) were analyzed using a text mining approach: latent semantic analysis (LSA). LSA and hierarchical clustering identified clusters of complaints for each severity level, which were compared and analyzed across time. **Results:** Cluster analysis identified eight clusters of fatal incidents and six clusters of incidents involving injury. Comparisons showed that although the airbag clusters across the two severity levels have the same most frequent terms, the circumstances around the incidents differ. The time trends show clear increases in complaints surrounding the Ford/Firestone tire recall and the Toyota unintended acceleration recall. Increases in complaints may be partially driven by these recall announcements and the associated media attention. **Conclusion:** Text mining can reveal useful information from

free-response databases that would otherwise be prohibitively time-consuming and difficult to summarize manually. **Application:** Text mining can extend human analysis capabilities for large free-response databases to support earlier detection of problems and more timely safety interventions.

- **Keywords:** latent semantic analysis, LSA, hierarchical clustering, cluster visualization, free-response data analysis, vehicle failures, crash analysis, vehicle technology, Toyota unintended acceleration, Ford/Firestone tire recall