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AUTOMATION, EXPERT SYSTEMS

Aya Hussein, Sondoss Elsawah, Hussein A. Abbass. [Trust Mediating Reliability–Reliance Relationship in Supervisory Control of Human–Swarm Interactions.](#) pp. 1237–1248.

Objective: This work aims to further test the theory that trust mediates the interdependency between automation reliability and the rate of human reliance on automation. **Background:** Human trust in automation has been the focus of many research studies. Theoretically, trust has been proposed to impact human reliance on automation by mediating the relationship between automation reliability and the rate of human reliance. Experimentally, however, the results are contradicting as some confirm the mediating role of trust, whereas others deny it. Hence, it is important to experimentally reinvestigate this role of trust and understand how the results should be interpreted in the light of existing theory. **Method:** Thirty-two subjects supervised a swarm of unmanned aerial vehicles (UAVs) in foraging missions in which the swarm provided recommendations on whether or not to collect potential targets, based on the information sensed by the UAVs. By manipulating the reliability of the recommendations, we observed changes in participants' trust and their behavioral responses. **Results:** A within-subject mediation analysis revealed a significant mediation role of trust in the relationship between swarm reliability and reliance rate. High swarm reliability increased the rate of correct acceptances, but decreased the rate of correct rejections. No significant effect of reliability was found on response time. **Conclusion:** Trust is not a mere by-product of the interaction; it possesses a predictive power to estimate the level of reliance on automation. **Application** The mediation role of trust confirms the significance of trust calibration in determining the appropriate level of reliance on swarm automation.

- **Keywords:** human–automation interaction, human–swarm interaction, design of experiments, foraging, within-subject mediation analysis, recommender systems

COGNITION

Michael David Wilson, Luke Strickland, Simon Farrell, Troy A. W. Visser, Shayne Loft. [***Prospective Memory Performance in Simulated Air Traffic Control: Robust to Interruptions but Impaired by Retention Interval.***](#) pp. **1249–1264.**

Objective: To examine the effects of interruptions and retention interval on prospective memory for deferred tasks in simulated air traffic control. **Background:** In many safety-critical environments, operators need to remember to perform a deferred task, which requires prospective memory. Laboratory experiments suggest that extended prospective memory retention intervals, and interruptions in those retention intervals, could impair prospective memory performance. **Method:** Participants managed a simulated air traffic control sector. Participants were sometimes instructed to perform a deferred handoff task, requiring them to deviate from a routine procedure. We manipulated whether an interruption occurred during the prospective memory retention interval or not, the length of the retention interval (37–117 s), and the temporal proximity of the interruption to deferred task encoding and execution. We also measured performance on ongoing tasks. **Results:** Increasing retention intervals (37–117 s) decreased the probability of remembering to perform the deferred task. Costs to ongoing conflict detection accuracy and routine handoff speed were observed when a prospective memory intention had to be maintained. Interruptions did not affect individuals' speed or accuracy on the deferred task. **Conclusion:** Longer retention intervals increase risk of prospective memory error and of ongoing task performance being impaired by cognitive load; however, prospective memory can be robust to effects of interruptions when the task environment provides cuing and offloading. **Application:** To support operators in performing complex and dynamic tasks, prospective memory demands should be reduced, and the retention interval of deferred tasks should be kept as short as possible.

- **Keywords:** deferred tasks, task interruptions, complex dynamic task, delay interval

INDIVIDUAL DIFFERENCES

Levi Swann, Vesna Popovic, Alethea Blackler, Helen Thompson. [***Airport Security Screener Problem-Solving Knowledge and Implications.***](#) pp. **1265–1285.**

Objective: This research investigates security screeners' knowledge and the effect that differences in knowledge have on the performance of problem-solving activities. We argue that the development of problem-solving knowledge enables security screeners to perform effective problem-solving activity, which assists search and decision-making processes. **Background:** Airport security screening research has investigated the many variables that affect security screeners' search and decision making during simulated threat-detection tasks. Although search and decision making are essential aspects of security screening, few studies have investigated the problem-solving knowledge and activities that support security screening task performance. **Method:** Sixteen more-experienced and 24 less-experienced security screeners were observed as they performed x-ray screening in the field at an Australian international airport's departure security checkpoint. Participants wore eye-tracking glasses and delivered concurrent verbal protocol. **Results:** When interacting with other security screeners, more-experienced screeners demonstrated situational knowledge more than less-experienced screeners, whereas less-experienced screeners experienced more insufficient knowledge. Lag-sequential analysis using combined data from both screener groups showed that

situational knowledge facilitated effective problem-solving activity to support search and decision making. Insufficient knowledge led screeners to seek assistance and defer decision making. **Conclusion:** This study expands current understandings of airport security screening. It demonstrates that security screeners develop knowledge that is specific to problem solving. This knowledge assists effective problem-solving activity to support search and decision making, and to mitigate uncertainty during the x-ray screening task. **Application:** Findings can inform future security screening processes, screener training, and technology support tools. Furthermore, findings are potentially transferable to other domains.

- **Keywords:** expert–novice differences, experience, knowledge elicitation, skilled performance, cognition

METHODS AND SKILLS

Sarah Malone, Roland Brünken. [Studying Gaze Behavior to Compare Three Different Hazard Perception Tasks.](#) pp. 1286–1303.

Objective: The aim of the current study was to compare the traditional, verbal, and motoric tasks regarding their contributions to hazard perception measurement. **Background:** Traditional hazard perception tasks require the participants to respond to filmed traffic conflicts in an imprecise way, such as by pressing a button. More sophisticated tasks include either verbal specification or motoric localization of the perceived hazards. The present study investigated the participants' gaze behavior when they were provided with an identical set of traffic animations but were instructed to perform one of three types of hazard perception tasks. **Method:** In an eye tracking study, 69 drivers were shown animated traffic scenarios and instructed to perform the traditional (press button), verbal, or speeded motoric localization hazard perception task. Eye tracking revealed whether and when the participant had fixated a certain hazard cue. **Results:** The participants in the traditional task group were slower to fixate emerging hazards, but quicker to respond to them than the participants of the verbal and the motoric groups. As a specific benefit, the verbal task differentiated between different types of failures. **Conclusion:** Additional verbal or speeded motoric localization tasks seem to have increased the participants' alertness when watching the animations. The verbal task provides valuable additional information regarding the participants' performance. To approximate real-life hazard perception ability, it is recommended that researchers and practitioners use a combination of different hazard perception tasks for assessment and training.

- **Keywords:** situation awareness, eye movements, tracking, perceptual-motor performance, response time

SURFACE TRANSPORTATION

Christopher D. Wickens, Adam Williams, Benjamin A. Clegg, C. A. P. Smith. [Nautical Collision Avoidance: The Cognitive Challenges of Balancing Safety, Efficiency, and Procedures.](#) pp. 1304–1321.

Objective: Experimentally investigate maneuver decision preferences in navigating ships to avoid a collision. How is safety (collision avoidance) balanced against efficiency (deviation from path and delay) and rules of the road under conditions of both trajectory certainty and uncertainty. **Background:** Human decision error is a prominent factor in nautical collisions, but the multiple factors of geometry of collisions and role of

uncertainty have been little studied in empirical human factors literature. **Approach:** Eighty-seven Mechanical Turk participants performed in a lower fidelity ship control simulation, depicting ownship and a cargo ship hazard on collision or near-collision trajectories of various conflict geometries, while controlling heading and speed with the sluggish relative dynamics. Experiment 1 involved the hazard on a straight trajectory. In Experiment 2, the hazard could turn on unpredictable trials. Participants were rewarded for efficiency and penalized for collisions or close passes. **Results:** Participants made few collisions, but did so more often when on a collision path. They sometimes violated the instructed rules of the road by maneuvering in front of the hazard ship's path. They preferred speed control to heading control. Performance degraded in conditions of uncertainty. **Conclusion:** Data reveal an understanding of maneuver decisions and conditions that affect the balance between safety and efficiency. **Application:** The simulation and data highlight the degrading role of uncertainty and provide a foundation upon which more complex questions can be asked, asked of more trained navigators, and decision support tools examined.

- **Keywords:** collision avoidance, nautical, decision making, ship navigation

Kristin Mühl, Christoph Strauch, Christoph Grabmaier, Susanne Reithinger, Anke Huckauf, Martin Baumann. [Get Ready for Being Chauffeured: Passenger's Preferences and Trust While Being Driven by Human and Automation.](#) pp. 1322–1338.

Objective: We investigated passenger's trust and preferences using subjective, qualitative, and psychophysiological measures while being driven either by human or automation in a field study and a driving simulator experiment. **Background:** The passenger's perspective has largely been neglected in autonomous driving research, although the change of roles from an active driver to a passive passenger is incontrovertible. Investigations of passenger's appraisals on self-driving vehicles often seem convoluted with active manual driving experiences instead of comparisons with being driven by humans. **Method:** We conducted an exploratory field study using an autonomous research vehicle ($N = 11$) and a follow-up experimental driving simulation ($N = 24$). Participants were driven on the same course by a human and an autonomous agent sitting on a passenger seat. Skin conductance, trust, and qualitative characteristics of the perceived driving situation were assessed. In addition, the effect of driving style (defensive vs. sporty) was evaluated in the simulator. **Results:** Both investigations revealed a close relation between subjective trust ratings and skin conductance, with increased trust and by trend reduced arousal for human compared with automation in control. Even though driving behavior was equivalent in the simulator when being driven by human and automation, passengers most preferred and trusted the human-defensive driver. **Conclusion:** Individual preferences for driving style and human or autonomous vehicle control influence trust and subjective driving characterizations. **Application:** The findings are applicable in human-automation research, reminding to not neglect subjective attributions and psychophysiological reactions as a result of ascribed control duties in relation to specific execution characteristics.

- **Keywords:** aggressive and risky driving, human-automation interaction, physiological measurement, trust in automation, vehicle automation

Ouren X. Kuiper, Jelte E. Bos, Eike A. Schmidt, Cyriel Diels, Stefan Wolter. [Knowing What's Coming: Unpredictable Motion Causes More Motion Sickness.](#) pp. 1339–1348.

Objective: This study explores the role of anticipation in motion sickness. We compared three conditions varying in motion predictability and assessed the effect of anticipation on subsequent illness ratings using a within-subjects design. **Background:** Anticipation

is thought to play a role in motion sickness by reducing the discrepancy between sensed and expected sensory information. However, both the exact role and potential magnitude of anticipation on motion sickness are unknown. **Method:** Participants ($N = 17$) were exposed to three 15-min conditions consisting of repeated fore-aft motion on a sled on a 40-m rail (1) at constant intervals and consistent motion direction, (2) at constant intervals but varied motion direction, and (3) at varied intervals but consistent motion direction. Conditions were otherwise identical in motion intensity and displacement, as they were composed of the same repetitions of identical blocks of motion. Illness ratings were recorded at 1-min intervals using an 11-point motion sickness scale. **Results:** Average illness ratings after exposure were significantly lower for the predictable condition, compared with both the directionally unpredictable condition and the temporally unpredictable condition. **Conclusion:** Unpredictable motion is significantly more provocative compared with predictable motion. Findings suggest motion sickness results from a discrepancy between sensed and expected motion, rather than from unpreparedness to motion. **Application:** This study underlines the importance of an individual's anticipation to motion in motion sickness. Furthermore, this knowledge could be used in domains such as that of autonomous vehicles to reduce carsickness.

- **Keywords:** motion sickness, multisensory integration, autonomous driving, attentional processes

Ning Li, Linda Ng Boyle. [Allocation of Driver Attention for Varying In-Vehicle System Modalities.](#) pp. 1349–1364.

Objective: This paper examines drivers' allocation of attention using response time to a tactile detection response task (TDRT) while interacting with an in-vehicle information system (IVIS) over time. **Background:** Longer TDRT response time is associated with higher cognitive workload. However, it is not clear what role is assumed by the human and system in response to varying in-vehicle environments over time. **Method:** A driving simulator study with 24 participants was conducted with a restaurant selection task of two difficulty levels (easy and hard) presented in three modalities (audio only, visual only, hybrid). A linear mixed-effects model was applied to identify factors that affect TDRT response time. A nonparametric time-series model was also used to explore the visual attention allocation under the hybrid mode over time. **Results:** The visual-only mode significantly increased participants' response time compared with the audio-only mode. Females took longer to respond to the TDRT when engaged with an IVIS. The study showed that participants tend to use the visual component more toward the end of the easy tasks, whereas the visual mode was used more at the beginning of the harder tasks. **Conclusion:** The visual-only mode of the IVIS increased drivers' cognitive workload when compared with the auditory-only mode. Drivers showed different visual attention allocation during the easy and hard restaurant selection tasks in the hybrid mode. **Application:** The findings can help guide the design of automotive user interfaces and help manage cognitive workload.

- **Keywords:** driver distraction, driving simulator study, secondary task, detection response task, cognitive workload

TRAINING, EDUCATION, INSTRUCTIONAL SYSTEMS

Chuhao Wu, Jackie Cha, Jay Sulek, Tian Zhou, Chandru P. Sundaram, Juan Wachs, Denny Yu. [Eye-Tracking Metrics Predict Perceived Workload in Robotic Surgical Skills Training.](#) pp. 1365–1386.

Objective: The aim of this study is to assess the relationship between eye-tracking measures and perceived workload in robotic surgical tasks. **Background:** Robotic

techniques provide improved dexterity, stereoscopic vision, and ergonomic control system over laparoscopic surgery, but the complexity of the interfaces and operations may pose new challenges to surgeons and compromise patient safety. Limited studies have objectively quantified workload and its impact on performance in robotic surgery. Although not yet implemented in robotic surgery, minimally intrusive and continuous eye-tracking metrics have been shown to be sensitive to changes in workload in other domains. **Methods:** Eight surgical trainees participated in 15 robotic skills simulation sessions. In each session, participants performed up to 12 simulated exercises. Correlation and mixed-effects analyses were conducted to explore the relationships between eye-tracking metrics and perceived workload. Machine learning classifiers were used to determine the sensitivity of differentiating between low and high workload with eye-tracking features. **Results:** Gaze entropy increased as perceived workload increased, with a correlation of .51. Pupil diameter and gaze entropy distinguished differences in workload between task difficulty levels, and both metrics increased as task level difficulty increased. The classification model using eye-tracking features achieved an accuracy of 84.7% in predicting workload levels. **Conclusion:** Eye-tracking measures can detect perceived workload during robotic tasks. They can potentially be used to identify task contributors to high workload and provide measures for robotic surgery training. **Application:** Workload assessment can be used for real-time monitoring of workload in robotic surgical training and provide assessments for performance and learning.

- **Keywords:** perceived workload, eye movements, robotics and telesurgery, simulation training, statistics and data analysis