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ACCIDENTS, HUMAN ERROR

Qiuyang Tang, Gang Guo, Zijian Zhang, Bingbing Zhang, Yingzhang Wu. ***Olfactory Facilitation of Takeover Performance in Highly Automated Driving.*** pp 553–564.

Objective: This study aims to quantify the impact of olfactory stimulation and takeover modality on the performance of takeovers in conditionally automated driving. **Background:** Takeover requests are important for the safety of automated vehicles. The reaction time and subsequent performance of drivers in the takeover process are crucial for safety. In this study, peppermint was adopted as an auxiliary modality to the tactile and auditory design of takeover requests. **Methods:** Sixty participants took part in the experiment, which required participants to avoid a stalled vehicle after they were awoken from a state of light sleep by a takeover request. Takeover modality (tactile, auditory, and combined) was the within-subjects factor. In the between-subjects design, half of the participants received a peppermint odor stimulation when the takeover request occurred, and the other half received a placebo (air). **Results:** The presence of peppermint odor did not influence the reaction time, but participants did show signs of being more alert afterwards. For the moment of takeover, use of the auditory modality had a significant positive effect on reaction time compared to the tactile conditions. **Conclusion:** Peppermint odor had a positive impact on drivers' takeover quality when engaged in nondriving-related activities such as light sleep, and the takeover request modalities were shown to be crucial for a safe and successful takeover. **Application:** The results will be useful as a reference for developers of automated driving systems to design human-machine interfaces, shorten the driver's reaction time, and improve takeover quality.

- **Keywords:** highly automated driving, driver behavior, sleep, takeover request, olfactory

BIOMECHANICS, ANTHROPOMETRY, WORK PHYSIOLOGY

Neal Wiggermann, Jie Zhou, Nancy McGann. [Effect of Repositioning Aids and Patient Weight on Biomechanical Stresses When Repositioning Patients in Bed.](#) pp. 565–577.

Objective: The aim of the study was to estimate the risk of injury when repositioning patients of different weight with commonly used repositioning aids. **Background:** Repositioning dependent patients in bed is the most common type of patient handling activity and is associated with high rates of musculoskeletal disorders in healthcare workers. Several studies have evaluated repositioning aids, but typically for a single patient weight and often without estimating risk of injury based on biomechanical analysis. **Method:** Ten nurses performed four repositioning activities on three participants (50, 77, 141 kg) using three repositioning aids (pair of friction-reducing sheets [FRS], turn and position glide sheet, air-assisted transfer device) and a draw sheet. Motion capture, hand forces, and ground reaction forces were recorded. Spine loading was estimated using a dynamic biomechanical model. **Results:** Hand forces and spine compression exceeded recommended limits for most patient weights and repositioning tasks with the draw sheet. FRS and glide sheet reduced these loads but still exceeded recommended limits for all but the 50-kg patient. Only the air-assisted transfer device reduced forces to accepted levels for all patient weights. Physical stresses were relatively low when turning patients. **Conclusion:** Most repositioning aids are insufficient to properly mitigate risk of musculoskeletal injury in healthcare workers. Only the air-assisted transfer device was sufficient to adequately mitigate the risk of injury when moving patients of average or above-average weight. **Application:** To safely move dependent patients, a robust solution requires mechanical lifts and may utilize air-assisted transfer devices for patient transfers.

- **Keywords:** patient handling, patient repositioning, hospital bed, medical devices and technologies, nursing and nursing systems

DISPLAYS AND CONTROLS

Tyler N. Morrison, Emanuele Rizzi, O. Anil Turkkkan, Richard J. Jagacinski, Haijun Su, Junmin Wang. [Drivers' Spatio-Temporal Attentional Distributions Are Influenced by Vehicle Dynamics and Displayed Point of View.](#) pp. 578–591.

Objective: The aim of this study is to measure drivers' attention to preview and their velocity and acceleration tracking error to evaluate two- and three-dimensional displays for following a winding roadway. **Background:** Display perturbation techniques and Fourier analysis of steering movements can be used to infer drivers' spatio-temporal distribution of attention to preview. Fourier analysis of tracking error time histories provides measures of position, velocity, and acceleration error. **Method:** Participants tracked a winding roadway with 1 s of preview in low-fidelity driving simulations. Position and rate-aided vehicle dynamics were paired with top-down and windshield displays of the roadway. **Results:** For both vehicle dynamics, tracking was smoother with the windshield display. This display emphasizes nearer preview positions and has a closer correspondence to the control-theoretic optimal attentional distributions for these tasks than the top-down display. This correspondence is interpreted as a form of stimulus-response compatibility. The position error and attentional signal-to-noise ratios did not differ between the two displays with position control, but with more complex rate-aided control much higher position error and much lower attentional signal-to-noise ratios occurred with the top-down display. **Conclusion:** Display-driven influences on the

distribution of attention may facilitate tracking with preview when they are similar to optimal attentional distributions derived from control theory. **Application:** Display perturbation techniques can be used to assess spatially distributed attention to evaluate displays and secondary tasks in the context of driving. This methodology can supplement eye movement measurements to determine what information is guiding drivers' actions.

- **Keywords:** driver behavior, attentional processes, perceptual-motor performance, control theory, stimulus-response compatibility

HUMAN-ROBOT INTERACTION

Caleb Furlough, Thomas Stokes, Douglas J. Gillan. *Attributing Blame to Robots: I. The Influence of Robot Autonomy*. pp. 592–602.

Objective: The research examined how humans attribute blame to humans, nonautonomous robots, autonomous robots, or environmental factors for scenarios in which errors occur. **Background:** When robots and humans serve on teams, human perception of their technological team members can be a critical component of successful cooperation, especially when task completion fails. **Methods:** Participants read a set of scenarios that described human-robot team task failures. Separate scenarios were written to emphasize the role of the human, the robot, or environmental factors in producing the task failure. After reading each scenario, the participants allocated blame for the failure among the human, robot, and environmental factors. **Results:** In general, the order of amount of blame was humans, robots, and environmental factors. If the scenario described the robot as nonautonomous, the participants attributed almost as little blame to them as to the environmental factors; in contrast, if the scenario described the robot as autonomous, the participants attributed almost as much blame to them as to the human. **Conclusion:** We suggest that humans use a hierarchy of blame in which robots are seen as partial social actors, with the degree to which people view them as social actors depending on the degree of autonomy. **Application:** The acceptance of robots by human co-workers will be a function of the attribution of blame when errors occur in the workplace. The present research suggests that greater autonomy for the robot will result in greater attribution of blame in work tasks.

- **Keywords:** social processes, human-automation interaction, human-robot interaction

Joseph B. Lyons, Thy Vo, Kevin T. Wynne, Sean Mahoney, Chang S. Nam, Darci Gallimore. [*Trusting Autonomous Security Robots: The Role of Reliability and Stated Social Intent*](#). pp. 603–618.

Objective: This research examined the effects of reliability and stated social intent on trust, trustworthiness, and one's willingness to endorse use of an autonomous security robot (ASR). **Background:** Human-robot interactions in the domain of security is plausible, yet we know very little about what drives acceptance of ASRs. Past research has used static images and game-based simulations to depict the robots versus actual humans interacting with actual robots. **Method:** A video depicted an ASR interacting with a human. The ASR reviewed access credentials and allowed entrance once verified. If the ASR could not verify one's credentials it instructed the visitor to return to the security checkpoint. The ASR was equipped with a nonlethal device and the robot used this device on one of the three visitors (a research confederate). Manipulations of reliability and stated social intent of the ASR were used in a 2 × 4 between subjects design (N = 320). **Results:** Reliability influenced trust and trustworthiness. Stated social intent influenced trustworthiness. Participants reported being more favorable toward use of the ASR in military contexts versus public contexts. **Conclusion:** The study demonstrated that

reliability of the ASR and statements regarding the ASR's stated social intent are important considerations influencing the trust process (inclusive of intentions to be vulnerable and trustworthiness perceptions). **Application:** If robotic systems are authorized to use force against a human, public acceptance may be increased with availability of the intent-based programming of the robot and whether or not the robot's decision was reliable.

- **Keywords:** trust in human-robot interaction, transparency, trustworthiness, benevolence, autonomous robots

Robert Valner, Jason Mario Dydynski, Sookyung Cho, Karl Kruusamäe. *Communication of Hazards in Mixed-Reality Telerobotic Systems: The Usage of Naturalistic Avoidance Cues in Driving Tasks.* pp. 619–634.

Objective: This study investigates the effect of naturalistic visual cues on human avoidance behavior for a potential use in telerobotic user interfaces incorporating mixed-reality environments (e.g., augmented reality). **Background:** Telerobotic systems used in hazardous environments require interfaces that draw operators' attention to potential dangers. Existing means of hazard notification can often distract or induce stress in operators. In the design and implementation of such interfaces, visual semiotics plays a critical role in creating more effective interfaces. Naturalistic visual cues such as Aposematism or Kindchenschema have proven effective to communicate danger or caution in nature, but the application of these cues in visual systems have yet to be thoroughly investigated. **Method:** A study was conducted where 40 volunteering participants were asked to control a remote vehicle in a simulated environment. The environment contained a set of neutral and visually augmented obstacles that were designed to provoke avoidance behavior. **Results:** The use of visual cues triggered greater avoidance behaviors in participants compared to neutral obstacles. The distance of avoidance was correlated with the type of cue present, with obstacles augmented by Aposematism (Cue A) having a greater participant-obstacle distance than Kindchenschema (Cue K). **Conclusions:** This study shows the potential for the incorporation of naturalistic visual cues as a means to designate warning or caution in telerobotic environments. **Applications:** The findings can offer practical guidelines for the design of visual cues in telerobotic interfaces. The further incorporation of such cues may reduce operator stress and the amount of human errors in telerobotic operations.

- **Keywords:** warning systems, warning compliance, situation awareness, vigilance, visual displays environment/context, teleoperation, assistive technologies, stress, driver behavior

INDIVIDUAL DIFFERENCES

Ann J. Carrigan, John Magnussen, Andrew Georgiou, Kim M. Curby, Thomas J. Palmeri, Mark W. Wiggins. [*Differentiating Experience From Cue Utilization in Radiological Assessments.*](#) pp. 635–646.

Objective: This research was designed to examine the contribution of self-reported experience and cue utilization to diagnostic accuracy in the context of radiology. **Background:** Within radiology, it is unclear how task-related experience contributes to the acquisition of associations between features with events in memory, or cues, and how they contribute to diagnostic performance. **Method:** Data were collected from 18 trainees and 41 radiologists. The participants completed a radiology edition of the established cue utilization assessment tool EXPERTise 2.0, which provides a measure of cue utilization based on performance on a number of domain-specific tasks. The participants also completed a separate image interpretation task as an independent

measure of diagnostic performance. **Results:** Consistent with previous research, a k-means cluster analysis using the data from EXPERTise 2.0 delineated two groups, the pattern of centroids of which reflected higher and lower cue utilization. Controlling for years of experience, participants with higher cue utilization were more accurate on the image interpretation task compared to participants who demonstrated relatively lower cue utilization ($p = .01$). **Conclusion:** This study provides support for the role of cue utilization in assessments of radiology images among qualified radiologists. Importantly, it also demonstrates that cue utilization and self-reported years of experience as a radiologist make independent contributions to performance on the radiological diagnostic task. **Application:** Task-related experience, including training, needs to be structured to ensure that learners have the opportunity to acquire feature–event relationships and internalize these associations in the form of cues in memory.

- **Keywords:** naturalistic decision making, radiology and medical imaging, organizational psychology

MOTOR BEHAVIOR

Hideyuki Kimpara, Kenechukwu C. Mbanisi, Zhi Li, Karen L. Troy, Danil Prokhorov, Michael A. Gennert. *Force Anticipation and Its Potential Implications on Feedforward and Feedback Human Motor Control*. pp. 647–662.

Objective: To investigate the effects of human force anticipation, we conducted an experimental load-pushing task with diverse combinations of informed and actual loading weights. **Background:** Human motor control tends to rely upon the anticipated workload to plan the force to exert, particularly in fast tasks such as pushing objects in less than 1 s. The motion and force responses in such tasks may depend on the anticipated resistive forces, based on a learning process. **Method:** Pushing performances of 135 trials were obtained from 9 participants. We varied the workload by changing the masses from 0.2 to 5 kg. To influence anticipation, participants were shown a display of the workload that was either correct or incorrect. We collected the motion and force data, as well as electromyography (EMG) signals from the actively used muscle groups. **Results:** Overanticipation produced overshoot performances in more than 80% of trials. Lighter actual workloads were also associated with overshoot. Pushing behaviors with heavier workloads could be classified into feedforward-dominant and feedback-dominant responses based on the timing of force, motion, and EMG responses. In addition, we found that the preceding trial condition affected the performance of the subsequent trial. **Conclusion:** Our results show that the first peak of the pushing force increases consistently with anticipatory workload. **Application:** This study improves our understanding of human motion control and can be applied to situations such as simulating interactions between drivers and assistive systems in intelligent vehicles.

- **Keywords:** motor control, cognitive task analysis, discrete event simulation, electromyography (EMG), upper extremity

PHYSIOLOGICAL AND PSYCHOLOGICAL CONDITIONS (“INTERNAL ENVIRONMENT”)

Deokhoon Jun, Venerina Johnston, Steven M. McPhail, Shaun O’Leary. *A Longitudinal Evaluation of Risk Factors and Interactions for the*

Development of Nonspecific Neck Pain in Office Workers in Two Cultures.
pp. 663–683.

Objective: To identify risk factors for the development of interfering neck pain in office workers including an examination of the interaction effects between potential risk factors. **Background:** The 1-year incidence of neck pain in office workers is reported as the highest of all occupations. Identifying risk factors for the development of neck pain in office workers is therefore a priority to direct prevention strategies. **Methods:** Participants included 214 office workers without neck pain from two cultures. A battery of measures evaluating potential individual and workplace risk factors were administered at baseline, and the incidence of interfering neck pain assessed monthly for 12 months. Survival analysis was used to identify relationships between risk factors and the development of interfering neck pain. **Results:** One-year incidence was 1.93 (95% CI [1.41, 2.64]) per 100 person months. Factors increasing the risk of developing interfering neck pain were older age, female gender, increased sitting hours, higher job strain, and stress. A neutral thorax sitting posture, greater cervical range of motion and muscle endurance, and higher physical activity were associated with a decreased risk of neck pain. The effects of some risk factors on the development of neck pain were moderated by the workers' coping resources. **Conclusion:** Multiple risk factors and interactions may explain the development of neck pain in office workers. Therefore, plans for preventing the development of interfering neck pain in office workers should consider multiple individual and work-related factors with some factors being potentially more modifiable than others.

- **Keywords:** neck pain, office workers, risk factors, interaction effect, incidence

TEAMS AND GROUPS

Anthony L. Baker, Joseph R. Keebler, Emily C. Anania, David Schuster, John P. Plummer. *Team Combat Identification: Effects of Gender, Spatial Visualization, and Disagreement.* pp. 684–695.

Objective: The combat identification (CID) abilities of same-gender and mixed-gender dyads were experimentally assessed, along with measures of spatial skills and team communication. **Background:** CID is a high-stakes decision-making task involving discrimination between friendly and enemy forces. Literature on CID is primarily focused on the individual, but the extensive use of teams in the military means that more team-based research is needed in this area. **Method:** After a set of training sessions, 39 dyads were tasked with identifying 10 armored vehicles in a series of pictures and videos. Team communication was recorded, transcribed, and coded for instances of disagreements. **Results:** Analyses indicated that males scored higher on a spatial visualization measure than did females. M-M teams performed significantly better than M-F teams on the CID task, but when spatial ability and team disagreements were added as predictors, the effect of team gender composition became nonsignificant. Spatial ability and team disagreement were significant predictors of team CID performance. **Conclusion:** Results suggest that spatial skills and team disagreement behaviors are more important for team CID performance than a team's gender composition. To our knowledge, this is the first lab study of team CID. **Application:** This research highlights the importance of understanding both individual differences (e.g., spatial skills) and team processes (e.g., communication) within CID training environments in the military context.

- **Keywords:** teams and groups, team communication, communication analysis, gender, training

Jason S. McCarley, Nathan Leggett, Alison Enright. [*Shared Gaze Fails to Improve Team Visual Monitoring.*](#) pp. 696–705.

Objective: The aim was to test the value of shared gaze as a way to improve team performance in a visual monitoring task. **Background:** Teams outperform individuals in monitoring tasks, but fall short of achievable levels. Shared-gaze displays offer a potential method of improving team efficiency. Within a shared-gaze arrangement, operators collaborate on a visual task, and each team member's display includes a cursor to represent the other teammates' point of regard. Past work has suggested that shared gaze allows operators to better communicate and coordinate their attentional scanning in a visual search task. The current experiments sought to replicate and extend earlier findings of inefficient team performance in a visual monitoring task, and asked whether shared gaze would improve team efficiency. **Method:** Participants performed a visual monitoring task framed as a sonar operation. Displays were matrices of luminance patches varying in intensity. The participants' task was to monitor for occasional critical signals, patches of high luminance. In Experiment 1, pairs of participants performed the task independently, or working as teams. In Experiment 2, teams of two participants performed the task with or without shared-gaze displays. **Results:** In Experiment 1, teams detected more critical signals than individuals, but were statistically inefficient; detection rates were lower than predicted by a control model that assumed pairs of operators searching in isolation. In Experiment 2, shared gaze failed to increase target detection rates. **Conclusion and application:** Operators collaborate inefficiently in visual monitoring tasks, and shared gaze does not improve their performance.

- **Keywords:** attentional processes, visual displays, mathematical modeling, eye movements/tracking, team collaboration

TRAINING, EDUCATION, INSTRUCTIONAL SYSTEMS

Alexandra D. Kaplan, Jessica Cruit, Mica Endsley, Suzanne M. Beers, Ben D. Sawyer, P. A. Hancock. *The Effects of Virtual Reality, Augmented Reality, and Mixed Reality as Training Enhancement Methods: A Meta-Analysis.* pp. 706–726.

Objective: The objective of this meta-analysis is to explore the presently available, empirical findings on transfer of training from virtual (VR), augmented (AR), and mixed reality (MR) and determine whether such extended reality (XR)-based training is as effective as traditional training methods. **Background:** MR, VR, and AR have already been used as training tools in a variety of domains. However, the question of whether or not these manipulations are effective for training has not been quantitatively and conclusively answered. Evidence shows that, while extended realities can often be time-saving and cost-saving training mechanisms, their efficacy as training tools has been debated. **Method:** The current body of literature was examined and all qualifying articles pertaining to transfer of training from MR, VR, and AR were included in the meta-analysis. Effect sizes were calculated to determine the effects that XR-based factors, trainee-based factors, and task-based factors had on performance measures after XR-based training. **Results:** Results showed that training in XR does not express a different outcome than training in a nonsimulated, control environment. It is equally effective at enhancing performance. **Conclusion:** Across numerous studies in multiple fields, extended realities are as effective of a training mechanism as the commonly accepted methods. The value of XR then lies in providing training in circumstances, which exclude traditional methods, such as situations when danger or cost may make traditional training impossible.

- **Keywords:** virtual environments, transfer of training, immersive environments, meta-analysis