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AUTOMATION, EXPERT SYSTEMS

Vanessa K. Bowden, Natalie Griffiths, Luke Strickland, Shayne Loft. *Detecting a Single Automation Failure: The Impact of Expected (But Not Experienced) Automation Reliability*. pp. 533–545.

Objective: Examine the impact of expected automation reliability on trust, workload, task disengagement, nonautomated task performance, and the detection of a single automation failure in simulated air traffic control. **Background:** Prior research has focused on the impact of experienced automation reliability. However, many operational settings feature automation that is reliable to the extent that operators will seldom experience automation failures. Despite this, operators must remain aware of when automation is at greater risk of failing. **Method:** Participants performed the task with or without conflict detection/resolution automation. Automation failed to detect/resolve one conflict (i.e., an automation miss). Expected reliability was manipulated via instructions such that the expected level of reliability was (a) constant or variable, and (b) the single automation failure occurred when expected reliability was high or low. **Results:** Trust in automation increased with time on task prior to the automation failure. Trust was higher when expecting high relative to low reliability. Automation failure detection was improved when the failure occurred under low compared with high expected reliability. Subjective workload decreased with automation, but there was no improvement to nonautomated task performance. Automation increased perceived task disengagement. **Conclusions:** Both automation reliability expectations and task experience played a role in determining trust. Automation failure detection was improved when the failure occurred at a time it was expected to be more likely. Participants did not effectively allocate any spared capacity to nonautomated tasks. **Applications:** The outcomes are applicable because operators in field settings likely form contextual expectations regarding the reliability of automation.

Cyrus K. Foroughi, Shannon Devlin, Richard Pak, Noelle L. Brown, Ciara Sibley, Joseph T. Coyne. *Near-Perfect Automation: Investigating Performance, Trust, and Visual Attention Allocation*. pp. 546–561.

Objective: Assess performance, trust, and visual attention during the monitoring of a near-perfect automated system. **Background:** Research rarely attempts to assess performance, trust, and visual attention in near-perfect automated systems even though they will be relied on in high-stakes environments. **Methods:** Seventy-three participants completed a 40-min supervisory control task where they monitored three search feeds. All search feeds were 100% reliable with the exception of two automation failures: one miss and one false alarm. Eye-tracking and subjective trust data were collected. **Results:** Thirty-four percent of participants correctly identified the automation miss, and 67% correctly identified the automation false alarm. Subjective trust increased when participants did not detect the automation failures and decreased when they did. Participants who detected the false alarm had a more complex scan pattern in the 2 min centered around the automation failure compared with those who did not. Additionally, those who detected the failures had longer dwell times in and transitioned to the center sensor feed significantly more often. **Conclusion:** Not only does this work highlight the limitations of the human when monitoring near-perfect automated systems, it begins to quantify the subjective experience and attentional cost of the human. It further emphasizes the need to (1) reevaluate the role of the operator in future high-stakes environments and (2) understand the human on an individual level and actively design for the given individual when working with near-perfect automated systems. **Application:** Multiple operator-level measures should be collected in real-time in order to monitor an operator's state and leverage real-time, individualized assistance.

BIOMECHANICS, ANTHROPOMETRY, WORK PHYSIOLOGY

Maria-Gabriela Garcia, Maria Gloria Roman, Andrea Davila, Bernard J. Martin. *Comparison of Physiological Effects Induced by Two Compression Stockings and Regular Socks During Prolonged Standing Work*. pp. 562–574.

Objective: The goal of this study was to evaluate and compare lower-leg muscle fatigue, edema, and discomfort induced by the prolonged standing of security guards wearing regular socks and those wearing 15–20 or 20–30 mmHg compression stockings as intervention. **Background:** Compression stockings are sometimes used by individuals standing all day at work. However, quantitative evidence showing their potential benefits for lower-leg health issues in healthy individuals during real working conditions is lacking. **Method:** Forty male security employees participated in the study. All were randomly assigned to the control or one of the two intervention groups (I15–20 or I20–30). Lower-leg muscle twitch force, volume, and discomfort ratings were measured before and after their regular 12-hr standing work shift. **Results:** Significant evidence of lower-leg long-lasting muscle fatigue, edema, and discomfort was observed after standing work for guards wearing regular socks. However, no significant changes were found for guards wearing either compression stockings. **Conclusion:** In healthy individuals, compression stockings seem to attenuate efficiently the tested outcomes in the lower leg resulting from prolonged standing. **Application:** Occupational activities requiring prolonged standing may benefit from 15–20 or 20–30 mmHg compression stockings. As similar benefits were observed for both levels of compression, the lower level may be sufficient.

Seulgi Kim, Ilseok Lee, Sang Hyeon Kang, Sangeun Jin. *Significance of Lower Body Postures in Chair Design*. pp. 575–591.

Objective: This study examined a system-level perspective to investigate the changes in the whole trunk and head postures while sitting with various lower extremity postures. **Background:** Sitting biomechanics has focused mainly on the lumbar region only, whereas the anatomy literature has suggested various links from the head and lower extremity. **Method:** Seventeen male participants were seated in six lower extremity postures, and the trunk kinematics and muscle activity measures were captured for 5 s. **Results:** Changes in the trunk-thigh angle and the knee angle affected the trunk and head postures and muscle recruitment patterns significantly, indicating significant interactions between the lower extremity and trunk while sitting. Specifically, the larger trunk-thigh angle (T135°) showed more neutral lumbar lordosis (4.0° on average), smaller pelvic flexion (1.8°), smaller head flexion (3.3°), and a less rounded shoulder (1.7°) than the smaller one (T90°). The smaller knee angle (K45°) revealed a more neutral lumbar lordosis (6.9°), smaller pelvic flexion (9.2°), smaller head flexion (2.6°), and less rounded shoulder (2.4°) than the larger condition (K180°). The more neutral posture suggested by the kinematic measures confirmed significantly less muscular recruitment in the trunk extensors, except for a significant antagonistic co-contraction. **Conclusion:** The lower and upper back postures were more neutral, and back muscle recruitment was lower with a larger trunk-thigh angle and a smaller knee angle, but at the cost of antagonistic co-contraction. **Application:** The costs and benefits of each lower extremity posture can be used to design an ergonomic chair and develop an improved sitting strategy.

COGNITION

Colleen E. Patton, Christopher D. Wickens, Kayla M. Noble, Benjamin A. Clegg, C. A. P. Smith. *Rendezvous Under Temporal Uncertainty*. pp. 592–617.

Objective: Three experiments sought to understand performance limitations in controlling a ship attempting to meet another moving ship that approached from various trajectories. The influence of uncertainty, resulting from occasional unpredictable delays in one's own movement, was examined. **Background:** Cognitive elements of rendezvous have been little studied. Related work such as the planning fallacy and bias toward underestimating time-to-contact imply a tendency toward late arrival at a rendezvous. **Methods:** In a simplified simulation, participants controlled the speed and/or heading of their own ship once per scenario to try to rendezvous with another ship. Forty-five scenarios of approximately 30 s were conducted with different starting geometries and, in two of three experiments, with different frequencies and lengths of the unexpected delays. **Results:** Perfect rendezvous were hard to obtain, with a general tendency to arrive late and pass behind the target vessel, although this was dependent on the angle of approach and relative speed. When occasional delays were introduced, less frequent but longer delays disrupted performance more than shorter but more frequent delays. Where delays were possible, but no delay occurred, there was no longer evidence of a general tendency to more frequently pass behind the target ship. Additionally, people did not wait to see if the unpredictable delays would occur before executing a course of action. Different control strategies were deployed and dual axis control was preferred. **Conclusions:** The tendency to arrive late and the influence of the possibility of uncertain delays are discussed in relationship to control strategies.

COMMUNICATION

Daphne E. Whitmer, Valerie K. Sims. *Fear Language in a Warning Is Beneficial to Risk Perception in Lower-Risk Situations*. pp. 618–635.

Objective: The goal was to examine the effectiveness of fear language in the protective action recommendation of an emergency warning, which instructs people how to prepare and stay safe. **Background:** Past work is limited because it has focused on describing the severity of the weather crisis, not improving the recommendation. Likewise, other research has examined fear appeals that overemphasize death, which leads to poor risk perceptions. **Method:** In Experiment 1, the presence of fear language and second-person personal pronouns (i.e., "you") in a recommendation was manipulated. Experiment 2 examined how fear language and a hurricane changing in intensity influenced risk perceptions across three decision points. **Results:** Experiment 1 suggested that fear language was more influential than a pronoun on risk perceptions. Experiment 2 suggested that fear language in a protective action recommendation was most impactful in the case of a hurricane decreasing in intensity. **Conclusion:** Protective action recommendations with fear language influence risk perceptions and behaviors. The magnitude of this influence is dependent on how people have categorized the hurricane (i.e., low vs. high risk). **Application:** These results demonstrate that fear appeals in hurricane warnings can be useful, especially in cases when a low to medium risk event is still extremely dangerous. Likewise, these results demonstrate a need for caution, as fear appeals are not a "one size-fits-all" approach to increasing risk perceptions and should be used thoughtfully. Recommendations of when to use fear appeals in protective action recommendations are provided based on the present data.

HEALTH CARE/HEALTH SYSTEMS

Christopher J. Hansen, Michael F. Rayo, Emily S. Patterson, Todd Yamokoski, [...]. *Perceptually Discriminating the Highest Priority Alarms Reduces Response Time: A Retrospective Pre-Post Study at Four Hospitals*. pp. 636–650.

Objective: Reduce nurse response time for emergency and high-priority alarms by increasing discriminability between emergency and all other alarms and suppressing redundant and likely false high-priority alarms in a secondary alarm notification system (SANS). **Background:** Emergency alarms are the most urgent, requiring immediate action to address a dangerous situation. They are clinician-triggered and have higher positive predictive value (PPV). High-priority alarms are automatically triggered and have lower PPV. **Method:** We performed a retrospective pre-post study, analyzing data 15 months before and 25 months after a SANS redesign was implemented in four hospitals. For emergency alarms, we incorporated digitized human speech to distinguish them from automatically triggered alarms, leaving their onset and escalation pathways unchanged. For automatically triggered alarms, we suppressed some by delaying initial onset and escalation by 20 s. We used linear mixed models to assess the change in response time, Fisher's exact test for the proportion of response times longer than 120 s, and control charts for process stability. **Results:** Response time for emergency alarms decreased at all hospitals (main, from 26.91 s to 22.32 s, $p < .001$; cardiac, from 127.10 s to 52.43 s, $p < .001$; cancer, from 18.03 s to 15.39 s, $p < .001$). Improvements were sustained. Automatically triggered alarms decreased 25.0%. Response time for the three automatically triggered cardiac alarms increased at the four hospitals. **Conclusion:** Auditory sound disambiguation was associated with a sustained reduced nurse response time for emergency alarms, but suppressing some high-priority automatically triggered

alarms was not. **Application:** Distinguishing and escalating urgent, actionable alarms with higher PPV improves response time.

SIMULATION AND VIRTUAL REALITY

Christopher D. Wickens, Domenick Mifsud, Richi Rodriguez, Francisco R. Ortega. *Mitigating the Costs of Spatial Transformations With a Situation Awareness Augmented Reality Display: Assistance for the Joint Terminal Attack Controller 3-17*. pp. 651–662.

Objective: Evaluate and model the advantage of a situation awareness (SA) supported by an augmented reality (AR) display for the ground-based joint terminal attack Controller (JTAC), in judging and describing the spatial relations between objects in a hostile zone. **Background:** The accurate world-referenced description of relative locations of surface objects, when viewed from an oblique slant angle (aircraft, observation post) is hindered by (1) the compression of the visual scene, amplified at a lower slang angle, (2) the need for mental rotation, when viewed from a non-northerly orientation. **Approach:** Participants viewed a virtual reality (VR)-simulated four-object scene from either of two slant angles, at each of four compass orientations, either unaided, or aided by an AR head-mounted display (AR-HMD), depicting the scene from a top-down (avoiding compression) and north-up (avoiding mental rotation) perspective. They described the geographical layout of four objects within the display. **Results:** Compared with the control condition, that condition supported by the north-up SA display shortened the description time, particularly on non-northerly orientations (9 s, 30% benefit), and improved the accuracy of description, particularly for the more compressed scene (lower slant angle), as fit by a simple computational model. **Conclusion:** The SA display provides large, significant benefits to this critical phase of ground-air communications in managing an attack—as predicted by the task analysis of the JTAC. **Application:** Results impact the design of the AR-HMD to support combat ground-air communications and illustrate the magnitude by which basic cognitive principles "scale up" to realistically simulated real-world tasks such as search and rescue.

SURFACE TRANSPORTATION

Dengbo He, Chelsea A. DeGuzman, Birsen Donmez. *Anticipatory Driving in Automated Vehicles: The Effects of Driving Experience and Distraction*. pp. 663.

Objective: To understand the influence of driving experience and distraction on drivers' anticipation of upcoming traffic events in automated vehicles. **Background:** In nonautomated vehicles, experienced drivers spend more time looking at cues that indicate upcoming traffic events compared with novices, and distracted drivers spend less time looking at these cues compared with nondistracted drivers. Further, pre-event actions (i.e., proactive control actions prior to traffic events) are more prevalent among experienced drivers and nondistracted drivers. However, there is a research gap on the combined effects of experience and distraction on driver anticipation in automated vehicles. **Methods:** A simulator experiment was conducted with 16 experienced and 16 novice drivers in a vehicle equipped with adaptive cruise control and lane-keeping assist systems (resulting in SAE Level 2 driving automation). Half of the participants in each experience group were provided with a self-paced primarily visual-manual secondary task.

Results: Drivers with the task spent less time looking at cues and were less likely to perform anticipatory driving behaviors (i.e., pre-event actions or preparation for pre-event actions such as hovering fingers over the automation disengage button). Experienced drivers exhibited more anticipatory driving behaviors, but their attention toward the cues was similar to novices for both task conditions. **Conclusion:** In line with nonautomated vehicle research, in automated vehicles, secondary task engagement impedes anticipation while driving experience facilitates anticipation. **Application:** Though Level 2 automation can relieve drivers of manually controlling the vehicle and allow engagement in distractions, visual-manual distraction engagement can impede anticipatory driving and should be restricted.

TEAMS AND GROUPS

Adam F. Werner, Jamie C. Gorman. *The Role of Visual and Auditory Communication in the Performance of a Joint Team Task*. pp. 663–694.

Objective: This study examines visual, auditory, and the combination of both (bimodal) coupling modes in the performance of a two-person perceptual-motor task, in which one person provides the perceptual inputs and the other the motor inputs. **Background:** Parking a plane or landing a helicopter on a mountain top requires one person to provide motor inputs while another person provides perceptual inputs. Perceptual inputs are communicated either visually, auditorily, or through both cues. **Methods:** One participant drove a remote-controlled car around an obstacle and through a target, while another participant provided auditory, visual, or bimodal cues for steering and acceleration. Difficulty was manipulated using target size. Performance (trial time, path variability), cue rate, and spatial ability were measured. **Results:** Visual coupling outperformed auditory coupling. Bimodal performance was best in the most difficult task condition but also high in the easiest condition. Cue rate predicted performance in all coupling modes. Drivers with lower spatial ability required a faster auditory cue rate, whereas drivers with higher ability performed best with a lower rate. **Conclusion:** Visual cues result in better performance when only one coupling mode is available. As predicted by multiple resource theory, when both cues are available, performance depends more on auditory cueing. In particular, drivers must be able to transform auditory cues into spatial actions. **Application:** Spotters should be trained to provide an appropriate cue rate to match the spatial ability of the driver or pilot. Auditory cues can enhance visual communication when the interpersonal task is visual with spatial outputs.