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AT THE FOREFRONT OF HF/E

Christopher D. Wickens. *Effort in Human Factors Performance and Decision Making.* S. 1329-1336.

Objective: The aim of this study was to demonstrate the importance of effort in human factors. **Background:** Effort has made its appearance in several diverse formats and applications. Eight of these are integrated in the current writing related to learning, looking, task switching, visual search termination, information access, choosing decision strategies, and behaving safely. **Method:** This is based upon a literature review. **Results:** The common elements of these different effort applications are highlighted, particularly, their manifestations in either implicit or explicit expected value decisions. **Conclusions:** There is a need to show how the metrics of effort and workload assessment influence decisions in human factors, particularly, those related to safety.

- **Keywords:** decision making, effort, mental workload, multitasking, safety

AVIATION AND AEROSPACE

Joan Cahill, Nick McDonald, and Captain Gabriel Losa. *A Sociotechnical Model of the Flight Crew Task.* S. 1337-1363.

Objective: The objective of this research was to advance an improved model of Flight Crew task performance. **Background:** Existing task models present a “local” description of Flight Crew task performance. **Method:** Process mapping workshops, interviews, and observations were conducted with both pilots and flight operations personnel from five airlines, as part of the Human Integration into the Lifecycle of Aviation Systems (HILAS) project. **Results:** The functional logic of the process dictates Flight Crew task requirements and specific task workflows. The Flight Crew task involves managing different levels of operational and environmental complexity, associated with the particular flight context. In so doing, the Flight Crew act as a coordinating interface between different human agents involved in the Active Flight Operations process and other processes that interace with this process. **Conclusion:** This article presents a new sociotechnical model of the Flight Crew task. The proposed model reflects a shift from a local explanation of Flight Crew task activity to a broader process-centric explanation. In so doing, it illuminates the complex role of procedures in commercial operations. **Application:** The task model suggests specific requirements for pilot task support tools, procedures design, performance evaluation and crew resource management (CRM) training. Also, this model might be used to assess future operational concepts and

associated technology requirements. Lastly, this model provides the basis for the operational validation of both existing and future cockpit technologies.

- **Keywords:** Flight Crew, task, process, fight operations, procedures, workflow, Crew Resource Management (CRM), Threat and Error Management (TEM), information flow, reporting, safety management

COGNITION

Michael B. Dillard, Joel S. Warm, Gregory J. Funke, Matthew E. Funke, Victor S. Finomore, Jr., Gerald Matthews, Tyler H. Shaw, and Raja Parasuraman. *The Sustained Attention to Response Task (SART) Does Not Promote Mindlessness During Vigilance Performance.* S. 1364-1379.

Objective In this study, we evaluated the validity of the Sustained Attention to Response Task (SART) as a means for promoting mindlessness in vigilance performance. **Background** Vigilance tasks typically require observers to respond to critical signals and to withhold responding to neutral events. The SART features the opposite response requirements, which supposedly leads it to promote a mindless, nonthoughtful approach to the vigilance task. To test that notion, we compared the SART to the traditional vigilance format (TVF) in terms of diagnostic accuracy assessed through decision theory measures of positive and negative predictive power (PPP and NPP), perceived mental workload indexed by the Multiple Resource Questionnaire, and oculomotor activity reflected in the Nearest Neighbor Index and fixation dwell times. **Method** Observers in TVF and SART conditions monitored a video display for collision flight paths in a simulated air traffic control task. **Results** Diagnostic accuracy in terms of NPP was high in both format conditions. While PPP was poorer in the SART than in the TVF, that result could be accounted for by a loss of motor control rather than a lack of mindfulness. Identical high levels of workload were generated by the TVF and SART tasks, and observers in both conditions showed similar dynamic scanning of the visual scene. **Conclusion** The data indicate that the SART is not an engine of mindlessness. **Application** The results challenge the widespread use of the SART to support a model in which mindlessness is considered to be the principal root of detection failures in vigilance.

- **Keywords:** vigilance, SART, mental workload, mindlessness model, resource model, MRQ, oculometrics, gaze control, positive predictive power, negative predictive power

Select this article Gary Klein, Louise Rasmussen, Mei-Hua Lin, Robert R. Hoffman, and Jason Case. *Influencing Preferences for Different Types of Causal Explanation of Complex Events.* S. 1380-1400.

Objective: We examined preferences for different forms of causal explanations for indeterminate situations. **Background:** Klein and Hoffman distinguished several forms of causal explanations for indeterminate, complex situations: single-cause explanations, lists of causes, and explanations that interrelate several causes. What governs our preferences for single-cause (simple) versus multiple-cause (complex) explanations? **Method:** In three experiments, we examined the effect of target audience, explanatory context, participant nationality, and explanation type. All participants were college students. Participants were given two scenarios, one regarding the U.S. economic collapse in 2007 to 2008 and the other about the sudden success of the U.S. military in Iraq in 2007. The participants were asked to assess various types of causal explanations for each of the scenarios, with reference to one or more purposes or audience for the explanations. **Results:** Participants preferred simple explanations for presentation to less sophisticated audiences. Malaysian students of Chinese ethnicity preferred complex

explanations more than did American students. The form of presentation made a difference: Participants preferred complex to simple explanations when given a chance to compare the two, but the preference for simple explanations increased when there was no chance for comparison, and the difference between Americans and Malaysians disappeared. **Conclusions:** Preferences for explanation forms can vary with the context and with the audience, and they depend on the nature of the alternatives that are provided. **Application:** Guidance for decision-aiding technology and training systems that provide explanations need to involve consideration of the form and depth of the accounts provided as well as the intended audience.

- **Keywords:** causality, causal reasoning, culture, explanations, complexity

Derek L. Mracek, Matthew L. Arsenault, Eric Anthony Day, Jay H. Hardy III, and Robert A. Terry. *A Multilevel Approach to Relating Subjective Workload to Performance After Shifts in Task Demand.* S. 1401-1413.

Objective: The aim of this laboratory experiment was to demonstrate how taking a longitudinal, multilevel approach can be used to examine the dynamic relationship between subjective workload and performance over a given period of activity involving shifts in task demand. **Background:** Subjective workload and conditions of the performance environment are oftentimes examined via cross-sectional designs without distinguishing within- from between-person effects. Given the dynamic nature of performance phenomena, multilevel designs coupled with manipulations of task demand shifts are needed to better model the dynamic relationships between state and trait components of subjective workload and performance. **Method:** With a sample of 75 college students and a computer game representing a complex decision-making environment, increases and decreases in task demand were counterbalanced and subjective workload and performance were measured concurrently in regular intervals within performance episodes. Data were analyzed using hierarchical linear modeling. **Results:** Both between- and especially within-person effects were dynamic. Nevertheless, at both levels of analysis, higher subjective workload reflected performance problems, especially more downstream from increases in task demand. **Conclusion:** As a function of cognitive-energetic processes, shifts in task demand are associated with changes in how subjective workload is related to performance over a given period of activity. Multilevel, longitudinal approaches are useful for distinguishing and examining the dynamic relationships between state and trait components of subjective workload and performance. **Application:** The findings of this research help to improve the understanding of how a sequence of demands can exceed a performer's capability to respond to further demands.

- **Keywords:** workload, workload history, overload, human performance modeling, shifts in task demand, multilevel analyses, dynamic relationships

DISPLAYS AND CONTROLS

John Towers, Robin Burgess-Limerick, and Stephan Riek. *Concurrent 3-D Sonifications Enable the Head-Up Monitoring of Two Interrelated Aircraft Navigation Instruments.* S. 1414-1427.

Objective: The aim of this study was to enable the head-up monitoring of two interrelated aircraft navigation instruments by developing a 3-D auditory display that encodes this navigation information within two spatially discrete sonifications. **Background:** Head-up monitoring of aircraft navigation information utilizing 3-D audio displays, particularly involving concurrently presented sonifications, requires additional research. **Method:** A flight simulator's head-down waypoint bearing and course deviation instrument readouts were conveyed to participants via a 3-D auditory display. Both readouts were separately represented by a colocated pair of continuous sounds, one

fixed and the other varying in pitch, which together encoded the instrument value's deviation from the norm. Each sound pair's position in the listening space indicated the left/right parameter of its instrument's readout. Participants' accuracy in navigating a predetermined flight plan was evaluated while performing a head-up task involving the detection of visual flares in the out-of-cockpit scene. **Results:** The auditory display significantly improved aircraft heading and course deviation accuracy, head-up time, and flare detections. Head tracking did not improve performance by providing participants with the ability to orient potentially conflicting sounds, suggesting that the use of integrated localizing cues was successful. **Conclusion:** A supplementary 3-D auditory display enabled effective head-up monitoring of interrelated navigation information normally attended to through a head-down display. **Application:** Pilots operating aircraft, such as helicopters and unmanned aerial vehicles, may benefit from a supplementary auditory display because they navigate in two dimensions while performing head-up, out-of-aircraft, visual tasks.

- **Keywords:** auditory displays, multimodality displays, flight displays, audition, situation awareness

NEUROERGONOMICS

Di Catherwood, Graham K. Edgar, Dritan Nikolla, Chris Alford, David Brookes, Steven Baker, and Sarah White. *Mapping Brain Activity During Loss of Situation Awareness: An EEG Investigation of a Basis for Top-Down Influence on Perception.* S. 1428-1452.

Objective: The objective was to map brain activity during early intervals in loss of situation awareness (SA) to examine any co-activity in visual and high-order regions, reflecting grounds for top-down influences on Level 1 SA. **Background:** Behavioral and neuroscience evidence indicates that high-order brain areas can engage before perception is complete. Inappropriate top-down messages may distort perception during loss of SA. Evidence of co-activity of perceptual and high-order regions would not confirm such influence but may reflect a basis for it. **Method:** SA and bias were measured using Quantitative Analysis of Situation Awareness and brain activity recorded with 128-channel EEG (electroencephalography) during loss of SA. One task (15 participants) required identification of a target pattern, and another task (10 participants) identification of "threat" in urban scenes. In both, the target was changed without warning, enforcing loss of SA. Key regions of brain activity were identified using source localization with standardized low-resolution electrical tomography (sLORETA) 150 to 160 ms post-stimulus onset in both tasks and also 100 to 110 ms in the second task. **Results:** In both tasks, there was significant loss of SA and bias shift ($p \leq .02$), associated at both 150- and 100-ms intervals with co-activity of visual regions and prefrontal, anterior cingulate and parietal regions linked to cognition under uncertainty. **Conclusion:** There was early co-activity in high-order and visual perception regions that may provide a basis for top-down influence on perception. **Application:** Co-activity in high- and low-order brain regions may explain either beneficial or disruptive top-down influence on perception affecting Level 1 SA in real-world operations.

- **Keywords:** QASA, electroencephalography, sLORETA, SA, source localization, top-downbias

PHYSIOLOGICAL AND PSYCHOLOGICAL CONDITIONS (INTERNAL ENVIRONMENT)

James L. Szalma. *On the Application of Motivation Theory to Human Factors/Ergonomics : Motivational Design Principles for Human–Technology Interaction.* S. 1453-1471.

Objective: Motivation is a driving force in human–technology interaction. This paper represents an effort to (a) describe a theoretical model of motivation in human technology interaction, (b) provide design principles and guidelines based on this theory, and (c) describe a sequence of steps for the evaluation of motivational factors in human–technology interaction. **Background:** Motivation theory has been relatively neglected in human factors/ergonomics (HF/E). In both research and practice, the (implicit) assumption has been that the operator is already motivated or that motivation is an organizational concern and beyond the purview of HF/E. However, technology can induce task-related boredom (e.g., automation) that can be stressful and also increase system vulnerability to performance failures. **Method:** A theoretical model of motivation in human–technology interaction is proposed, based on extension of the self-determination theory of motivation to HF/E. This model provides the basis for both future research and for development of practical recommendations for design. **Results:** General principles and guidelines for motivational design are described as well as a sequence of steps for the design process. **Conclusion:** Human motivation is an important concern for HF/E research and practice. Procedures in the design of both simple and complex technologies can, and should, include the evaluation of motivational characteristics of the task, interface, or system. In addition, researchers should investigate these factors in specific human–technology domains. **Application:** The theory, principles, and guidelines described here can be incorporated into existing techniques for task analysis and for interface and system design.

- **Keywords:** motivation and technology, motivation and human factors/ergonomics, hedonomics, eudaimonic design, self-determination theory, work motivation

SIMULATION AND VIRTUAL REALITY

Bruce Bridgeman, Sabine Blaesi, and Richard Campusano. *Optical Correction Reduces Simulator Sickness in a Driving Environment. S. 1472-1481.*

Objective: We propose and test a method to reduce simulator sickness. **Background:** Prolonged work in driving simulators often leads to nausea and other symptoms summarized as simulator sickness. Visual/vestibular mismatches are a frequently addressed cause; we investigate another possibility, mismatch between actual distance to a screen and depicted distances in the simulator's graphics. **Method:** Drivers negotiated a figure-8 course in a photorealistic simulator. They reported discomfort and vection every 10 minutes up to 40 min. A correction group wore optometric test frames with +1.75 diopter lenses and prisms to converge parallel lines of sight on a screen 56 cm from the driver's eyes, preserving the normal accommodative convergence-to-accommodation (AC/A) ratio. A control group wore neutral lenses in the same test frames. In other experiments head tilt simulated vestibular experience on curves. **Results:** The optical correction significantly reduced simulator sickness measured on a 10-point discomfort scale, where 1 is no problem and 10 is about to vomit. Vection ratings were similar for correction and control groups. Some drivers failed to complete the course because of high discomfort ratings, crashes, or other causes. Head tilt in the direction opposite each curve while wearing the correction did not affect discomfort, while tilt in the same direction as each curve made simulator sickness worse. **Conclusion:** Optical corrections can significantly reduce simulator sickness, though they do not eliminate it. Head tilt while driving is not recommended. **Application:** Simple optical corrections in spectacle frames, easily purchased at any optical facility, should be used in screen-based driving simulators. Strength of the correction depends on distance from the driver to the screen.

- **Keywords:** simulator sickness, simulation and virtual reality, driver behavior, surface transportation, visionsensory and perceptual processes, forces and

moments, biomechanics, anthropometry, work physiology, interface evaluation, human-computer interaction, computer systems, simulation, methods and skills

Joseph R. Keebler, Florian Jentsch, and David Schuster. *The Effects of Video Game Experience and Active Stereoscopy on Performance in Combat Identification Tasks*. S. 1482-1496.

Objective We investigated the effects of active stereoscopic simulation-based training and individual differences in video game experience on multiple indices of combat identification (CID) performance. **Background** Fratricide is a major problem in combat operations involving military vehicles. In this research, we aimed to evaluate the effects of training on CID performance in order to reduce fratricide errors. **Method** Individuals were trained on 12 combat vehicles in a simulation, which were presented via either a non-stereoscopic or active stereoscopic display using NVIDIA's GeForce shutter glass technology. Self-report was used to assess video game experience, leading to four between-subjects groups: high video game experience with stereoscopy, low video game experience with stereoscopy, high video game experience without stereoscopy, and low video game experience without stereoscopy. We then tested participants on their memory of each vehicle's alliance and name across multiple measures, including photographs and videos. **Results** There was a main effect for both video game experience and stereoscopy across many of the dependent measures. Further, we found interactions between video game experience and stereoscopic training, such that those individuals with high video game experience in the non-stereoscopic group had the highest performance outcomes in the sample on multiple dependent measures. **Conclusion** This study suggests that individual differences in video game experience may be predictive of enhanced performance in CID tasks. **Application** Selection based on video game experience in CID tasks may be a useful strategy for future military training. Future research should investigate the generalizability of these effects, such as identification through unmanned vehicle sensors.

- **Keywords:** combat identification decision making active stereoscopic displays video game experience learning and memory training technologies

SURFACE TRANSPORTATION

Gregory M. Fitch, Darrell S. Bowman, and Robert E. Llaneras. *Distracted Driver Performance to Multiple Alerts in a Multiple-Conflict Scenario*. S. 1497-1505.

Objective: We investigated whether collision avoidance systems (CASs) should present individual crash alerts in a multiple-conflict scenario or present only one alert in response to the first conflict. **Background:** Secondary alerts may startle, confuse, or interfere with drivers' execution of an emergency maneuver. **Method:** Fifty-one participants followed a pickup truck around a test track. Once the participant was visually distracted, a trailing sedan repositioned itself into the participant's blind spot while a box was dropped from the truck. Participants received a forward collision warning (FCW) alert as the box landed. Twenty-six drivers swerved left in response to the box, encountering a lateral conflict with the adjacent sedan. Half of these 26 drivers received a lane-change merge (LCM) alert. **Results:** Drivers who received both the FCW and LCM alerts were significantly faster at steering away from the lateral crash threat than the drivers who received only the FCW alert (1.70 s vs. 2.76 s, respectively). Drivers liked receiving the LCM alert, rated it to be useful, found it easy to understand (despite being presented after the FCW alert), and did not find it to be startling. **Conclusion:** Drivers who are familiar with CASs benefit from, and feel it is appropriate to generate, multiple alerts in a multiple-conflict scenario. **Application:** The results may inform the design of CASs for connected and automated vehicles.

- **Keywords:** advanced driver assistance system, alert, collision avoidance system, connected vehicle, driver distraction

TRAINING, EDUCATION, INSTRUCTIONAL SYSTEMS

Stephen M. Casner, Richard W. Geven, Matthias P. Recker, and Jonathan W. Schooler. *The Retention of Manual Flying Skills in the Automated Cockpit.* S. 1506-1516.

Objective: The aim of this study was to understand how the prolonged use of cockpit automation is affecting pilots' manual flying skills. **Background:** There is an ongoing concern about a potential deterioration of manual flying skills among pilots who assume a supervisory role while cockpit automation systems carry out tasks that were once performed by human pilots. **Method:** We asked 16 airline pilots to fly routine and nonroutine flight scenarios in a Boeing 747-400 simulator while we systematically varied the level of automation that they used, graded their performance, and probed them about what they were thinking about as they flew. **Results:** We found pilots' instrument scanning and manual control skills to be mostly intact, even when pilots reported that they were infrequently practiced. However, when pilots were asked to manually perform the cognitive tasks needed for manual flight (e.g., tracking the aircraft's position without the use of a map display, deciding which navigational steps come next, recognizing instrument system failures), we observed more frequent and significant problems. Furthermore, performance on these cognitive tasks was associated with measures of how often pilots engaged in task-unrelated thought when cockpit automation was used. **Conclusion:** We found that while pilots' instrument scanning and aircraft control skills are reasonably well retained when automation is used, the retention of cognitive skills needed for manual flying may depend on the degree to which pilots remain actively engaged in supervising the automation.

- **Keywords:** manual flying skills, atrophy, retention, procedural, mind wandering