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AT THE FOREFRONT OF HF/E

Anne Collins McLaughlin, Vicky E. Byrne. *A Fundamental Cognitive Taxonomy for Cognition Aids*. pp. 865–873.

Objective: This study aimed to organize the literature on cognitive aids to allow comparison of findings across studies and link the applied work of aid development to psychological constructs and theories of cognition. **Background:** Numerous taxonomies have been developed, all of which label cognitive aids via their surface characteristics. This complicates integration of the literature, as a type of aid, such as a checklist, can provide many different forms of support (cf. prospective memory for steps and decision support for alternative diagnoses). **Method:** In this synthesis of the literature, we address the disparate findings and organize them at their most basic level: Which cognitive processes does the aid *need* to support? Which processes *do* they support? Such processes include attention, perception, decision making, memory, and declarative knowledge. **Results:** Cognitive aids can be classified into the processes they support. Some studies focused on how an aid supports the cognitive processes demanded by the task (aid function). Other studies focused on supporting the processes needed to utilize the aid (aid usability). **Conclusion:** Classifying cognitive aids according to the processes they support allows comparison across studies in the literature and a formalized way of planning the design of new cognitive aids. Once the literature is organized, theory-based guidelines and applied examples can be used by cognitive aid researchers and designers. **Application:** Aids can be designed according to the cognitive processes they need to support. Designers can be clear about their focus, either examining how to support specific cognitive processes or improving the usability of the aid.

- **Keywords:** cognitive aids, cognitive psychology, attention, memory, checklists, crisis checklists

AUTOMATION, EXPERT SYSTEMS

Monica Tatasciore, Vanessa K. Bowden, Troy A. W. Visser, Steph I. C. Michailovs, Shayne Loft. *The Benefits and Costs of Low and High Degree of Automation*. pp. 874–896.

Objective: The objective of this study is to examine the effects of low and high degree of automation (DOA) on performance, subjective workload, situation awareness (SA), and return-to-manual control in simulated submarine track management. **Background:** Theory and meta-analytic evidence suggest that as DOA increases, operator performance improves and workload decreases, but SA and return-to-manual control declines. Research also suggests that operators have particular difficulty regaining manual control if automation provides incorrect advice. **Method:** Undergraduate student participants completed a submarine track management task that required them to track the position and behavior of contacts. Low DOA supported information acquisition and analysis, whereas high DOA recommended decisions. At a late stage in the task, automation was either unexpectedly removed or provided incorrect advice. **Results:** Relative to no automation, low DOA moderately benefited performance but impaired SA and non-automated task performance. Relative to no automation and low DOA, high DOA benefited performance and lowered workload. High DOA did impair non-automated task performance compared with no automation, but this was equivalent to low DOA. Participants were able to return-to-manual control when they knew low or high DOA was disengaged, or when high DOA provided incorrect advice. **Conclusion:** High DOA improved performance and lowered workload, at no additional cost to SA or return-to-manual performance when compared with low DOA. **Application:** Designers should consider the likely level of uncertainty in the environment and the consequences of return-to-manual deficits before implementing low or high DOA.

- **Keywords:** automation, submarine track management, situation awareness, workload, complacency

AVIATION AND AEROSPACE

Nout C. M. van Zon, Clark Borst, Daan M. Pool, Marinus M. van Paassen. [*Touchscreens for Aircraft Navigation Tasks: Comparing Accuracy and Throughput of Three Flight Deck Interfaces Using Fitts' Law*](#). pp. 897–908.

Objective: Use Fitts' law to compare accuracy and throughput of three flight deck interfaces for navigation. **Background:** Industry is proposing touch-based solutions to modernize the flight management system. However, research evaluating touchscreen effectiveness for navigation tasks in terms of accuracy and throughput on the flight deck is lacking. **Method:** An experiment was conducted with 14 participants in a flight simulator, aimed at creating Fitts' law accuracy and throughput models of three different flight deck interfaces used for navigation: the mode control panel, control display unit, and a touch-based navigation display. The former two constitute the conventional interface between the pilot and the flight management system, and the latter represents the industry-proposed solution for the future. **Results:** Results indicate less accurate performance with the touchscreen navigation display compared to the other two interfaces and the throughput was lowest with the mode control panel. The control display unit was better in both accuracy and throughput, which is found to be largely attributed to the tactile and physical nature of the interface. **Conclusion:** Although performance in terms of accuracy and throughput was better with the control display unit, a question remains whether, when used during a more realistic navigation task, performance is still better compared to a touch-based interface. **Application:** This paper complements previous studies in the usage of aircraft touchscreens with new empirical

insights into their accuracy and throughput, compared to conventional flight deck interfaces, using Fitts' law.

- **Keywords:** touchscreens, interface evaluation, human performance modeling, coordinated action, flight displays, Fitts' law

BIOMECHANICS, ANTHROPOMETRY, WORK PHYSIOLOGY

Cazmon Suri, Iman Shojaei, Babak Bazrgari. *Effects of School Backpacks on Spine Biomechanics During Daily Activities: A Narrative Review of Literature.* pp. 909–918.

Objective: The purpose of this narrative review is to summarize the effects of carrying school backpacks on spine and low-back biomechanics as a risk factor for low back pain in young individuals. **Background:** Backpacks constitute a considerable daily load for schoolchildren. Consistently, a large number of children attribute their low back pain experience to backpack use. **Method:** A literature search was conducted using a combination of keywords related to the impact of carrying backpacks on lower back biomechanics. The references of each identified study were further investigated to identify additional studies. **Results:** Twenty-two studies met inclusion criteria. A total of 1,159 people aged 7 to 27 years were included in the studies. The added load of a backpack and the changes in spinal posture when carrying a backpack impose considerable demand on internal tissues and likely result in considerable spinal loads. The findings included results related to the effects of backpack weight and position on trunk kinematics and spine posture as well as trunk muscle activity during upright standing, walking, and ascending and descending stairs. **Conclusion:** Backpack-induced changes in trunk kinematics for a given activity reflect alterations in mechanical demand of the activity on the lower back that should be balanced internally by the active and passive responses of lower back tissues. Although the reported alterations in trunk muscle activities and lumbar posture are indications of changes in the active and passive response of the lower back tissues, the resultant effects on spinal load, that is, an important causal factor for low back pain, remains to be investigated in the future. A knowledge of backpack-induced changes in spinal loads can inform design of interventions aimed at reduction of spinal load via improved backpack design or limitation on carrying duration. **Application:** This narrative review is intended to serve as an educational article for students and trainees in ergonomics and occupational biomechanics.

- **Keywords:** narrative review, kinematics, children, low back pain, posture, backpack

Xingda Qu, Yongxun Xie, Xinyao Hu, Hongbo Zhang. *Effects of Fatigue on Balance Recovery From Unexpected Trips.* pp. 919–927.

Objective: The objective was to examine how physical fatigue and mental fatigue affected balance recovery from unexpected trips. **Background:** Trips are the leading cause for occupational falls that are a multifactorial problem. Recognizing risk factors is the first step in accident control. Fatigue is one of the most common task-related risk factors for occupational falls. Fatigue typically can be divided into physical fatigue and mental fatigue, both of which are common in occupational settings. **Method:** One hundred eight young volunteers participated in the experiment. They were evenly divided into three groups: no fatigue group, physical fatigue group, and mental fatigue group. Each participant performed four walking trials on a linear walkway at their self-selected normal speed. The first three trials were normal walking trials. A trip was induced to participants in the fourth walking trial using a metal pole. Balance recovery from

unexpected trips was characterized by trunk flexion and first recovery step measures. **Results:** Recovery step length was smaller and maximum trunk flexion became larger in the mental fatigue group compared with those in the no fatigue group. Physical fatigue did not significantly affect trunk flexion and first recovery step measures. **Conclusion:** Mental fatigue increased the likelihood of loss of balance. Thus, mental fatigue could be a risk factor for trips and falls. To prevent trip-related falls, interventions should be adopted to prevent prolonged exposures to cognitively demanding activities in occupational settings.

- **Keywords:** falls, trips, physical fatigue, mental fatigue, balance recovery

COGNITION

Charlotte Mallat, Julien Cegarra, Christophe Calmettes, Rémi L. Capa. *A Curvilinear Effect of Mental Workload on Mental Effort and Behavioral Adaptability: An Approach With the Pre-Ejection Period.* pp. 928–939.

Objective: We tested Hancock and Szalma’s mental workload model, which has never been experimentally validated at a global level with the measure of the pre-ejection period (PEP), an index of beta-adrenergic sympathetic impact. **Background:** Operators adapt to mental workload. When mental workload level increases, behavioral and physiological adaptability intensifies to reduce the decline in performance. However, if the mental workload exceeds an intermediate level, behavioral and physiological adaptability will decrease to protect individuals from excessive perturbations. This decrease is associated with a change in behavioral strategies and disengagement. **Method:** The experimental task was a modified Fitts’ task used in Hancock and Caird. Five levels of task difficulty were computed. Behavioral and physiological adaptability was indexed by the performance with speed–accuracy trade-off and PEP reactivity. **Results:** A curvilinear effect of task difficulty on PEP reactivity was significant, with high reactivity at the intermediate level but low reactivity at other levels. We observed a linear effect of task difficulty on error rate and a curvilinear effect on movement time. A decline in performance was noted up to the intermediate level, with a speed–accuracy trade-off above this level showing a faster movement time. **Conclusion:** We observed for the first time behavioral and physiological adaptability as a function of mental workload. **Application:** The results have important implications for the modeling of mental workload, particularly in the context of the performance-sensitive domain (car driving and air traffic control). They can help guide the design of human–computer interaction to maximize adaptive behavior, that is, the “comfort zone.”

- **Keywords:** workload, effort, performance, cardiovascular reactivity

COMMUNICATION

Ehsan Garosi, Reza Kalantari, Ahmad Zanjirani Farahani, Mojgan Zuaktafi, Esmaeil Hosseinzadeh Roknabadi, Ehsan Bakhshi. *Concerns About Verbal Communication in the Operating Room: A Field Study.* pp. 940–953.

Objective: To assess verbal communication patterns which could contribute to poor performance among surgical team members in an operating room. **Background:** There exist certain challenges in communication in health care settings. Poor communication can have negative effects on the performance of a surgical team and patient safety. A

communication pattern may be associated with poor performance when the process of sending and receiving information is interrupted or the content of conversation is not useful. **Method:** This cross-sectional field study was conducted with 54 surgical teams working in two Iranian hospitals during 2015. Two observers recorded all verbal communications in an operating room. An in-depth assessment of various annotated transcripts by an expert panel was used to assess verbal communication patterns in the operating room. **Results:** Verbal communication patterns which could contribute to poor performance were observed in 63% of the surgeries, categorized as communication failures (17 events), protests (23 events), and irrelevant conversations (164 events). The anesthesiologists and the circulating nurses had the most concerning communication patterns. The failure of devices and poor planning were important factors that contributed to concerning patterns. **Conclusion:** Concerning patterns of verbal communication are not rare in operating rooms. Analyzing the annotated transcripts of surgeries can conduce to identifying all these patterns, and their causes. Concerning communication patterns can be reduced in the operating room by providing interventions, properly planning for surgeries, and fixing defective devices. **Application:** The method used in this study can be followed to assess communication problems in operating rooms and to find solutions.

- **Keywords:** communication analysis, team communication, patient safety, surgical care

HEALTH CARE/HEALTH SYSTEMS

Matthew L. Bolton, Xi Zheng, Meng Li, Judy Reed Edworthy, Andrew D. Boyd. *An Experimental Validation of Masking in IEC 60601-1-8:2006-Compliant Alarm Sounds.* pp. 954–972

Objective: This research investigated whether the psychoacoustics of simultaneous masking, which are integral to a model-checking-based method, previously developed for detecting perceivability problems in alarm configurations, could predict when IEC 60601-1-8-compliant medical alarm sounds are audible. **Background:** The tonal nature of sounds prescribed by IEC 60601-1-8 makes them potentially susceptible to simultaneous masking: where concurrent sounds render one or more inaudible due to human sensory limitations. No work has experimentally assessed whether the psychoacoustics of simultaneous masking accurately predict IEC 60601-1-8 alarm perceivability. **Method:** In two signal detection experiments, 28 nursing students judged whether alarm sounds were present in collections of concurrently sounding standard-compliant tones. The first experiment used alarm sounds with single-frequency (primary harmonic) tones. The second experiment's sounds included the additional, standard-required frequencies (often called subharmonics). T tests compared miss, false alarm, sensitivity, and bias measures between masking and nonmasking conditions and between the two experiments. **Results:** Miss rates were significantly higher and sensitivity was significantly lower for the masking condition than for the nonmasking one. There were no significant differences between the measures of the two experiments. **Conclusion:** These results validate the predictions of the psychoacoustics of simultaneous masking for medical alarms and the masking detection capabilities of our method that relies on them. The results also show that masking of an alarm's primary harmonic is sufficient to make an alarm sound indistinguishable. **Application:** Findings have profound implications for medical alarm design, the international standard, and masking detection methods.

- **Keywords:** medical devices and technologies, audition, patient safety, psychophysical methods, signal detection theory

HUMAN-COMPUTER INTERACTION, COMPUTER SYSTEMS

Sean W. Kortschot, Greg A. Jamieson. *Classification of Attentional Tunneling Through Behavioral Indices*. pp. 973–986.

Objective: The objective of this study was to develop a machine learning classifier to infer attentional tunneling through behavioral indices. This research serves as a proof of concept for a method for inferring operator state to trigger adaptations to user interfaces. **Background:** Adaptive user interfaces adapt their information content or configuration to changes in operating context. Operator attentional states represent a promising class of triggers for these adaptations. Behavioral indices may be a viable alternative to physiological correlates for triggering interface adaptations based on attentional state. **Method:** A visual search task sought to induce attentional tunneling in participants. We analyzed user interaction under tunnel and non-tunnel conditions to determine whether the paradigm was successful. We then examined the performance trade-offs stemming from attentional tunnels. Finally, we developed a machine learning classifier to identify patterns of interaction characteristics associated with attentional tunnels. **Results:** The experimental paradigm successfully induced attentional tunnels. Attentional tunnels were shown to improve performance when information appeared within them, but to hinder performance when it appeared outside. Participants were found to be more tunneled in their second tunnel trial relative to their first. Our classifier achieved a classification accuracy similar to comparable studies (area under curve = 0.74). **Conclusion:** Behavioral indices can be used to infer attentional tunneling. There is a performance trade-off from attentional tunneling, suggesting the opportunity for adaptive systems. **Application:** This research applies to adaptive automation aimed at managing operator attention in information-dense work domains.

- **Keywords:** attentional processes, adaptive automation, attentional tunneling, passive data monitoring, machine learning

Na Du, Kevin Y. Huang, X. Jessie Yang. *Not All Information Is Equal: Effects of Disclosing Different Types of Likelihood Information on Trust, Compliance and Reliance, and Task Performance in Human-Automation Teaming*. pp. 987–1001.

Objective: The study examines the effects of disclosing different types of likelihood information on human operators' trust in automation, their compliance and reliance behaviors, and the human-automation team performance. **Background:** To facilitate appropriate trust in and dependence on automation, explicitly conveying the likelihood of automation success has been proposed as one solution. Empirical studies have been conducted to investigate the potential benefits of disclosing likelihood information in the form of automation reliability, (un)certainly, and confidence. Yet, results from these studies are rather mixed. **Method:** We conducted a human-in-the-loop experiment with 60 participants using a simulated surveillance task. Each participant performed a compensatory tracking task and a threat detection task with the help of an imperfect automated threat detector. Three types of likelihood information were presented: overall likelihood information, predictive values, and hit and correct rejection rates. Participants' trust in automation, compliance and reliance behaviors, and task performance were measured. **Results:** Human operators informed of the predictive values or the overall likelihood value, rather than the hit and correct rejection rates, relied on the decision aid more appropriately and obtained higher task scores. **Conclusion:** Not all likelihood information is equal in aiding human-automation team performance. Directly presenting the hit and correct rejection rates of an automated decision aid should be avoided. **Application:** The findings can be applied to the design of automated decision aids.

- **Keywords:** human–robot interaction, trust in automation, likelihood alerts, Bayesian inference, base rate fallacy

MOTOR BEHAVIOR

Hyun Chae Chung, Gyoojae Choi, Muhammad Azam. [*Effects of Initial Starting Distance and Gap Characteristics on Children’s and Young Adults’ Velocity Regulation When Intercepting Moving Gaps.*](#) pp. 1002–1018.

Objective: This study investigated how children and young adults regulate their velocity when crossing roads under varying traffic conditions. **Background:** To cross roads safely, pedestrians must adapt their movements to the moving vehicles around them while tightly coupling their movement to visual information. **Method:** Using an Oculus Rift, 16 children and 16 young adults walked on a treadmill and intercepted gaps between two simulated moving vehicles in an immersive virtual environment. We varied the participants’ initial distance from the curb to the interception point, as well as gap characteristics, including gap size and vehicle size. **Results:** Varying the initial distance led to systematic adjustments in participants’ approach velocities. The inter-vehicle gap and the vehicle size affected the crossing position induced by the initial distance. However, participants did not systematically scale their positions according to the initial distance in narrow gap. Notably, children did not finely tune their movements when they approached wide gap from a closer distance or when they approached the large vehicle from closer distance. **Conclusion:** Children were less precise in coupling their movements to the moving vehicle in complex traffic environments. In particular, large moving vehicles approaching at closer distances can pose risks when children cross roads. **Application:** These findings suggest the need for an intervention program to improve children’s skill in perceiving larger vehicles and timing their movements when crossing roads. We suggest using an interactive virtual reality system to practice this skill.

- **Keywords:** gap crossing, coupling, perception-action, virtual reality, speed

SURFACE TRANSPORTATION

Anthony D. McDonald, Thomas K. Ferris, Tyler A. Wiener. *Classification of Driver Distraction: A Comprehensive Analysis of Feature Generation, Machine Learning, and Input Measures.* pp. 1019–1035.

Objective: The objective of this study was to analyze a set of driver performance and physiological data using advanced machine learning approaches, including feature generation, to determine the best-performing algorithms for detecting driver distraction and predicting the source of distraction. **Background:** Distracted driving is a causal factor in many vehicle crashes, often resulting in injuries and deaths. As mobile devices and in-vehicle information systems become more prevalent, the ability to detect and mitigate driver distraction becomes more important. **Method:** This study trained 21 algorithms to identify when drivers were distracted by secondary cognitive and texting tasks. The algorithms included physiological and driving behavioral input processed with a comprehensive feature generation package, Time Series Feature Extraction based on Scalable Hypothesis tests. **Results:** Results showed that a Random Forest algorithm, trained using only driving behavior measures and excluding driver physiological data, was the highest-performing algorithm for accurately classifying driver distraction. The

most important input measures identified were lane offset, speed, and steering, whereas the most important feature types were standard deviation, quantiles, and nonlinear transforms. **Conclusion:** This work suggests that distraction detection algorithms may be improved by considering ensemble machine learning algorithms that are trained with driving behavior measures and nonstandard features. In addition, the study presents several new indicators of distraction derived from speed and steering measures. **Application:** Future development of distraction mitigation systems should focus on driver behavior-based algorithms that use complex feature generation techniques.

- **Keywords:** distraction classification, cognitive distraction, machine learning, time-series feature generation, physiological measures