

# Human Factors – rok 2019, roč. 61

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### AT THE FOREFRONT OF HF/E

#### **Kevin B. Bennett, John Flach. *Ecological Interface Design: Thirty-Plus Years of Refinement, Progress, and Potential*. S. 513–525**

**Objective:** The objective is to provide a review of ecological interface design (EID), to illustrate its value to human factors/ergonomics, and to identify areas for future research and development. **Background:** EID uses mature interface technologies to provide decision making and problem solving support. A variety of theoretical concepts and analytical tools have been developed to meet the associated challenges. EID provides support that is simultaneously grounded in the practical realities of a work domain and tailored to human capabilities and limitations. **Method:** EID's theoretical foundation is discussed briefly. Concrete examples of ecological and traditional interfaces are provided. Different categories of work domains are described, as well as the associated implications for interface design. A targeted literature review is conducted and the experimental outcomes are summarized. A representative evaluation is discussed, and interpretations of performance are provided. **Results:** The evidence reveals that EID has been remarkably successful in significantly improving performance for work domains with constraints that are law driven (e.g., process control). In contrast, work domains that are intent-driven (e.g., information retrieval) have, by and large, been ignored. Also, few studies have addressed nonvisual displays. **Conclusion:** EID has not yet realized its potential to improve safety and efficiency across the entire continuum of work domains. **Application:** EID provides a single integrated framework that is (a) sufficiently comprehensive to deal with complicated work domains and (b) capable of producing innovative support that will generalize to actual work settings.

- **Keywords:** ecological interface design, human-computer interaction, computer interface, displays and controls, display design principles, graphical user interfaces (GUI), visual, pictorial, displays

### BIOMECHANICS, ANTHROPOMETRY, WORK PHYSIOLOGY

**Alison C. McDonald, Daanish M. Mulla, Peter J. Keir. *Using EMG Amplitude and Frequency to Calculate a Multimuscle Fatigue Score and Evaluate Global Shoulder Fatigue*. S. 526–536.**

**Objective:** The authors developed a function to quantify fatigue in multiple shoulder muscles by generating a single score using relative changes in EMG amplitude and frequency over time. **Background:** Evaluating both frequency and amplitude components of the electromyographic signal provides a more complete evaluation of muscle fatigue than either variable alone; however, little effort has been made to combine time and frequency domains for the evaluation of myoelectric fatigue. **Method:** Surface EMG was measured from 14 shoulder muscles while participants performed simulated, repetitive work tasks until exhaustion. Each 60-s work cycle consisted of four tasks (dynamic push, dynamic pull, static drill, static force target matching task) scaled to participants' anthropometrics and strength. The function was generated to calculate a multimuscle fatigue score (MMFS) based on changes in EMG frequency, amplitude, and the number of muscles showing signs of myoelectric fatigue (increase in EMG amplitude; decrease in EMG frequency). **Results:** The function was evaluated through changes in MMFS over time: first ( $31.8 \pm 14.6$ ), middle ( $47.6 \pm 25.3$ ), last ( $58.6 \pm 35.5$ ) reference exertions ( $p < .05$ ). The evaluation of the relationships between MMFS and changes in strength ( $r = -0.510$ ) and MMFS and perceived fatigue (RPF) ( $r = 0.298$ ) showed significant relationships over time ( $p < .05$ ). MMFS scores increased over time ( $p < .05$ ) with significant relationships between MMFS and strength changes and RPF ( $p < .05$ ). **Conclusion and application:** The MMFS allows for comparisons between workplace tasks, which can aid in workplace design to mitigate the development of fatigue.

- **Keywords:** quantification, fatigue, electromyography, shoulder, muscles

## HEALTH CARE/HEALTH SYSTEMS

**Michael T. Pascale, Penelope Sanderson, David Liu, Ismail Mohamed, Birgit Brecknell, Robert G. Loeb. *The Impact of Head-Worn Displays on Strategic Alarm Management and Situation Awareness*. S. 537–563.**

**Objective:** To investigate whether head-worn displays (HWDs) help mobile participants make better alarm management decisions and achieve better situation awareness than alarms alone. **Background:** Patient alarms occur frequently in hospitals but often do not require clinical intervention. Clinicians may become desensitized to alarms and fail to respond to clinically relevant alarms. HWDs could make patient information continuously accessible, support situation awareness, and help clinicians prioritize alarms. **Method:** Experiment 1 ( $n = 76$ ) tested whether nonclinicians monitoring simulated patients benefited from vital sign information continuously displayed on an HWD while they performed a secondary calculation task. Experiment 2 ( $n = 13$ ) tested, across three separate experimental sessions, how effectively nursing trainees monitored simulated patients' vital signs under three different display conditions while they assessed a simulated patient. **Results:** In Experiment 1, participants who had access to continuous patient information on an HWD responded to clinically important alarms 25.9% faster and were 6.7 times less likely to miss alarms compared to participants who only heard alarms. In Experiment 2, participants using an HWD answered situation awareness questions 18.9% more accurately overall than when they used alarms only. However, the effect was significant in only two of the three experimental sessions. **Conclusion:** HWDs may help users maintain continuous awareness of multiple remote processes without affecting their performance on ongoing tasks. **Application:** The outcomes may apply to contexts where access to continuous streams of information from remote locations is useful, such as patient monitoring or clinical supervision.

- **Keywords:** head-worn displays, divided attention, monitoring, alarms, alarm fatigue

**Frank A. Drews, Boaz A. Markewitz, Gregory J. Stoddard, Matthew H. Samore. *Interruptions and Delivery of Care in the Intensive Care Unit. S. 564–576.***

**Objective:** This study samples interruption frequency in intensive care unit (ICU) settings to assess the relationship between interruptions and common patient hazards. **Background:** Task interruptions are accident contributors in numerous industries. Recently, studies on health care interruptions and their impact on patient hazards have received attention. **Method:** Seven ICUs in four hospitals participated in a 24-month study. Experienced ICU nurses directly observed nursing tasks, interruptions, and patient hazards (delays in care, breaks in device task protocols, and patient safety hazards). **Results:** During 1,148 hours of observation, 175 nurses performed 74,733 nursing tasks. Interruptions occurred at a rate of 4.95 per hour, and 8.4% of tasks were interrupted. Interruptions originated mostly from humans (65.9%), alarms (24.1%), and others (10%). A total of 774 patient hazards were observed, with a hazard occurring on average every 89 minutes. Relative to noninterrupted tasks, device alarm interrupted nonstructured tasks were associated with increased rates of delays in care and safety hazards (rate ratio [RR] = 3.19). In contrast, rate of delays in care and safety hazards did not increase during human interrupted tasks (RR = 1.13). Rates of protocol nonadherence varied by device type and were highest during artificial airway, medication administration, chest tube, and supplemental oxygen management. **Conclusion:** Interruptions in the ICU are frequent and contribute to patient hazards, especially when caused by device alarms during nonstructured tasks. Nonadherence to protocols is common and contributed to patient hazards. **Application:** The findings suggest a need for improvement in task and device design to reduce patient hazards.

- **Keywords:** interruptions, devices, tasks, patient hazards

## HUMAN-COMPUTER INTERACTION, COMPUTER SYSTEMS

**Aiping Xiong, Robert W. Proctor, Weining Yang, Ninghui Li. *Embedding Training Within Warnings Improves Skills of Identifying Phishing Webpages. S. 577–595.***

**Objective:** Evaluate the effectiveness of training embedded within security warnings to identify phishing webpages. **Background:** More than 20 million malware and phishing warnings are shown to users of Google Safe Browsing every week. Substantial click-through rate is still evident, and a common issue reported is that users lack understanding of the warnings. Nevertheless, each warning provides an opportunity to train users about phishing and how to avoid phishing attacks. **Method:** To test use of phishing-warning instances as opportunities to train users' phishing webpage detection skills, we conducted an online experiment contrasting the effectiveness of the current Chrome phishing warning with two training-embedded warning interfaces. The experiment consisted of three phases. In Phase 1, participants made login decisions on 10 webpages with the aid of warning. After a distracting task, participants made legitimacy judgments for 10 different login webpages without warnings in Phase 2. To test the long-term effect of the training, participants were invited back a week later to participate in Phase 3, which was conducted similarly as Phase 2. **Results:** Participants differentiated legitimate and fraudulent webpages better than chance. Performance was similar for all interfaces in Phase 1 for which the warning aid was present. However, training-embedded interfaces provided better protection than the Chrome phishing warning on both subsequent phases. **Conclusion:** Embedded training is a

complementary strategy to compensate for lack of phishing webpage detection skill when phishing warning is absent. **Application:** Potential applications include development of training-embedded warnings to enable security training at scale.

- **Keywords:** cybersecurity, phishing, training, action on cybersecurity, procedural knowledge

**Frederik Naujoks, Christian Purucker, Katharina Wiedemann, Claus Marberger. *Noncritical State Transitions During Conditionally Automated Driving on German Freeways: Effects of Non-Driving Related Tasks on Takeover Time and Takeover Quality.* S. 596–613.**

**Objective:** This study aimed at investigating the driver's takeover performance when switching from working on different non-driving related tasks (NDRTs) while driving with a conditionally automated driving function (SAE L3), which was simulated by a Wizard of Oz vehicle, to manual vehicle control under naturalistic driving conditions. **Background:** Conditionally automated driving systems, which are currently close to market introduction, require the user to stay fallback ready. As users will be allowed to engage in more complex NDRTs during the automated drive than when driving manually, the time needed to regain full manual control could likely be increased. **Method:** Thirty-four users engaged in different everyday NDRTs while driving automatically with a Wizard of Oz vehicle. After approximately either 5 min or 15 min of automated driving, users were requested to take back vehicle control in noncritical situations. The test drive took place in everyday traffic on German freeways in the metropolitan area of Stuttgart. **Results:** Particularly tasks that required users to turn away from the central road scene or hold an object in their hands led to increased takeover times. Accordingly, increased variance in the driver's lane position was found shortly after the switch to manual control. However, the drivers rated the takeover situations to be mostly "harmless." **Conclusion:** Drivers managed to regain control over the vehicle safely, but they needed more time to prepare for the manual takeover when the NDRTs caused motoric workload. **Application:** The timings found in the study can be used to design comfortable and safe takeover concepts for automated vehicles.

- **Keywords:** conditionally automated driving, non-driving related tasks, control transitions, takeover performance

## HUMAN-ROBOT INTERACTION

**Tracy Sanders, Alexandra Kaplan, Ryan Koch, Michael Schwartz, P. A. Hancock. *The Relationship Between Trust and Use Choice in Human-Robot Interaction.* S. 614–626.**

**Objective:** To understand the influence of trust on use choice in human-robot interaction via experimental investigation. **Background:** The general assumption that trusting a robot leads to using that robot has been previously identified, often by asking participants to choose between manually completing a task or using an automated aid. Our work further evaluates the relationship between trust and use choice and examines factors impacting choice. **Method:** An experiment was conducted wherein participants rated a robot on a trust scale, then made decisions about whether to use that robotic agent or a human agent to complete a task. Participants provided explicit reasoning for their choices. **Results:** While we found statistical support for the "trust leads to use" relationship, qualitative results indicate other factors are important as well. **Conclusion:** Results indicated that while trust leads to use, use is also heavily influenced by the specific task at hand. Users more often chose a robot for a dangerous task where loss of

life is likely, citing safety as their primary concern. Conversely, users chose humans for the mundane warehouse task, mainly citing financial reasons, specifically fear of job and income loss for the human worker. **Application:** Understanding the factors driving use choice is key to appropriate interaction in the field of human-robot teaming.

- **Keywords:** human-robot interaction, human-automation interaction, trust, use choice, reliance

## **SIMULATION AND VIRTUAL REALITY**

**Rafaela Heloisa Carvalho Machado, André Luis Helleno, Maria Célia de Oliveira, Mário Sérgio Corrêa dos Santos, Renan Meireles da Costa Dias. *Analysis of the Influence of Standard Time Variability on the Reliability of the Simulation of Assembly Operations in Manufacturing Systems. S. 627–641.***

**Objective:** The aim of this article is to analyze the influence of the variability of the standard time in the simulation of the assembly operations of manufacturing systems. **Background:** Discrete event simulation (DES) has been used to provide efficient analysis during the design of a process or scenario. However, the modeling activities of new configurations face the problem of data availability and reliability when it comes to seeking standard times that are effective in representing the actual process under analysis, especially when the process cannot be monitored. **Method:** The methods-time measurement (MTM) is used as a source of standard times for simulation. Assembly activities were performed at a Learning Factory facility, which provided the necessary structure for simulating real production processes. Simulation performances using different variability of standard times were analyzed to define the impact of data characteristics. **Results:** The MTM standard time presented an error of approximately 5%. The definition of the data variability of standard times and the statistical distribution impacts were shown in the simulation results, with errors above 6% being observed, interfering with the model reliability. **Conclusion:** Based on the study, to increase the adherence of a simulation to represent a real process, it is recommended to use triangular distributions with central values greater than those established via the MTM for the representation of the standard times of new assembly processes or scenarios using DES. **Application:** The study contributions can be applied in assembly line design, providing a reliable model representing real processes and scenarios.

- **Keywords:** discrete event simulation, methods-time measurement, work measurement, assembly workstation, operations research, industrial environment, virtual environment

## **SURFACE TRANSPORTATION**

**Anthony D. McDonald, Hananeh Alambeigi, Johan Engström, Gustav Markkula, Tobias Vogelpohl, Jarrett Dunne, Norbert Yuma. *Toward Computational Simulations of Behavior During Automated Driving Takeovers: A Review of the Empirical and Modeling Literatures. S. 642–688.***

**Objective:** This article provides a review of empirical studies of automated vehicle takeovers and driver modeling to identify influential factors and their impacts on takeover performance and suggest driver models that can capture them. **Background:**

Significant safety issues remain in automated-to-manual transitions of vehicle control. Developing models and computer simulations of automated vehicle control transitions may help designers mitigate these issues, but only if accurate models are used. Selecting accurate models requires estimating the impact of factors that influence takeovers.

**Method:** Articles describing automated vehicle takeovers or driver modeling research were identified through a systematic approach. Inclusion criteria were used to identify relevant studies and models of braking, steering, and the complete takeover process for further review. **Results:** The reviewed studies on automated vehicle takeovers identified several factors that significantly influence takeover time and post-takeover control. Drivers were found to respond similarly between manual emergencies and automated takeovers, albeit with a delay. The findings suggest that existing braking and steering models for manual driving may be applicable to modeling automated vehicle takeovers.

**Conclusion:** Time budget, repeated exposure to takeovers, silent failures, and handheld secondary tasks significantly influence takeover time. These factors in addition to takeover request modality, driving environment, non-handheld secondary tasks, level of automation, trust, fatigue, and alcohol significantly impact post-takeover control. Models that capture these effects through evidence accumulation were identified as promising directions for future work. **Application:** Stakeholders interested in driver behavior during automated vehicle takeovers may use this article to identify starting points for their work.

- **Keywords:** autonomous driving, driver behavior, simulation, meta-analysis, control theory