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ACCIDENTS, HUMAN ERROR

Alireza Noroozi, Rouzbeh Abbassi, Scott MacKinnon, Faisal Khan, Nima Khakzad. *Effects of Cold Environments on Human Reliability Assessment in Offshore Oil and Gas Facilities.* S. 825-839.

Objective: This paper proposes a new methodology that focuses on the effects of cold and harsh environments on the reliability of human performance. **Background:** As maritime operations move into Arctic and Antarctic environments, decision makers must be able to recognize how cold weather affects human performance and subsequently adjusts management and operational tools and strategies. **Method:** In the present work, a revised version of the Human Error Assessment and Reduction Technique (HEART) methodology has been developed to assess the effects of cold on the likelihood of human error in offshore oil and gas facilities. This methodology has been applied to post-maintenance tasks of offshore oil and gas facility pumps to investigate how management, operational, and equipment issues must be considered in risk analysis and prediction of human error in cold environments. **Results:** This paper provides a proof of concept indicating that the risk associated with operations in cold environments is greater than the risk associated with the same operations performed in temperate climates. It also develops guidelines regarding how this risk can be assessed. The results illustrate that in post-maintenance procedures of a pump, the risk value related to the effect of cold and harsh environments on operator cognitive performance is twice as high as the risk value when performed in normal conditions. **Conclusion:** The present work demonstrates significant differences between human error probabilities (HEPs) and associated risks in normal conditions as opposed to cold and harsh environments. This study also highlights that the cognitive performance of the human operator is the most important factor affected by the cold and harsh conditions. **Application:** The methodology developed in this paper can be used for reevaluating the HEPs for particular scenarios that occur in harsh environments since these HEPs may not be comparable to similar scenarios in normal conditions.

- **Keywords:** cold regions, human error, maintenance, risk analysis, offshore oil and gas industry

AUTOMATION, EXPERT SYSTEMS

Joachim Meyer, Rebecca Wiczorek, Torsten Günzler. *Measures of Reliance and Compliance in Aided Visual Scanning.* S. 840-849.

Objective: We study the dependence or independence of reliance and compliance as two responses to alarms to understand the mechanisms behind these responses. **Background:** Alarms, alerts, and other binary cues affect user behavior in complex ways. The suggestion has been made that there are two different responses to alerts—compliance (the tendency to perform an action cued by the alert) and reliance (the tendency to refrain from actions as long as no alert is issued). The study tests the degree to which these two responses are indeed independent. **Method:** An experiment tested the effects of the positive and negative predictive values of the alerts (PPV and NPV) on measures of compliance and reliance based on cutoff settings, response times, and subjective confidence. **Results:** For cutoff settings and response times, compliance was unaffected by the irrelevant NPV, whereas reliance depended on the irrelevant PPV. For subjective estimates, there were no significant effects of the irrelevant variables. **Conclusion:** Results suggest that compliance is relatively stable and unaffected by irrelevant information (the NPV), whereas reliance is also affected by the PPV. The results support the notion that reliance and compliance are separate, but related, forms of trust. **Application:** False alarm rates, which affect PPV, determine both the response to alerts (compliance) and the tendency to limit precautions when no alert is issued (reliance).

- **Keywords:** trust, warnings, alerts, reliance, compliance, automation, signal detection theory, confidence

BIOMECHANICS, ANTHROPOMETRY, WORK PHYSIOLOGY

Jonathan DeShaw, Salam Rahmatalla. *Predictive Discomfort in Single- and Combined-Axis Whole-Body Vibration Considering Different Seated Postures.* S. 850-863.

Objective: The aim of this study was to develop a predictive discomfort model in single-axis, 3-D, and 6-D combined-axis whole-body vibrations of seated occupants considering different postures. **Background:** Non-neutral postures in seated whole-body vibration play a significant role in the resulting level of perceived discomfort and potential long-term injury. The current international standards address contact points but not postures. **Method:** The proposed model computes discomfort on the basis of static deviation of human joints from their neutral positions and how fast humans rotate their joints under vibration. Four seated postures were investigated. For practical implications, the coefficients of the predictive discomfort model were changed into the Borg scale with psychophysical data from 12 volunteers in different vibration conditions (single-axis random fore-aft, lateral, and vertical and two magnitudes of 3-D). The model was tested under two magnitudes of 6-D vibration. **Results:** Significant correlations ($R^2 = .93$) were found between the predictive discomfort model and the reported discomfort with different postures and vibrations. The ISO 2631-1 correlated very well with discomfort ($R^2 = .89$) but was not able to predict the effect of posture. **Conclusion:** Human discomfort in seated whole-body vibration with different non-neutral postures can be closely predicted by a combination of static posture and the angular velocities of the joint. **Application:** The predictive discomfort model can assist ergonomists and human factors researchers design safer environments for seated operators under vibration. The model can be integrated with advanced computer biomechanical models to investigate the complex interaction between posture and vibration.

- **Keywords:** discomfort, model, whole-body vibration, perception, standards, seated posture, joint motion, angular velocity

Judith E. Gold, Feroze B. Mohamed, Sayed Ali, Mary F. Barbe. *Serum and MRI Biomarkers in Mobile Device Texting : a Pilot Study.* S. 864-872.

Objective: We aimed to determine if serum biochemical and MRI biomarkers differed between high volume (≥ 230 texts sent/day; $n = 5$) and low volume (≤ 25 texts

sent/day; $n = 5$) texters. A secondary aim was to ascertain what correlations between the biochemical and imaging biomarkers could tell us about the pathophysiology of early onset tendinopathies. **Background:** Text messaging has become widespread, particularly among college-aged young adults. There is concern that high rates of texting may result in musculoskeletal disorders, including tendinopathies. Pathophysiology of tendinopathies is largely unknown. **Method:** Ten females with a mean age of 20 were recruited. We examined serum for 20 biomarkers of inflammation, tissue degeneration, and repair. We used conventional MRI and MRI mean intratendinous signal intensity (MISI) to assess thumb tendons. Correlations between MISI and serum biomarkers were also examined. **Results:** Three high volume texters had MRI tendinopathy findings as did one low volume texter. Increased serum TNF-R1 was found in high volume texters compared to low volume texters, as were nonsignificant increases in MISI in two thumb tendons. Serum TNF-R1 and TNF- α correlated with MISI in these tendons, as did IL1-R1. **Conclusion:** These results suggest that early onset tendinopathy with concurrent inflammation may be occurring in prolific texters. Further studies with larger sample sizes are needed for confirmation. **Application:** High volume texting may be a risk factor for thumb tendinopathy in later years. Multidisciplinary research using biochemical and imaging biomarkers may be used to gain insight into pathophysiological processes in musculoskeletal disorders.

- **Keywords:** musculoskeletal disorder, tendinitis, tendon, tendinopathy, SMS, inflammation, cytokines, intratendinous signal intensity

Hongwei Hsiao, Jennifer Whitestone, Tsui-Ying Kau, Richard Whisler, J. Gordon Routley, Michael Wilbur. *Sizing Firefighters : Method and Implications.* Sd. 873-910.

Objective: This article reports new anthropometric information of U.S. firefighters for fire apparatus design applications (Study 1) and presents a data method to assist in firefighter anthropometric data usage for research-to-practice propositions (Study 2). **Background:** Up-to-date anthropometric information of the U.S. firefighter population is needed for updating ergonomic and safety specifications for fire apparatus. **Method:** A stratified sampling plan of three-age by three-race/ethnicity combinations was used to collect anthropometric data of 863 male and 88 female firefighters across the U.S. regions; 71 anthropometric dimensions were measured (Study 1). Differences among original, weighted, and normality transformed data from Study 1 were compared to allowable observer errors (Study 2). **Results:** On average, male firefighters were 9.8 kg heavier and female firefighters were 29 mm taller than their counterparts in the general U.S. population. They also have larger upper-body builds than those of the general U.S. population. The data in weighted, unweighted, and normality transformed modes were compatible among each other with a few exceptions. **Conclusion:** The data obtained in this study provide the first available U.S. national firefighter anthropometric information for fire apparatus designs. The data represent the demographic characteristics of the current firefighter population and, except for a few dimensions, can be directly employed into fire apparatus design applications without major weighting or nonnormality concerns. **Application:** The up-to-date firefighter anthropometric data and data method will benefit the design of future fire apparatus and protective equipment, such as seats, body restraints, cabs, gloves, and bunker gear.

- **Keywords:** firefighter, anthropometry, cab, protective equipment, body build, apparatus

COGNITION

Jessica L. Wildman, Eduardo Salas, Charles P. R. Scott. *Measuring Cognition in Teams : a Cross-Domain Review.* S. 911-941.

Objective: The purpose of this article is twofold: to provide a critical cross-domain evaluation of team cognition measurement options and to provide novice researchers with practical guidance when selecting a measurement method. **Background:** A vast selection of measurement approaches exist for measuring team cognition constructs including team mental models, transactive memory systems, team situation awareness, strategic consensus, and cognitive processes. **Methods:** Empirical studies and theoretical articles were reviewed to identify all of the existing approaches for measuring team cognition. These approaches were evaluated based on theoretical perspective assumed, constructs studied, resources required, level of obtrusiveness, internal consistency reliability, and predictive validity. **Results:** The evaluations suggest that all existing methods are viable options from the point of view of reliability and validity, and that there are potential opportunities for cross-domain use. For example, methods traditionally used only to measure mental models may be useful for examining transactive memory and situation awareness. The selection of team cognition measures requires researchers to answer several key questions regarding the theoretical nature of team cognition and the practical feasibility of each method. **Conclusions:** We provide novice researchers with guidance regarding how to begin the search for a team cognition measure and suggest several new ideas regarding future measurement research. **Applications:** We provide (1) a broad overview and evaluation of existing team cognition measurement methods, (2) suggestions for new uses of those methods across research domains, and (3) critical guidance for novice researchers looking to measure team cognition.

- **Keywords:** team cognition, measurement, mental models, transactive memory, situation awareness, strategic consensus

DISPLAYS AND CONTROLS

Cosima Piepenbrock, Susanne Mayr, and Axel Buchner. *Positive Display Polarity Is Particularly Advantageous for Small Character Sizes: Implications for Display Design. S. 942-951.*

Objective: To test the display luminance hypothesis of the positive polarity advantage and gain insights for display design, the joint effects of display polarity and character size were assessed with a proofreading task. **Background:** Studies have shown that dark characters on light background (positive polarity) lead to better legibility than do light characters on dark background (negative polarity), presumably due to the typically higher display luminance of positive polarity presentations. **Method:** Participants performed a proofreading task with black text on white background or white text on black background. Texts were presented in four character sizes (8, 10, 12, and 14 pt; corresponding to 0.22°, 0.25°, 0.31°, and 0.34° of vertical visual angle). **Results:** A positive polarity advantage was observed in proofreading performance. Importantly, the positive polarity advantage linearly increased with decreasing character size. **Conclusion:** The findings are in line with the assumption that the typically higher luminance of positive polarity displays leads to an improved perception of detail. **Application:** The implications seem important for the design of text on such displays as those of computers, automotive control and entertainment systems, and smartphones that are increasingly used for the consumption of text-based media and communication. The sizes of these displays are limited, and it is tempting to use small font sizes to convey as much information as possible. Especially with small font sizes, negative polarity displays should be avoided.

- **Keywords:** display polarity, contrast polarity, positive polarity advantage, character size, font size, mobile devices, smartphones, text-based communication, detail perception, display design

Francis T. Durso, Sadaf Kazi, Cale M. Darling. *The Role of Number of Tasks in Determining the Relevance of Information*. S. 952-957.

Objective: Our objective was to explore the value of considering the number of tasks that use a piece of information when calculating the relevance information has to an operator. **Background:** Whereas frequency and criticality of information are often identified as information attributes, the number of tasks that use the information is rarely considered. **Method:** We calculated the relevance of pieces of information in air traffic control using criticality and frequency, and compared it to a formula that also considered the number of tasks. **Results:** Including number of tasks resulted in information ranking that better accounted for aircraft relevant information, and better supported the information needs of air traffic controllers as determined by judgments of controllers. **Conclusion:** The attribute of number of tasks is valuable in calculating the relevance of information. **Application:** Interface designers should consider the number of tasks that use a particular piece of information when determining the placement of information within a display.

- **Keywords:** task analysis, number of tasks, information relevance

HEALTH CARE/HEALTH SYSTEMS

Tobias Grundgeiger, Bonnie Harris, Nicholas Ford, Michael Abbey, Penelope M. Sanderson, Balasubramanian Venkatesh. *Emergency Medical Equipment Storage : Benefits of Visual Cues Tested in Field and Simulated Settings*. S. 958-972.

Objective: We tested the effectiveness of an illustrated divider ("the divider") for bedside emergency equipment drawers in an intensive care unit (ICU). In Study 1, we assessed whether the divider increases completeness and standardizes the locations of emergency equipment within the drawer. In Study 2, we investigated whether the divider decreases nurses' restocking and retrieval times and decreases their workload. **Background:** Easy access to fully stocked emergency equipment is important during emergencies. However, inefficient equipment storage and cognitively demanding work settings might mean that drawers are incompletely stocked and access to items is slow. **Method:** A pre-post-post study investigated drawer completeness and item locations before and after the introduction of the divider to 30 ICU drawers. A subsequent experiment measured item restocking time, item retrieval time, and subjective workload for nurses. **Results:** At 2 weeks and 10 weeks after the divider was introduced, the completeness of the drawer increased significantly compared with before the divider was introduced. The divider decreased the variability of the locations of the 17 items in the drawer to 16% of its original value. Study 2 showed that restocking times but not retrieval times were significantly faster with the divider present. For both tasks, nurses rated their workload lower with the divider. **Conclusions:** The divider improved the standardization and completeness of emergency equipment. In addition, restocking times and workload were decreased with the divider. **Application:** Redesigning storage for certain equipment using human factors design principles can help to speed and standardize restocking and ease access to equipment.

- **Keywords:** health care quality improvement, patient safety, equipment design

HUMAN-COMPUTER INTERACTION, COMPUTER SYSTEMS

Bryan A. Campbell, Chad C. Tossell, Michael D. Byrne, Philip Kortum. *Toward More Usable Electronic Voting : Testing the Usability of a Smartphone Voting System*. S. 973-985.

Objective: The goal of this research was to assess the usability of a voting system designed for smartphones. **Background:** Smartphones offer remote participation in elections through the use of pervasive technology. Voting on these devices could, among other benefits, increase voter participation while allowing voters to use familiar technology. However, the usability of these systems has not been assessed. **Method:** A mobile voting system optimized for use on a smartphone was designed and tested against traditional voting platforms for usability. **Results:** There were no reliable differences between the smartphone-based system and other voting methods in efficiency and perceived usability. More important, though, smartphone owners committed fewer errors on the mobile voting system than on the traditional voting systems. **Conclusion:** Even with the known limitations of small mobile platforms in both displays and controls, a carefully designed system can provide a usable voting method. Much of the concern about mobile voting is in the area of security; therefore, although these results are promising, security concerns and usability issues arising from mitigating them must be strongly considered. **Application:** The results of this experiment may help to inform current and future election and public policy officials about the benefits of allowing voters to vote with familiar hardware.

- **Keywords:** interface, usability, voting, mobile

SURFACE TRANSPORTATION SYSTEMS

Anthony D. McDonald, John D. Lee, Chris Schwarz, Timothy L. Brown. *Steering in a Random Forest : Ensemble Learning for Detecting Drowsiness-Related Lane Departures.* S. 986-989.

Objective: The aim of this study was to design and evaluate an algorithm for detecting drowsiness-related lane departures by applying a random forest classifier to steering wheel angle data. **Background:** Although algorithms exist to detect and mitigate driver drowsiness, the high rate of false alarms and missed detection of drowsiness represent persistent challenges. Current algorithms use a variety of data sources, definitions of drowsiness, and machine learning approaches to detect drowsiness. **Method:** We develop a new approach for detecting drowsiness-related lane departures using steering wheel angle data that employ an ensemble definition of drowsiness and a random forest algorithm. Data collected from 72 participants driving the National Advanced Driving Simulator are used to train and evaluate the model. The model's performance was assessed relative to a commonly used algorithm, percentage eye closure (PERCLOS). **Results:** The random forest steering algorithm had a higher classification accuracy and area under the receiver operating characteristic curve than PERCLOS and had comparable positive predictive value. The algorithm succeeds at identifying two key scenarios associated with the drowsiness detection task. These two scenarios consist of instances when drivers depart their lane because they fail to modulate their steering behavior according to the demands of the simulated road and instances when drivers correctly modulate their steering behavior according to the demands of the road. **Conclusion:** The random forest steering algorithm is a promising approach to detect driver drowsiness. The algorithm's ties to consequences of drowsy driving suggest that it can be easily paired with mitigation systems.

- **Keywords:** drowsiness detection, lane departure, random forest, machine learning, steering wheel angle

TRAINING, EDUCATION, INSTRUCTIONAL SYSTEMS

Thomas F. Carolan, Shaun D. Hutchins, Christopher D. Wickens, John M. Cumming. *Costs and Benefits of More Learner Freedom : Meta-Analyses of Exploratory and Learner Control Training Methods.* S. 990-1014.

Objective: Individual meta-analyses were conducted for six training methods as part of a U.S. Army basic research project. The objective was to identify evidence-based guidelines for the effectiveness of each training method, under different moderating conditions, for cognitive skill transfer in adult learning. Results and implications for two of these training methods, learner control (LC) and exploratory learning (EL), are discussed. LC provides learners with active control over training variables. EL requires learners to discover relationships and interactions between variables. **Background:** There is mixed evidence on the effectiveness of both LC and EL learning methods on transfer relative to more guided training methods. Cognitive load theory (CLT) provides a basis for predicting that training strategies that manage intrinsic load of a task during training and minimize extraneous load will avail more resources that can be devoted to learning. **Method:** Meta-analyses were conducted using a Hedges's *g* analysis of effect sizes. Control conditions with little to no learner freedom were contrasted with treatment conditions manipulating more learner freedom. **Results:** Overall more LC was no different from training with limited or no learner control, and more EL was less effective than limited or no exploration; however, each can be effective under certain conditions. Both strategies have been more effective for cognitive skill learning than for knowledge recall tasks. LC exhibited more benefit to very near transfer, whereas EL's benefit was to far transfer. **Conclusion:** Task type, transfer test, and transfer distance moderate the overall transfer cost of more learner freedom. **Application:** The findings are applicable to the development of instructional design guidelines for the use of LC and EL in adult skill training.

- **Keywords:** training strategies, transfer of training, cognitive load theory, exploratory learning, learner control, meta-analysis