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**Special Section: 2018 Human Factors Prize for Excellence
in Human Factors/Ergonomics Research: Applications of
Mixed Reality**



AT THE FOREFRONT OF HF/E

P. A. Hancock. *On the Dynamics of Conspicuity*. S. 857–865.

Objective: To examine the influences of dynamic conspicuity on object recognition and to evaluate the real-world implications of these processes. **Background:** Conspicuity is the major influence on persons' abilities to recognize the presence of entities within their environment. Shortfalls in sensory and cognitive conspicuity are implicated in many, if not most, real-world systemic failures. **Method:** The present observations derive from an overview of relevant empirical research allied to a synthetic integration. From these foundations, I articulate a proposed taxonomy through which to parse the essential dimensions of conspicuity. **Results:** The taxonomy features three axes related to (a) modality (e.g., visual vs. auditory, etc.), (b) processing directionality (e.g., top-down vs. bottom-up information flow), and finally (c) temporality (i.e., the differences between static vs. dynamic presentations). **Conclusion:** Existing conspicuity studies have primarily featured static, sensory comparisons. Exploration of the other quadrants of the proposed taxonomy can serve to frame future conspicuity research. This taxonomic description also provides the basis from which to understand failure etiology in a wide spectrum of human-machine systems. **Application:** Improvements in the understanding of conspicuity can help in all domains of HF/E and can serve to reduce failure in a wide variety of operational contexts.

- **Keywords:** dynamic conspicuity, conspicuity taxonomy, real-world applications

SPECIAL SECTION: 2018 HUMAN FACTORS PRIZE FOR EXCELLENCE IN HUMAN FACTORS/ERGONOMICS RESEARCH: APPLICATIONS OF MIXED REALITY

HUMAN FACTORS PRIZE WINNER

Adam M. Braly, Benjamin Nuernberger, So Young Kim. *Augmented Reality Improves Procedural Work on an International Space Station Science Instrument. S. 866–878.*

Objective: The purpose of the current study was to determine whether an augmented reality instruction method would result in faster task completion times, lower mental workload, and fewer errors for simple tasks in an operational setting. **Background:** Prior research on procedural work that directly compared augmented reality instructions to traditional instruction methods (e.g., paper) showed that augmented reality instructions can enhance procedural work, but this was not true for simple tasks in an operational setting. **Method:** Participants completed simple procedural tasks on spaceflight hardware using an augmented reality instruction method and a paper instruction method. **Results:** Our results showed that the augmented reality instruction method resulted in faster task completion times and lower levels of mental and temporal demand compared with paper instructions. When participants used the augmented reality instruction method before the paper instruction method, there was a transfer of training that improved a subsequent procedure using the paper instruction method. **Conclusion:** An off-the-shelf augmented reality head-mounted display (HoloLens) can enhance procedural work for simple tasks in an operational setting. **Application:** The ability of augmented reality to enhance procedural work for simple tasks in an operational setting can help in reducing costs and mitigating risks that could ultimately lead to accidents and critical failures.

- **Keywords:** augmented reality, procedural work, spaceflight

SPECIAL SECTION: 2018 HUMAN FACTORS PRIZE FOR EXCELLENCE IN HUMAN FACTORS/ERGONOMICS RESEARCH: APPLICATIONS OF MIXED REALITY

HUMAN FACTORS PRIZE FINALIST

Cheng-Long Deng, Peng Geng, Yi-Fei Hu, Shu-Guang Kuai. *Beyond Fitts's Law: A Three-Phase Model Predicts Movement Time to Position an Object in an Immersive 3D Virtual Environment. S. 879–894.*

Objective: The study examines the factors determining the movement time (MT) of positioning an object in an immersive 3D virtual environment. **Background:** Positioning an object into a prescribed area is a fundamental operation in a 3D space. Although Fitts's law models the pointing task very well, it does not apply to a positioning task in an immersive 3D virtual environment since it does not consider the effect of object size in the positioning task. **Method:** Participants were asked to position a ball-shaped object into a spherical area in a virtual space using a handheld or head-tracking controller in the ray-casting technique. We varied object size (OS), movement amplitude (A), and target tolerance (TT). MT was recorded and analyzed in three phases: acceleration, deceleration, and correction. **Results:** In the acceleration phase, MT was inversely related to object size and positively proportional to movement amplitude. In the deceleration phase, MT was primarily determined by movement amplitude. In the correction phase, MT was affected by all three factors. We observed similar results whether participants used a handheld controller or head-tracking controller. We thus

propose a three-phase model with different formulae at each phase. This model fit participants' performance very well. **Conclusion:** A three-phase model can successfully predict MT in the positioning task in an immersive 3D virtual environment in the acceleration, deceleration, and correction phases, separately. **Application:** Our model provides a quantitative framework for researchers and designers to design and evaluate 3D interfaces for the positioning task in a virtual space.

- **Keywords:** Fitts's law, distal positioning, 3D interaction, movement trajectory, modeling

BIOMECHANICS, ANTHROPOMETRY, WORK PHYSIOLOGY

Arthur Stewart, Alan Nevill, Christopher Johnson. *The Ability of Adults of Different Size to Egress Through Confined Space Apertures. S. 895–905.*

Objective: To determine minimum egress apertures in healthy adults of different body size. **Background:** Body space requirements have traditionally been considered from an industrial perspective, facilitating safe confined-space working. However, increased typical body size resulting from global obesity renders traditional assumptions of body size inappropriate. This has potentially far-reaching consequences for evacuation planning, due to diminished clearance space, slower movement, and increased chance of physical entrapment. Critically, no current literature describes the minimum apertures adults can negotiate. **Method:** Forty-eight men and 40 women underwent anthropometric and 3-D scanning assessments from which anatomical dimensions were extracted. Additionally, a wall egress task was undertaken through an aperture that was progressively narrowed until individuals failed to pass. Minimum egress aperture was predicted from anatomical variables using backwards elimination regression. **Results:** Minimum wall egress was best predicted from mass, abdominal depth, bideltoid breadth and chest depth. Passes and fails, discriminated using binary logistic regression, identified chest depth and abdominal depth as influential for wall egress success at selected apertures, with a gender interaction manifest at abdominal depth. **Conclusion:** Minimum egress aperture relates to body size and can be predicted from anatomical variables; however, men and women display subtle differences in egress capability. **Application:** In public and industrial settings, egress capability in restricted spaces is affected by size and gender, with profound implications for safety, which relate to increased typical body size associated with global obesity.

- **Keywords:** anthropometry, extreme environments, pedestrian safety, architecture, gender

COGNITION

José Ignacio López-Sánchez, P. A. Hancock. *Diminishing Cognitive Capacities in an Ever Hotter World: Evidence From an Applicable Power-Law Description. S. 906–919.*

Objective: Modeling and evaluating a series of power law descriptions for boundary conditions of undiminished cognitive capacities under thermal stress. **Background:** Thermal stress degrades cognition, but precisely which components are affected, and to what degree, has yet to be fully determined. With increasing global temperatures, this need is becoming urgent. Power-law distributions have proven their utility in describing differing natural mechanisms, including certain orders of human performance, but never as a rationalization of stress-altered states of attention. **Method:** From a survey of

extant empirical data, absolute thresholds for thermal tolerance for varying forms of cognition were identified. These thresholds were then modeled using a rational power-law description. The implications of the veracity of that description were then identified and analyzed. **Results:** Cognitive performance thresholds under thermal stress are advanced as power-law relationships, $t = f(T) = c[(T - T_{ref})/T_{ref}]^{-\alpha}$. Coherent scaling parameters for diverse cognitive functionalities are specified that are consistent with increases in deep (core) body temperature. Therefore, scale invariance provides a “universal constant,” viz, 20% detriment in mental performance per 10% increase in T deviation, from a comfortable reference temperature T_{ref} . **Conclusion:** We know the thermal range within which humans can survive is quite narrow. The presented power-law descriptions imply that if making correct decisions is critical for our future existence, then our functional thermal limits could be much more restricted than previously thought. **Application:** We provide our present findings, such that others can both assess and mitigate the effects of adverse thermal loads on cognition, in whatever human scenario they occur.

- **Keywords:** temperature, stress, cognition, decision making, human error

CONSUMER PRODUCTS, TOOLS

Michael J. Kalsher, William G. Obenauer, Christopher F. Weiss.
Reconsidering the Role of Design Standards in Developing Effective Safety Labeling: Monolithic Recipes or Collections of Separable Features?
S. 920–952.

Objective: This research investigated whether safety labeling design guidelines, such as the American National Standards Institute (ANSI) Z535 series, contribute to better warnings. **Background:** Studies investigating the impact of safety label formatting on warning effectiveness have produced mixed findings. Additionally, research has failed to find a consistent relationship between measures of predicted and actual compliance. One commonality is that all of these studies have investigated the ANSI Z535 guidelines as a binary variable rather than as an integrative system of separable features. **Method:** We measured predicted compliance using both a within-subjects and a between-subjects design, but actual compliance using only a between-subjects design. Data were analyzed using both analysis of variance and linear/probit regressions to test the relationships between warning features recommended in the ANSI Z535 guidelines and measures of behavioral compliance. **Results:** Predicted compliance assessed via a within-subjects design differed greatly from predicted compliance assessed via a between-subjects design. Levels of predicted and actual compliance were most similar when both measures were assessed using a between-subjects design. Consistent with previous research, location had a strong relationship with actual compliance, but surprisingly, presence of an ANSI-style orange warning header had a negative relationship with compliance. **Conclusion:** The choice of experimental design and analytical methods can dramatically influence a study’s results and conclusions drawn. This research identified several aspects of experimental design that should be considered in future research on warning effectiveness. **Application:** Testing features recommended in the ANSI Z535 guidelines under varying conditions can contribute to the development of more effective warnings.

- **Keywords:** warning systems, warnings, warning compliance, experimental design, statistics, data analysis

DISPLAYS AND CONTROL

Kim-Phuong L. Vu, Yuting Sun. *Population Stereotypes for Objects and Representations: Response Tendencies for Interacting With Everyday Objects and Interfaces.* S. 953–975.

Objective: The objective of the study is to replicate and extend population stereotypes from a broad range of users for display-control relations of common interfaces using pictures/images of the objects. **Background:** Population stereotypes for display-control configurations refer to people's tendencies to associate certain control actions with display properties. An interface will benefit by being designed in a manner that is consistent with the stereotypes. The stimuli used in the present study include conceptual replications of objects that have been examined previously and new ones. **Method:** An online survey was designed to collect data about participants' natural response tendencies or interpretations of the meaning associated with objects, representations, and colors. Participants were obtained through MTurk from the United States, India, and UK. **Results:** We replicated 76% and partially replicated an additional 16% of the stereotypic responses found in prior studies. Considering the full data set, we found stereotypic responses for 62% of the stimuli that are consistent across the three countries in which the participants were located, although the strength of these stereotypes may differ by location. For the remaining 38% of the stimuli, population stereotypes still emerged for some locations. Few gender differences were found. **Conclusion:** Cross-cultural stereotypic responses exist for many objects, representations, and display-control configurations. However, because stereotypes can be limited to specific regions or change over time, we recommend that they be captured periodically to ensure design guidelines based on the stereotypes remain valid. **Application:** Designers can use the stereotypic responses to guide design decisions.

- **Keywords:** displays and controls, display design principles, display-control compatibility, product design, ecological interface design

SENSORY AND PERCEPTUAL PROCESSES

Douglas S. Brungart, Sarah E. Kruger, Tricia Kwiatkowski, Thomas Heil, Julie Cohen. [*The Effect of Walking on Auditory Localization, Visual Discrimination, and Aurally Aided Visual Search.*](#) S. 976–991.

Objective: The present study was designed to examine the impact that walking has on performance in auditory localization, visual discrimination, and aurally aided visual search tasks. **Background:** Auditory localization and visual search are critical skills that are frequently conducted by moving observers, but most laboratory studies of these tasks have been conducted on stationary listeners who were either seated or standing during stimulus presentation. **Method:** Thirty participants completed three different tasks while either standing still or while walking at a comfortable self-selected pace on a treadmill: (1) an auditory localization task, where they identified the perceived location of a target sound; (2) a visual discrimination task, where they identified a visual target presented at a known location directly in front of the listener; and (3) an aurally aided visual search task, where they identified a visual target that was presented in the presence of multiple visual distracters either in isolation or in conjunction with a spatially colocated auditory cue. **Results:** Participants who were walking performed auditory localization and aurally aided visual search tasks significantly faster than those who were standing, with no loss in accuracy. **Conclusion:** The improved aurally aided visual search performance found in this experiment may be related to enhanced overall activation caused by walking. It is also possible that the slight head movements required may have provided auditory cues

that enhanced localization accuracy. **Application:** The results have potential applications in virtual and augmented reality displays where audio cues might be presented to listeners while walking.

- **Keywords:** dual task, time sharing, task switching, cognition, multisensory integration, sensory and perceptual processes, kinesthesia, proprioception, orientation, balance, virtual environments, simulation, virtual reality

Wim van Winsum. *Optic Flow and Tunnel Vision in the Detection Response Task*. S. 992–1003.

Objective: In a driving simulator, a backwards counting task, a simple steering task, and a fully autonomous driving task were applied to study the independent effects of cognitive load, visual-cognitive-manual load, and optic flow on visual detection response task (vDRT) performance. The study was designed to increase the understanding of the processes underlying vDRT effects. **Background:** The tunnel vision effect induced by a “steering while driving” task found in a previous study was investigated further in this experiment. **Method:** Stimulus eccentricity and conspicuity were applied as within-subjects factors. **Results:** Cognitive load, visual-cognitive-manual load, and optic flow all resulted in increased vDRT response time (RT). Cognitive load and visual-cognitive-manual load both increased RT but revealed no interaction of task by stimulus eccentricity. However, optic flow resulted in a task by stimulus eccentricity interaction on vDRT RT that was evidence of a tunnel vision effect. **Conclusion:** The results suggested that optic flow may be a factor responsible for tunnel vision while driving, although this does not support the tunnel vision model because it is unrelated to workload. However, the results supported the general interference model for cognitive workload. **Application:** The results have implications for the diagnosticity of the vDRT. During driving tasks, tunnel vision effects may occur as a result of optic flow, and these effects are unrelated to workload.

- **Keywords:** workload, optic flow, peripheral detection task, detection response task, tunnel vision

SIMULATION AND VIRTUAL REALITY

René Reinhard, Ender Tutulmaz, Hans M. Rutrecht, Patricia Hengstenberg, Britta Geissler, Heiko Hecht, Axel Müttray. *Effects of Visually Induced Motion Sickness on Emergency Braking Reaction Times in a Driving Simulator*. S. 1004–1018.

Objective: The study explores associations of visually induced motion sickness (VIMS) with emergency braking reaction times (RTs) in driving simulator studies. It examines the effects over the progression of multiple simulated drives. **Background:** Driving simulator usage has many advantages for RT studies; however, if it induces VIMS, the observed driving behavior might deviate from real-world driving, potentially masking or skewing results. Possible effects of VIMS on RT have long been entertained, but the progression of VIMS across simulated drives has so far not been sufficiently considered. **Method:** Twenty-eight adults completed six drives on 2 days in a fixed-base driving simulator. At five points during each drive, pedestrians entered the road, necessitating emergency braking maneuvers. VIMS severity was assessed every minute using the 20-point Fast Motion Sickness Scale. The progression of VIMS was considered in mixed model analyses. **Results:** RT predictions were improved by considering VIMS development over time. Here, the relationship of VIMS and RT differed across days and drives. Increases in VIMS symptom severity predicted more prolonged RT after repeated drives on a given day and earlier within each drive. **Conclusion:** The assessment of

VIMS in RT studies can be beneficial. In this context, VIMS measurements in close temporal proximity to the behaviors under study are promising and offer insights into VIMS and its consequences, which are not readily obtainable through questionnaires. **Application:** Driving simulator-based RT studies should consider cumulative effects of VIMS on performance. Measurement and analysis strategies that consider the time-varying nature of VIMS are recommended.

- **Keywords:** driving simulation, simulator sickness, Fast Motion Sickness Scale, generalized mixed models, time-varying covariate