

Human Factors – rok 2010, roč. 52

Číslo 1



AGING AND INDIVIDUAL DIFFERENCES

Yang, Bing-Shiang; Ashton-Miller, James A. Effect of Practice on Stepping Movements Onto Laterally Compliant Raised Structures: Age Differences in Healthy Males. S. 3-16(14).

Objective: The aim of this study was to examine effects of practice and age on step-up movements onto raised structures. **Background:** Falls from laterally compliant structures, such as stepladders, often cause injuries in elderly persons. Although age differences in step-up movements onto raised structures with unexpected structural compliance have been reported, practice effects of such movement control have not been investigated. **Method:** Movement behavior of 20 healthy adults (10 young and 10 older males) was measured while they stepped up onto a raised structure with no compliance (i.e., rigid) (C_0), a small amount of mediolateral compliance (C_1), or greater mediolateral compliance (C_2). The conditions C_0 , C_1 , and C_2 were presented in three sets of six fixed-order trials with step-up movements performed at a comfortable speed. Practice effects in step-up behavior were examined by comparing data within each trial block with the use of repeated-measures ANOVA. **Results:** Practice significantly reduced the stepping duration (T_s) needed to complete the step-up movement ($p < .001$). With practice, older males reduced their lateral oscillations 26% to 40% for C_1 and C_2 , whereas the corresponding results for young males lay between 8% and 17%, respectively. The age difference in T_s decreased across six consecutive trials but remained significant, especially on the structure with greater compliance. **Conclusion:** With practice, both young and elderly men adapted their stepping behavior to the presence of lateral structural compliance, but it is noteworthy from a fall-injury prevention perspective that the elderly men required more trials to do so. **Application:** Designers and users of raised structures, such as stepladders, should be aware of the age difference of people using such structures and should minimize the structure compliance when designing them.

- **Keywords:** AGING; RECOGNITION; SENSORY AND PERCEPTUAL PROCESSES; ACCIDENTS; SAFETY; AND HUMAN ERROR; BALANCE; PRACTICE EFFECTS; STEPPING MOVEMENTS; STEPLADDERS; ELDERLY INJURIES; MOVEMENT CONTROL; MEDIOLATERAL COMPLIANCE; STEP-UP BEHAVIOR; STEPPING DURATION; LATERAL OSCILLATIONS; FALL INJURY PREVENTION; STRUCTURE COMPLIANCE; SUPPORT SURFACE; SYSTEM IDENTIFICATION; FALL RISK

AUTOMATION, EXPERT SYSTEMS

Cummings, M.L.; Clare, Andrew; Hart, Christin. *The Role of Human-Automation Consensus in Multiple Unmanned Vehicle Scheduling. S. 17-27(11).*

Objective: This study examined the impact of increasing automation replanning rates on operator performance and workload when supervising a decentralized network of heterogeneous unmanned vehicles. **Background:** Futuristic unmanned vehicles systems will invert the operator-to-vehicle ratio so that one operator can control multiple dissimilar vehicles connected through a decentralized network. Significant human-automation collaboration will be needed because of automation brittleness, but such collaboration could cause high workload. **Method:** Three increasing levels of replanning were tested on an existing multiple unmanned vehicle simulation environment that leverages decentralized algorithms for vehicle routing and task allocation in conjunction with human supervision. **Results:** Rapid replanning can cause high operator workload, ultimately resulting in poorer overall system performance. Poor performance was associated with a lack of operator consensus for when to accept the automation's suggested prompts for new plan consideration as well as negative attitudes toward unmanned aerial vehicles in general. Participants with video game experience tended to collaborate more with the automation, which resulted in better performance. **Conclusion:** In decentralized unmanned vehicle networks, operators who ignore the automation's requests for new plan consideration and impose rapid replans both increase their own workload and reduce the ability of the vehicle network to operate at its maximum capacity. **Application:** These findings have implications for personnel selection and training for futuristic systems involving human collaboration with decentralized algorithms embedded in networks of autonomous systems.

- **Keywords:** UNMANNED VEHICLES; HUMAN SUPERVISORY CONTROL; WORKLOAD; HUMAN-AUTOMATION COLLABORATION; SCHEDULING; VEHICLE ROUTING; TRUST; HUMAN-AUTOMATION CONSENSUS; OPERATOR-TO-VEHICLE RATIO; DECENTRALIZED NETWORK; AUTOMATION BRITTLINESS; TASK ALLOCATION; UNMANNED AERIAL VEHICLES; UAV

DISPLAYS AND CONTROLS

Damle, Amod. *Using Monochromatic Design Views to Avoid a Premature Fixation on Design Solutions. S. 28-40(13).*

This study investigates whether the availability of a monochromatic design view can prevent an early fixation on details during the preliminary stages of a design task. **Background:** Design students are trained to tentatively sketch the overall form of a design concept before attending to its details. Literature suggests that using multiple colors for sketching a concept causes a gestalt-like grouping phenomenon and influences designers to adopt a contrasting strategy of adding details before sketching the overall form. An empirical study was conducted to assess the validity of these findings. **Method:** In the study, 20 participants, randomly assigned to two groups, were allowed to use multiple colors to sketch a design concept within a digital sketching environment. However, only the single-color group had the ability to view a sketch, as it would appear in monochrome. **Results:** Both groups parsed the design concepts into their basic components and used colors as a means of distinguishing one component from another. However, the single-color group added significantly more details than the first or the multicolor group after sketching the overall form. **Conclusion:** Verbal reports suggest that the single-color group was able to avoid an early fixation on details because the single-color view eliminated the discontinuities induced by the variation in color and allowed the participants to attend to the overall form instead of the individual components. **Application:** The current findings highlight the importance of providing a monochrome design view within a sketching environment to avoid an early fixation on a specific design solution.

- **Keywords:** DESIGN COGNITION; CREATIVITY; SKETCHING; REPRESENTATION AIDING; GRAPHIC DESIGN TOOLS; HUMAN-COMPUTER INTERACTION; HCI; COMPUTER SYSTEMS; DISPLAYS AND CONTROLS; PROTOTYPING; VISUAL DISPLAYS; GESTALT; PERCEPTUAL GROUPING; PERCEPTION; MONOCHROMATIC DESIGN VIEWS; FIXATION AVOIDANCE; DESIGN TASK; DESIGN CONCEPT; DESIGN DETAILS; MULTIPLE COLORS; DIGITAL SKETCHING ENVIRONMENT; SINGLE COLOR VIEW; COGNITIVE BIAS

McIntire, John P.; Havig, Paul R.; Watamaniuk, Scott N.J.; Gilkey, Robert H. *Visual Search Performance With 3-D Auditory Cues : Effects of Motion, Target Location, and Practice. S. 41-53(13).*

Objectives: We evaluate visual search performance in both static (nonmoving) and dynamic (moving) search environments with and without spatial (3-D) auditory cues to target location. Additionally, the effects of target trajectory, target location, and practice are assessed. **Background:** Previous research on aurally aided visual search has shown a significant reduction in response times when 3-D auditory cues are displayed, relative to unaided search. However, the vast majority of this research has examined only searches for static targets in static visual environments. The present experiment was conducted to examine the effect of dynamic stimuli upon aurally aided visual search performance. **Method:** The 8 participants conducted repeated searches for a single visual target hidden among 15 distracting stimuli. The four main conditions of the experiment consisted of the four possible combinations of 3-D auditory cues (present or absent) and search environment (static or dynamic). **Results:** The auditory cues were comparably effective at reducing search times in dynamic environments (-25%) as in static environments (-22%). Audio cues helped all participants. The cues were most beneficial when the target appeared at large eccentricities and on the horizontal plane. After a brief initial exposure to 3-D audio, no training or practice effects with 3-D audio were found. **Conclusion:** We conclude that 3-D audio is as beneficial in environments comprising moving stimuli as in those comprising static stimuli. **Application:** Operators in dynamic environments, such as aircraft cockpits, ground vehicles, and command-and-control centers, could benefit greatly from 3-D auditory technology when searching their environments for visual targets or other time-critical information.

- **Keywords:** VISUAL SEARCH; 3-D AUDIO; VIRTUAL AUDIO; SPATIAL AUDIO; MOTION; SOUND LOCALIZATION; DYNAMIC SEARCH; ATTENTIONAL CUEING; AUDIOVISUAL INTERACTION; DISPLAYS; AUDITORY DISPLAYS; REACTION TIME; AUDITION; VISION; HUMAN-COMPUTER INTERACTION; HCI; COMPUTER SYSTEMS; DISPLAYS AND CONTROLS; PSYCHOMOTOR PROCESSES; SENSORY AND PERCEPTUAL PROCESSES; VISUAL SEARCH PERFORMANCE; STATIC AND DYNAMIC SEARCH; SEARCH ENVIRONMENTS; SPATIAL AUDITORY CUES; TARGET LOCATION; TARGET TRAJECTORY; AURALLY AIDED VISUAL SEARCH; DYNAMIC STIMULI; MOVING STIMULI; STATIC STIMULI; 3-D AUDITORY CUES

McKeown, Denis; Isherwood, Sarah; Conway, Gareth. *Auditory Displays as Occasion Setters. S. 54-62(9).*

Objective: The aim of this study was to evaluate whether representational sounds that capture the richness of experience of a collision enhance performance in braking to avoid a collision relative to other forms of warnings in a driving simulator. **Background:** There is increasing interest in auditory warnings that are informative about their referents. But as well as providing information about some intended object, warnings may be designed to set the occasion for a rich body of information about the outcomes of behavior in a particular context. These richly informative warnings may offer performance advantages, as they may be rapidly processed by users. **Method:** An auditory occasion setter for a collision (a recording of screeching brakes indicating imminent collision) was compared with two other auditory warnings (an abstract and an "environmental" sound), a speech

message, a visual display, and no warning in a fixed-base driving simulator as interfaces to a collision avoidance system. The main measure was braking response times at each of two headways (1.5 s and 3 s) to a lead vehicle. **Results:** The occasion setter demonstrated statistically significantly faster braking responses at each headway in 8 out of 10 comparisons (with braking responses equally fast to the abstract warning at 1.5 s and the environmental warning at 3 s). **Conclusion:** Auditory displays that set the occasion for an outcome in a particular setting and for particular behaviors may offer small but critical performance enhancements in time-critical applications. **Application:** The occasion setter could be applied in settings where speed of response by users is of the essence.

- **Keywords:** AUDITORY DISPLAYS; DRIVING; OCCASION SETTERS; DISPLAYS AND CONTROLS; DRIVER BEHAVIOR; COLLISION AVOIDANCE; AUDITORY WARNINGS

Stoelen, Martin F.; Akin, David L. *Assessment of Fitts' Law for Quantifying Combined Rotational and Translational Movements. S. 63-77(15).*

Objective: To develop a model for human performance in combined translational and rotational movements based on Fitts' law. **Background:** Fitts' law has been successfully applied to translational movements in the past, providing generalization beyond a specific task as well as performance predictions. For movements involving both translations and rotations, no equivalent theory exists, making comparisons of input devices for these movements more ambiguous. **Method:** The study consisted of three experiments. In the first two, participants performed either pure translational or pure rotational movements of 1 degree of freedom. The third experiment involved the same movements combined. **Results:** On average, the performance times for combined movements were equal to the sum of the times for equivalent separate rotational and translational movements. A simple Fitts' law equivalent for combined movements with a similar slope as the separate components was proposed. In addition, a significant degree of coordination of the combined movements was found. This had a strong bias toward a parallel execution in 12 out of 13 participants. **Conclusion:** Combined movements with rotations and translations of 1 degree of freedom can be approximated using a simple Fitts' law equivalent. The rotational and translational components appear to be coordinated by the central nervous system to generate a parallel execution. **Application:** The results may help drive human interface designs and provide insights into the coordination of combined movements. Future extensions may be possible for the movements of higher degrees of freedom used in robot teleoperation and virtual reality applications.

- **Keywords:** FITTS' LAW; INTERFACE EVALUATION; USABILITY; HUMAN-COMPUTER INTERACTION; HCI; HUMAN PERFORMANCE MODELING; ROBOT TELEOPERATION; COMPUTER SYSTEMS; ROTATIONAL AND TRANSLATIONAL MOVEMENTS; PERFORMANCE PREDICTION; INPUT DEVICES; MOVEMENT COORDINATION; CENTRAL NERVOUS SYSTEM; VIRTUAL REALITY; DEGREES OF FREEDOM

Harrison, William J.; Thompson, Matthew B.; Sanderson, Penelope M. *Multisensory Integration With a Head-Mounted Display : Background Visual Motion and Sound Motion. S. 78-91(14).*

Objective: The aim of this study was to assess how background visual motion and the relative movement of sound affect a head-mounted display (HMD) wearer's performance at a task requiring integration of auditory and visual information. **Background:** HMD users are often mobile. A commercially available speaker in a fixed location delivers auditory information affordably to the HMD user. However, previous research has shown that mobile HMD users perform poorly at tasks that require integration of visual and

auditory information when sound comes from a free-field speaker. The specific cause of the poor task performance is unknown. **Method:** Participants counted audiovisual events that required integration of sounds delivered via a free-field speaker and vision on an HMD. Participants completed the task while either walking around a room, sitting in the room, or sitting inside a mobile room that allowed separate manipulation of background visual motion and speaker motion. **Results:** Participants' accuracy at counting target audiovisual events was worse when participants were walking than when sitting at a desk, $p = .032$. Compared with when they were sitting at a desk, participants' accuracy at counting target audiovisual events showed a trend to be worse when they experienced a combination of background visual motion and the relative movement of sound, $p = .058$. **Conclusion:** Multisensory integration performance is least effective when HMD users experience a combination of background visual motion and relative movement of sound. Eye reflexes may play an important role. **Application:** Results apply to situations in which HMD wearers are mobile when receiving multimodal information, as in health care and military contexts.

- **Keywords:** MULTISENSORY INTEGRATION; WEARABLE COMPUTING; HEAD-MOUNTED DISPLAYS; AUDITORY DISPLAYS; VECTION; EYE MOVEMENT; BACKGROUND VISUAL MOTION; MOBILE HEAD-MOUNTED DISPLAYS; FREE-FIELD SPEAKER; SPEAKER MOTION; OPTOKINETIC NYSTAGMUS; SELF-MOTION; MULTIMODAL DISPLAYS; DISPLAYS AND CONTROLS; PSYCHOMOTOR PROCESSES; TRACKING; VISION; EVENT DETECTION; PERCEPTUAL PERFORMANCE; VISUAL PERFORMANCE

Thompson, Matthew B.; Tear, Morgan J.; Sanderson, Penelope M. *Multisensory Integration With a Head-Mounted Display : Role of Mental and Manual Load. S. 92-104(13).*

Objective: The aim of this study was to replicate the finding that multisensory integration with a head-mounted display (HMD) is particularly difficult when a person is walking and hearing sound from a free-field speaker, and to extend the finding with a response method intended to reduce workload. **Background:** HMDs can support the information needs of workers whose work requires mobility, but some low-cost solutions for delivering auditory information may be less effective than others. **Method:** For the study, 24 participants detected whether shapes moving on the HMD screen made a sound appropriate to their forms when they collided with other shapes. Independent variables were self-motion (participants were mobile or seated), sound delivery (free-field speakers or an earpiece), and response method (noting mismatches via a mental count or via a manual clicker). **Results:** Unexpectedly, overall mismatch task accuracy was worse with the clicker ($p = .027$) than without. Participants also reported that it was harder to time-share the mismatch task with clicker responses ($p = .033$). In the clicker condition, self-motion and sound delivery interacted but in the opposite direction to the previous study. **Conclusion:** The best way of delivering auditory information to mobile workers performing a multisensory integration task with an HMD may depend on whether responding involves mental load or manual load. Broader theories are needed to capture factors influencing performance. **Application:** Until more powerful theory is developed, designers should perform careful formative and summative tests of whether the activities to be performed by mobile HMD wearers will make some sound delivery solutions less effective than others.

- **Keywords:** MULTISENSORY INTEGRATION; WEARABLE COMPUTING; HEAD-MOUNTED DISPLAY; SELF-MOTION; AUDITORY DISPLAYS; SOUND DELIVERY SOLUTIONS; EARPIECE; DETECTION OF MULTIMODAL EVENTS; WORKLOAD; SENSORY AND PERCEPTUAL PROCESSES; DISPLAYS AND CONTROLS; VISUAL DISPLAYS; OBJECT DISPLAYS; MENTAL WORKLOAD; MANUAL WORKLOAD; ATTENTIONAL PROCESSES; RESPONSE MODES; VECTION; MOBILE WORK; FREE-FIELD SPEAKERS; AUDITORY INFORMATION; MOVEMENT OF SHAPES;

SELF-MOTION AND SOUND DELIVERY INTERACTION; MOBILE WORKERS;
MULTISENSORY INTEGRATION TASK; MENTAL AND MANUAL LOAD; MOBILE
HMD WEARERS; PERCEPTUAL PERFORMANCE; MOTOR PERFORMANCE

SENSORY AND PERCEPTUAL PROCESSES

Kortum, Philip; Sullivan, Marc. *The Effect of Content Desirability on Subjective Video Quality Ratings*. S. 105-118(14).

Objective: The purpose of this study was to examine the impact of the desirability of content on viewers' ratings of subjective video quality. **Background:** Most subjective video quality studies use short-duration clips that are specially designed to exercise the encoding algorithms and do not consider the desirability of the content as a variable. **Method:** In four studies, we employed a total of 100 participants and 180 movie clips encoded at nine levels from 550 kbps up to DVD quality. Participants viewed clips that were 2 min in length and then were asked about video quality of the clips and desirability of the movie content. **Results:** The results of these studies show that there is a strong correlation between the desirability of movie content and subjective ratings of video quality. This strong relationship holds across a wide range of encoding levels and movie content when that content is viewed under longer, more naturalistic viewing conditions. **Conclusion:** The effects of content should be considered when evaluating the subjective quality of encoded video content, as these effects can be as large as those seen between low- and high-quality encodings. **Application:** Researchers and practitioners trying to determine acceptable levels of video quality for actual consumption by consumers may find that the results and methods described here allow for a more accurate assessment of levels of video quality that are acceptable in a fielded service.

- **Keywords:** VIDEO QUALITY; SUBJECTIVE VIDEO QUALITY; VIDEO CONTENT; IMAGE PERCEPTION; MEAN OPINION SCORE; NATURALISTIC VIEWING CONDITIONS

TRAINING, EDUCATION, INSTRUCTIONAL SYSTEMS

Burkolter, Dina; Meyer, Bertolt; Kluge, Annette; Sauer, Jürgen. *Assessment of Structural Knowledge as a Training Outcome in Process Control Environments*. S. 119-138(20).

Objective: The objective of the present studies was to apply a novel method for structural knowledge assessment to process control to assess the potential of its measures as a training outcome. **Background:** Traditionally, knowledge is assessed by verbal achievement tests on the subject matter. However, traditional methods are regarded as limited in their ability to assess higher-order learning or understanding. **Method:** Two experiments (Experiment 1, $N = 41$; Experiment 2, $N = 50$) were conducted in which participants were given a 4-hr training session on a simulated process control task. At a later testing session, participants worked on the task for 70 min and completed knowledge tests on declarative, procedural, and structural knowledge. Structural knowledge was measured with the computer-based Association Structure Test (AST), which combines an association task and Pathfinder network on the basis of relatedness ratings. **Results:** In both studies, structural knowledge was significantly related to diagnostic performance, and evidence was found for internal consistency as well as convergent and predictive validity. **Conclusion:** Findings indicate that structural assessment with the AST shows promise as a training outcome in process control. **Application:** Potential applications of this research include the improvement of training design, delivery, and evaluation.

- **Keywords:** PROCESS CONTROL SYSTEMS; TRAINING; STRUCTURAL KNOWLEDGE; KNOWLEDGE ELICITATION; TRAINING EVALUATION;

AUTOMATION; EDUCATION; INSTRUCTIONAL SYSTEMS; MANUFACTURING;
PROCESS CONTROL ENVIRONMENTS; TRAINING MEASURES; HIGHER-ORDER
LEARNING; PATHFINDER NETWORK; RELATEDNESS RATINGS; DIAGNOSTIC
PERFORMANCE; CONVERGENT AND PREDICTIVE VALIDITY; ASSOCIATION
TASK; TRAINING OUTCOME; KNOWLEDGE ASSESSMENT