

## Human Factors – rok 2014, roč. 56

### Číslo 4 (June)



#### ACCIDENTS, HUMAN ERROR

**Jinglong Wu, Jiajia Yang, Masayuki Yoshitake.** *Pedal Errors Among Younger and Older Individuals During Different Pedal Operating Conditions.* S. 621-630.

**Objective:** The objective of this study was to investigate the characteristics of pedal errors by younger and older drivers that relate to sudden unintended acceleration (SUA) accidents. **Background:** SUA during an accident is a serious issue that causes numerous critical injuries and deaths every year. Previous studies have indicated that the major factor in these accidents is pedal error; however, the characteristics that relate to SUA accidents in older drivers remain unclear. **Method:** Twenty younger drivers (YDs;  $23.1 \pm 0.22$  years) and 20 older drivers (ODs;  $68.9 \pm 1.16$  years) used either one or both feet to participate in six tasks that involved pressing accelerator or brake pedals in response to various visual stimuli. **Results:** Both the reaction times (RTs) and the pedal error rates of the YD and OD groups significantly increased with the difficulty of the task. Other than the simple reaction condition, we found that the pedal error rates were significantly higher for the OD group than for the YD group; the OD group also demonstrated longer RTs. Moreover, the rates of accelerator error were consistently two or three times higher than the rates of brake error in both the YD and OD groups. **Conclusion:** For the older population, the use of the left foot to operate the brake pedal and the right foot to operate the accelerator could decrease the accelerator error rate and may reduce the rate of SUA-related accidents that are caused by pedal error.

- **Keywords:** pedal error, sudden unintended acceleration, aging effect, motor vehicle accident

**Frédéric Dehais, Mickaël Causse, François Vachon, Nicolas Régis, Eric Menant, Sébastien Tremblay.** *Failure to Detect Critical Auditory Alerts in the Cockpit: Evidence for Inattentive Deafness.* S. 631-644.

**Objective:** The aim of this study was to test whether inattentive deafness to critical alarms would be observed in a simulated cockpit. **Background:** The inability of pilots to detect unexpected changes in their auditory environment (e.g., alarms) is a major safety problem in aeronautics. In aviation, the lack of response to alarms is usually not attributed to attentional limitations, but rather to pilots choosing to ignore such warnings due to decision biases, hearing issues, or conscious risk taking. **Method:** Twenty-eight general aviation pilots performed two landings in a flight simulator. In one scenario an auditory alert was triggered alone, whereas in the other the auditory alert occurred while the pilots dealt with a critical windshear. **Results:** In the windshear scenario, 11 pilots

(39.3%) did not report or react appropriately to the alarm whereas all the pilots perceived the auditory warning in the no-windshear scenario. Also, of those pilots who were first exposed to the no-windshear scenario and detected the alarm, only three suffered from inattentive deafness in the subsequent windshear scenario. **Conclusion:** These findings establish inattentive deafness as a cognitive phenomenon that is critical for air safety. Pre-exposure to a critical event triggering an auditory alarm can enhance alarm detection when a similar event is encountered subsequently. **Application:** Case-based learning is a solution to mitigate auditory alarm misperception.

- **Keywords:** inattentive deafness, auditory alarms, warning misperception, aeronautics, eye tracking, psychophysiology

## **BIOMECHANICS, ANTHROPOMETRY, WORK PHYSIOLOGY**

**Ranjana K. Mehta, Raja Parasuraman. *Effects of Mental Fatigue on the Development of Physical Fatigue : a Neuroergonomic Approach. S. 645-656.***

**Objective:** The present study used a neuroergonomic approach to examine the interaction of mental and physical fatigue by assessing prefrontal cortex activation during submaximal fatiguing handgrip exercises. **Background:** Mental fatigue is known to influence muscle function and motor performance, but its contribution to the development of voluntary physical fatigue is not well understood. **Method:** A total of 12 participants performed separate physical (control) and physical and mental fatigue (concurrent) conditions at 30% of their maximal handgrip strength until exhaustion. Functional near infrared spectroscopy was employed to measure prefrontal cortex activation, whereas electromyography and joint steadiness were used simultaneously to quantify muscular effort. **Results:** Compared to the control condition, blood oxygenation in the bilateral prefrontal cortex was significantly lower during submaximal fatiguing contractions associated with mental fatigue at exhaustion, despite comparable muscular responses. **Conclusion:** The findings suggest that interference in the prefrontal cortex may influence motor output during tasks that require both physical and cognitive processing. **Application:** A neuroergonomic approach involving simultaneous monitoring of brain and body functions can provide critical information on fatigue development that may be overlooked during traditional fatigue assessments.

- **Keywords:** cognitive demand, motor performance, endurance, near infrared spectroscopy, cerebral oxygenation, prefrontal cortex

**Robert G. Radwin, Amrish O. Chourasia, Robert S. Howery, Frank J. Fronczak, Thomas Y. Yen, Yashpal Subedi, Mary E. Sesto. *Factors Influencing Power Hand Tool Fastening Accuracy and Reaction Forces. S. 657-668.***

**Objective:** A laboratory study investigated the relationship between power hand tool and task-related factors affecting threaded fastener torque accuracy and associated handle reaction force. **Background:** We previously developed a biodynamic model to predict handle reaction forces. We hypothesized that torque accuracy was related to the same factors that affect operator capacity to react against impulsive tool forces, as predicted by the model. **Method:** The independent variables included tool (pistol grip on a vertical surface, right angle on a horizontal surface), fastener torque rate (hard, soft), horizontal distance (30 cm and 60 cm), and vertical distance (80 cm, 110 cm, and 140 cm). Ten participants (five male and five female) fastened 12 similar bolts for each experimental condition. **Results:** Average torque error (audited – target torque) was affected by fastener torque rate and operator position. Torque error decreased 33% for soft torque rates, whereas handle forces greatly increased (170%). Torque error also decreased for

the far horizontal distance 7% to 14%, when vertical distance was in the middle or high, but handle force decreased slightly 3% to 5%. **Conclusion:** The evidence suggests that although both tool and task factors affect fastening accuracy, they each influence handle reaction forces differently. We conclude that these differences are attributed to different parameters each factor influences affecting the dynamics of threaded faster tool operation. Fastener torque rate affects the tool dynamics, whereas posture affects the spring-mass-damping biodynamic properties of the human operator. **Application:** The prediction of handle reaction force using an operator biodynamic model may be useful for codifying complex and unobvious relationships between tool and task factors for minimizing torque error while controlling handle force.

- **Keywords:** biomechanics, ergonomic design, occupational safety and health, power hand tools, crewdriver

**Alicia Kurowski, Bryan Buchholz, ProCare Research Team, Laura Punnett.** *A Physical Workload Index to Evaluate a Safe Resident Handling Program for Nursing Home Personnel.* S. 669-683.

**Objective:** The aim of this study was to obtain a comprehensive analysis of the physical workload of clinical staff in long-term care facilities, before and after a safe resident handling program (SRHP). **Background:** Ergonomic exposures of health care workers include manual handling of patients and many non-neutral postures. A comprehensive assessment requires the integration of loads from these varied exposures into a single metric. **Method:** The Postures, Activities, Tools, and Handling observational protocol, customized for health care, was used for direct observations of ergonomic exposures in clinical jobs at 12 nursing homes before the SRHP and 3, 12, 24, and 36 months afterward. Average compressive forces on the spine were estimated for observed combinations of body postures and manual handling and then weighted by frequencies of observed time for the combination. These values were summed to obtain a biomechanical index for nursing assistants and nurses across observation periods. **Results:** The physical workload index (PWI) was much higher for nursing assistants than for nurses and decreased more after 3 years (-24% versus -2.5%). Specifically during resident handling, the PWI for nursing assistants decreased by 41% of baseline value. **Conclusion:** Spinal loading was higher for nursing assistants than for nurses in long-term care centers. Both job groups experienced reductions in physical loading from the SRHP, especially the nursing assistants and especially while resident handling. **Application:** The PWI facilitates a comprehensive investigation of physical loading from both manual handling and non-neutral postures. It can be used in any work setting to identify high-risk tasks and determine whether reductions in one exposure are offset by increases in another.

- **Keywords:** intervention effectiveness, ergonomic tools and methods, health care ergonomics

**Richard T. Stone, Brandon F. Moeller, Robert R. Mayer, Bryce Rosenquist, Darin Van Ryswyk, Drew Eichorn.** *Biomechanical and Performance Implications of Weapon Design: Comparison of Bullpup and Conventional Configurations.* S. 684-695.

**Objective:** Shooter accuracy and stability were monitored while firing two bullpup and two conventional configuration rifles of the same caliber in order to determine if one style of weapon results in superior performance. **Background:** Considerable debate exists among police and military professionals regarding the differences between conventional configuration weapons, where the magazine and action are located ahead of the trigger, and bullpup configuration, where they are located behind the trigger (closer to the user). To date, no published research has attempted to evaluate this question from a physical

ergonomics standpoint, and the knowledge that one style might improve stability or result in superior performance is of interest to countless military, law enforcement, and industry experts. **Method:** A live-fire evaluation of both weapon styles was performed using a total of 48 participants. Shooting accuracy and fluctuations in biomechanical stability (center of pressure) were monitored while subjects used the weapons to perform standard drills. **Results:** The bullpup weapon designs were found to provide a significant advantage in accuracy and shooter stability, while subjects showed considerable preference toward the conventional weapons. **Conclusion:** Although many mechanical and maintenance issues must be considered before committing to a bullpup or conventional weapon system, it is clear in terms of basic human stability that the bullpup is the more advantageous configuration. **Application:** Results can be used by competitive shooter, military, law enforcement, and industry experts while outfitting personnel with a weapon system that leads to superior performance.

- **Keywords:** biomechanics, design, firearms, stability, bullpup, weapon configuration, rifle ergonomics

## COGNITION

**Malcolm Hobbs, Philip A. Higham, Wendy Kneller. *Memory and Metacognition in Dangerous Situations : Investigating Cognitive Impairment From Gas Narcosis in Undersea Divers. S. 696-709.***

**Objective:** The current study tested whether undersea divers are able to accurately judge their level of memory impairment from inert gas narcosis. **Background:** Inert gas narcosis causes a number of cognitive impairments, including a decrement in memory ability. Undersea divers may be unable to accurately judge their level of impairment, affecting safety and work performance. **Method:** In two underwater field experiments, performance decrements on tests of memory at 33 to 42 m were compared with self-ratings of impairment and resolution. The effect of depth (shallow [1-11 m] vs. deep [33-42 m]) was measured on free-recall (Experiment 1;  $n = 41$ ) and cued-recall (Experiment 2;  $n = 39$ ) performance, a visual-analogue self-assessment rating of narcotic impairment, and the accuracy of judgements-of-learning (JOLs). **Results:** Both free- and cued-recall were significantly reduced in deep, compared to shallow, conditions. This decrement was accompanied by an increase in self-assessed impairment. In contrast, resolution (based on JOLs) remained unaffected by depth. The dissociation of memory accuracy and resolution, coupled with a shift in a self-assessment of impairment, indicated that divers were able to accurately judge their decrease in memory performance at depth. **Conclusion:** These findings suggest that impaired self-assessment and resolution may not actually be a symptom of narcosis in the depth range of 33 to 42 m underwater and that the divers in this study were better equipped to manage narcosis than prior literature suggested. The results are discussed in relation to implications for diver safety and work performance.

- **Keywords:** memory, inert gas narcosis, metacognition, diving, judgements of learning, free recall, cued recall, resolution, diver safety

**Daniel Gartenberg, Leonard Breslow, J. Malcolm McCurry, J. Greg Trafton. *Situation Awareness Recovery. S. 710-727.***

**Objective:** We describe a novel concept, situation awareness recovery (SAR), and we identify perceptual and cognitive processes that characterize SAR. **Background:** Situation awareness (SA) is typically described in terms of perceiving relevant elements of the environment, comprehending how those elements are integrated into a meaningful whole, and projecting that meaning into the future. Yet SA fluctuates during the time course of a task, making it important to understand the process by which SA is recovered after it is degraded. **Method:** We investigated SAR using different types of interruptions

to degrade SA. In Experiment 1, participants watched short videos of an operator performing a supervisory control task, and then the participants were either interrupted or not interrupted, after which SA was assessed using a questionnaire. In Experiment 2, participants performed a supervisory control task in which they guided vehicles to their respective targets and either experienced an interruption, during which they performed a visual search task in a different panel, or were not interrupted. **Results:** The SAR processes we identified included shorter fixation durations, increased number of objects scanned, longer resumption lags, and a greater likelihood of refixating on objects that were previously looked at. **Conclusions:** We interpret these findings in terms of the memory-for-goals model, which suggests that SAR consists of increased scanning in order to compensate for decay, and previously viewed cues act as associative primes that reactivate memory traces of goals and plans.

- **Keywords:** attention, supervisory control, eye movements, memory for goals, situation awareness

**Ioanna Katidioti, Niels A. Taatgen. *Choice in Multitasking : How Delays in the Primary Task Turn a Rational Into an Irrational Multitasker. S. 728-736.***

**Objective:** The objective was to establish the nature of choice in cognitive multitasking. **Background:** Laboratory studies of multitasking suggest people are rational in their switch choices regarding multitasking, whereas observational studies suggest they are not. Threaded cognition theory predicts that switching is opportunistic and depends on availability of cognitive resources. **Method:** A total of 21 participants answered e-mails by looking up information (similar to customer service employees) while being interrupted by chat messages. They were free to choose when to switch to the chat message. We analyzed the switching behavior and the time they needed to complete the primary mail task. **Results:** When participants are faced with a delay in the e-mail task, they switch more often to the chat task at high-workload points. Choosing to switch to the secondary task instead of waiting makes them slower. It also makes them forget the information in the e-mail task half of the time, which slows them down even more. **Conclusion:** When many cognitive resources are available, the probability of switching from one task to another is high. This does not necessarily lead to optimal switching behavior. **Application:** Potential applications of this research include the minimization of delays in task design and the inability or discouragement of switching in high-workload moments.

- **Keywords:** multitasking, interruption, attention, workload, delay human-computer interaction

**Stephen J. Guastello, Matthew Malon, Paul Timm, Kelsey Weinberger, Hillary Gorin, Megan Fabisch, Kirsten Poston. *Catastrophe Models for Cognitive Workload and Fatigue in a Vigilance Dual Task. S. 737-751.***

**Objective:** This study investigated two cusp catastrophe models for cognitive workload and fatigue for a vigilance dual task, the role of emotional intelligence and frustration in the performance dynamics, and the dynamics for individuals and teams of two participants. **Background:** The effects of workload, fatigue, practice, and time on a specific task can be separated with the two models and an appropriate experimental design. Group dynamics add further complications to the understanding of workload and fatigue effects for teams. **Method:** In this experiment, 141 undergraduates responded to target stimuli that appeared on a simulated security camera display at three rates of speed while completing a jigsaw puzzle. Participants worked alone or in pairs and completed additional measurements prior to or after the main tasks. **Results:** The workload cusp verified the expected effects of speed and frustration on change in performance. The fatigue cusp showed that positive and negative changes in

performance were greater if more work on the secondary task was completed and whether the participants who started with the fast vigilance condition demonstrated less fatigue. **Conclusion:** The results supported the efficacy of the cusp models and suggested, furthermore, that training modules that varied speed of presentation could buffer the effects of fatigue. **Application:** The cusp models can be used to analyze virtually any cognitively demanding task set. The particular results generalize to vigilance tasks, although a wider range of conditions within vigilance tasks needs to be investigated further.

- **Keywords:** cognitive workload, fatigue, cusp catastrophe, speed, dual task performance, vigilance

## DISPLAYS AND CONTROLS

**Anna Pereira, Chih-Ming Hsieh, Charles Laroche, David Rempel.** *The Effect of Keyboard Key Spacing on Typing Speed, Error, Usability, and Biomechanics, Part 2: Vertical Spacing.* S. 752-759.

**Objective:** The objective was to evaluate the effects of vertical key spacing on a conventional computer keyboard on typing speed, percentage error, usability, forearm muscle activity, and wrist posture for both females with small fingers and males with large fingers. **Background:** Part 1 evaluated primarily horizontal key spacing and found that for male typists with large fingers, productivity and usability were similar for spacings of 17, 18, and 19 mm but were reduced for spacings of 16 mm. Few other key spacing studies are available, and the international standards that specify the spacing between keys on a keyboard have been mainly guided by design convention. **Method:** Experienced female typists ( $n = 26$ ) with small fingers (middle finger length  $\leq 7.71$  cm or finger breadth of  $\leq 1.93$  cm) and male typists ( $n = 26$ ) with large fingers (middle finger length  $\geq 8.37$  cm or finger breadth of  $\geq 2.24$  cm) typed on five keyboards that differed primarily in vertical key spacing (17 × 18, 17 × 17, 17 × 16, 17 × 15.5, and 18 × 16 mm) while typing speed, error, fatigue, preference, forearm muscle activity, and wrist posture were recorded. **Results** Productivity and usability ratings were significantly worse for the keyboard with 15.5 mm vertical spacing compared to the other keyboards for both groups. There were few significant differences on usability ratings between the other keyboards. Reducing vertical key spacing, from 18 to 17 to 16 mm, had no significant effect on productivity or usability. **Conclusions:** The findings support the design of keyboards with vertical key spacings of 16, 17, or 18 mm. **Applications:** These findings may influence keyboard design and standards.

- **Keywords:** key pitch, keyboard design, usability, tool design, switch, wrist posture

## INDIVIDUAL DIFFERENCES

**Raja Parasuraman, Brian Kidwell, Ryan Olmstead, Ming-Kuan Lin, Ryan Jankord, Pamela Greenwood.** *Interactive Effects of the COMT Gene and Training on Individual Differences in Supervisory Control of Unmanned Vehicles.* S. 760-771.

**Objective:** We examined whether a gene known to influence dopamine availability in the prefrontal cortex is associated with individual differences in learning a supervisory control task. **Background:** Methods are needed for selection and training of human operators who can effectively supervise multiple unmanned vehicles (UVs). Compared to the valine (Val) allele, the methionine (Met) allele of the COMT gene has been linked to superior executive function, but it is not known whether it is associated with training-related effects in multi-UV supervisory control performance. **Method:** Ninety-nine healthy adults

were genotyped for the COMT Val158Met single nucleotide polymorphism (rs4680) and divided into Met/Met, Val/Met, and Val/Val groups. Participants supervised six UVs in an air defense mission requiring them to attack incoming enemy aircraft and protect a no-fly zone from intruders in conditions of low and high task load (numbers of enemy aircraft). Training effects were examined across four blocks of trials in each task load condition. **Results:** Compared to the Val/Met and Val/Val groups, Met/Met individuals exhibited a greater increase in enemy targets destroyed and greater reduction in enemy red zone incursions across training blocks. **Conclusion:** Individuals with the COMT Met/Met genotype can acquire skill in executive function tasks, such as multi-UV supervisory control, to a higher level and/or faster than other genotype groups. **Application:** Potential applications of this research include the development of individualized training methods for operators of multi-UV systems and selecting personnel for complex supervisory control tasks.

- **Keywords:** COMT, executive function, genetics, individual differences, neuroergonomics, supervisory control, training, unmanned vehicles

**Sophie Savel, Carolyn Drake. *Auditory Azimuthal Localization Performance in Water as a Function of Prior Exposure.* S. 772-783.**

**Objective:** We report two psychoacoustical experiments that assessed the relationship between auditory azimuthal localization performance in water and duration of prior exposure to the milieu. **Background:** The adaptability of spatial hearing abilities has been demonstrated in air for both active and passive exposures to altered localization cues. Adaptability occurred faster and was more complete for elevation perception than for azimuth perception. In water, spatial hearing is believed to solely rely on smaller than normal cues-to-azimuth: interaural time differences. This should produce a medial bias in localization judgments toward the center of the horizontal plane, unless the listeners have adapted to the environment. **Method:** Azimuthal localization performance was measured in seawater for eight azimuthal directions of a low-frequency (<500 Hz) auditory target. Seventeen participants performed a forced-choice task in Experiment 1. Twenty-eight other participants performed a pointing task in Experiment 2. **Results:** In both experiments we observed poor front/back discrimination but accurate left/right discrimination, regardless of prior exposure. A medial bias was found in azimuth perception, whose size decreased as the exposure duration of the participant increased. **Conclusion:** The study resembles earlier results showing that passive exposure to altered azimuth cues elicits the adaptability of internal audio-spatial maps, that is, the behavioral plasticity of spatial hearing abilities. **Application:** Studies of the adaptability of the auditory system to altered spatial information may yield practical implications for scuba divers, hearing-impaired listeners with reduced sensitivity to spatial cues, and various normal-hearing users of virtual auditory displays.

- **Keywords:** auditory localization, binaural cues, learning, adaptability, plasticity, exposure, water

## **SIMULATION AND VIRTUAL REALITY**

**Nancy A. Baker, Karen Jacobs. *The Feasibility and Accuracy of Using a Remote Method to Assess Computer Workstations.* S. 784-788.**

**Objective:** The objective was to test the accuracy of using remote methods (tele-ergonomics) to identify potential mismatches between workers and their computer workstations. **Background:** Remote access to ergonomic assessments and interventions using two-way interactive communications, tele-ergonomics, increases the ability to deliver computer ergonomic services. However, this mode of delivery must first be tested for accuracy. **Method:** In this single group study, the computer workstations of 30 participants who reported mild to moderate discomfort were remotely assessed using

photographs taken by a research assistant and the self-report Computer Workstation Checklist (CWC) completed by the study participant. Mismatches identified remotely by an ergonomics expert were compared to results obtained from an onsite computer workstation visit completed by the same expert. **Results:** We accurately identified 92% of mismatches. The method was more sensitive (0.97) than specific (0.88), indicating that experts using the remote method were likely to overidentify mismatches. **Conclusion:** These results suggest that an expert using the self-reported CWC combined with workstation photographs can accurately identify mismatches between workers and their computer workstations. **Application:** Remote assessment is a promising method to improve access to computer workstation ergonomic assessments.

- **Keywords:** ergonomics, telehealth, validity, musculoskeletal symptoms

## **SURFACE TRANSPORTATION SYSTEMS**

**Tibor Petzoldt, Hanna Bellem, Josef F. Krems. *The Critical Tracking Task : a Potentially Useful Method to Assess Driver Distraction?* S. 789-808.**

**Objective:** We report on four experiments that investigated the critical tracking task's (CTT) potential as a tool to measure distraction. **Background:** Assessment of the potential of new in-vehicle information systems to be distracting has become an important issue. An easy-to-use method, which might be a candidate to assess this distraction, is the CTT. The CTT requires an operator to stabilize a bar, which is displayed on a computer screen, such that it does not depart from a predefined target position. As the CTT reflects various basic aspects of the operational level of the driving task, we used it as a simple surrogate for driving to assess the CTT's capabilities. **Method:** We employed secondary tasks of varying demand, artificial tasks as well as tasks representative of secondary tasks while driving, and asked participants to perform them together with the CTT in parallel. CTT performance, secondary task performance, and subjective ratings of load were recorded and analyzed. **Results:** Overall, the CTT was able to differentiate between different levels of demand elicited by the secondary tasks. The results obtained corresponded with our a priori assumptions about the respective secondary tasks' potential to distract. **Conclusion:** It appears that the CTT can be used to assess in-vehicle information systems with regard to their potential to distract drivers. Additional experiments are necessary to further clarify the relationship between driving and CTT performance. **Application:** The CTT can provide a cost-effective solution as part of a battery of tests for early testing of new in-vehicle devices.

- **Keywords:** inattention, in-vehicle information systems, surrogate reference task, evaluation methods