

Ergonomics– rok 2013, ročník 56

Číslo 5



Peter A. Hancock, Joseph E. Mercado, James Merlo & Jan B.F. Van Erp.
Improving target detection in visual search through the augmenting multi-sensory cues. Pages 729-738.

The present experiment tested 60 individuals on a multiple screen, visual target detection task. Using a within-participant design, individuals received no-cue augmentation, an augmenting tactile cue alone, an augmenting auditory cue alone or both of the latter augmentations in combination. Results showed significant and substantive improvements in performance such that successful search speed was facilitated by more than 43%, errors of omission were reduced by 86% and errors of commission were reduced by more than 77% in the combinatorial cueing condition compared with the non-cued control. These outcomes were not a trade of performance efficiency for associated mental effort because recorded levels of cognitive workload were also reduced by more than 30% in the multi-cued circumstance compared with the control condition. When the tactile modality was incorporated it led to the highest gain in performance speed, when the auditory modality was incorporated, it led to the best levels of performance accuracy. The combined condition rendered the best of each from of performance increment. Reasons for this outcome pattern are discussed alongside their manifest practical benefits.

Practitioner Summary: This experiment tested 60 individuals on a multiple screen, visual target detection task. Individuals received no-cue augmentation, tactile cue alone, an augmenting auditory cue alone or both of the latter augmentations in combination. Results showed significant and substantive improvements in the combinatorial cueing condition compared with the non-cued control.

- **Keywords:** auditory cueing, tactile cueing, augmented support, target detection, visual search

Thomas Fincannon, Joseph R. Keebler, Florian Jentsch & Michael Curtis.
The influence of camouflage, obstruction, familiarity and spatial ability on target identification from an unmanned ground vehicle. Pages 739-751.

The purpose of this study was to examine the effects of environmental and cognitive factors on the identification of targets from an unmanned ground vehicle (UGV). This was accomplished by manipulating obstruction, camouflage and familiarity of objects in the environment, while also measuring spatial ability. The effects of these variables on target

identification were studied by measuring performance of participants that observed pre-recorded video from a 1:35 scaled military operations in urban terrain facility. Analyses indicated that a combination of camouflage and obstruction caused the most detrimental effects on performance, and that there were differences in the recognition of familiar and unfamiliar targets. Further analysis indicated that these detrimental effects could only be overcome with a combination of target familiarity and spatial ability. The findings highlight the degree to which environmental factors hinder performance and the need for a multidimensional approach for improving performance under these conditions. Areas in need of future research are also discussed.

Practitioner Summary: Cognitive theory is applied to the problem of perception from UGVs. Results from an experimental study indicate that a combination of camouflage and obstruction caused the most detrimental effects on performance, with differences in the recognition of both familiar and unfamiliar targets. Familiarity and spatial ability interacted to predict the performance.

- **Keywords:** UGV, unmanned ground vehicle, remote environments, visual search, object recognition, reconnaissance, obstruction, camouflage, familiarity

Marc Mouzé-Amady, Eric Raufaste, Henri Prade & Jean-Pierre Meyer. *Fuzzy-TLX: using fuzzy integrals for evaluating human mental workload with NASA-Task Load index in laboratory and field studies. Pages 752-763.*

The aim of this study was to assess mental workload in which various load sources must be integrated to derive reliable workload estimates. We report a new algorithm for computing weights from qualitative fuzzy integrals and apply it to the National Aeronautics and Space Administration -Task Load index (NASA-TLX) subscales in order to replace the standard pair-wise weighting technique (PWT). In this paper, two empirical studies were reported: (1) In a laboratory experiment, age- and task-related variables were investigated in 53 male volunteers and (2) In a field study, task- and job-related variables were studied on aircrews during 48 commercial flights. The results found in this study were as follows: (i) in the experimental setting, fuzzy estimates were highly correlated with classical (using PWT) estimates; (ii) in real work conditions, replacing PWT by automated fuzzy treatments simplified the NASA-TLX completion; (iii) the algorithm for computing fuzzy estimates provides a new classification procedure sensitive to various variables of work environments and (iv) subjective and objective measures can be used for the fuzzy aggregation of NASA-TLX subscales.

Practitioner Summary: NASA-TLX, a classical tool for mental workload assessment, is based on a weighted sum of ratings from six subscales. A new algorithm, which impacts on input data collection and computes weights and indexes from qualitative fuzzy integrals, is evaluated through laboratory and field studies. Pros and cons are discussed.

- **Keywords:** fuzzy integral, NASA-TLX, ageing, stress

Miranda Cornelissen, Paul M. Salmon, Roderick McClure & Neville A. Stanton. *Using cognitive work analysis and the strategies analysis diagram to understand variability in road user behaviour at intersections. Pages 764-780.*

In this article, an application of cognitive work analysis (CWA), using the strategies analysis diagram (SAD) method, to model performance variability in road transport, is presented. Specifically, the method was used to describe performance variability across four road user groups (drivers, cyclists, motorcyclists and pedestrians) when turning right at an urban signalised intersection. The analysis demonstrated that the method was

able to identify a comprehensive range of strategies that road users can potentially use while turning right at an intersection, thereby describing a range of performance variability within intersection systems. Furthermore, the method identified constraints, disturbances, changes in circumstances and other influences on road user performance variability. It is concluded that the CWA/SAD approach was able to describe both the different ways in which activities can be executed and disturbances, situations and constraints that create performance variability. The implications of these findings for road design and intersection safety are discussed along with the benefits and drawbacks of the methodology used.

Practitioner Summary: Recently, the strategies analysis diagram was proposed as a method to support the cognitive work analysis framework in modelling performance variability. This article evaluated this method within a complex sociotechnical system, namely road transport. The application provided insight into performance variability across road user groups when turning right at intersections.

- **Keywords:** cognitive work analysis, strategies analysis diagram, performance variability, road transport

Carmen L. Smith, Jane L. Whitelaw & Brian Davies. *Carbon dioxide rebreathing in respiratory protective devices: influence of speech and work rate in full-face masks.* Pages 781-790.

Carbon dioxide (CO₂) rebreathing has been recognised as a concern regarding respirator use and is related to symptoms of discomfort, fatigue, dizziness, headache, muscular weakness and drowsiness. Previous investigations are limited by small sample size and have not evaluated the relationship between CO₂ inhalation and phonic respiration (breathing during speech) in respiratory protective devices (RPDs). A total of 40 workers trained in the use of RPDs performed a graded exercise test on a cycle ergometer that increased in workload every 5 min. During the third minute of each stage, participants read aloud a prepared text. Measures of mixed expired CO₂ (PECO₂), mixed inspired CO₂ (PICO₂) and respiration were monitored. The results showed that phonic respiration and low work rates contributed to significantly higher levels of CO₂ rebreathing. Aiming to reduce CO₂ exposure may result in improved wear time of RPDs. It is recommended that these findings be incorporated in technical specifications regarding human factors for RPDs.

Practitioner Summary: Carbon dioxide (CO₂) rebreathing in respiratory protective devices (RPDs) has been highlighted as a key concern regarding respirator use. However, the problem is relatively under researched. This paper presents novel findings on the impact of phonic respiration (breathing during speech) and CO₂ concentrations in RPDs.

- **Keywords:** carbon dioxide rebreathing, phonic respiration, speech, respiratory protective devices

Anas A. AlGhamri, Susan L. Murray & V. A. Samaranayake. *The effects of wearing respirators on human fine motor, visual, and cognitive performance.* Pages 791-802.

When selecting a respirator, it is important to understand how employees' motor, visual and cognitive abilities are impacted by the personal protective equipment. This study compares dust, powered-air-purifying and full-face, negative-pressure respirators. Thirty participants performed three varied tasks. Each participant performed each task without a respirator and while wearing the three respirator types. The tasks included a hand tool dexterity test, the Motor-Free Visual Perception Test and the Serial Sevens Test to evaluate fine motor, visual and cognitive performance, respectively. The time required for task completion and the errors made were measured. Analysis showed no significant

effect due to respirator use on the task completion time. A significant increase was found in the error rate when participants performed the cognitive test wearing the full-face, negative-pressure respirator. Participants had varying respirator preferences. They indicated a potential for full-face, negative-pressure respirators to negatively affect jobs demanding high cognitive skills such as problem solving and decision-making.

Practitioner summary: while respirators are life-saving personal protective equipment (PPE), they can unintentionally reduce human performance, especially if job characteristics are not considered during PPE selection. An experiment was conducted to compare three respirators (dust respirator, powered-air-purifying respirators and full-face respirator) for varying task types. The full-face respirator was found to affect human cognitive performance negatively.

- **Keywords:** dust respirator, PAPR, full-face, fine motor task, visual task, cognitive task

Eddy Elton, Daniel Johnson, Colette Nicolle & Laurence Clift. *Supporting the development of inclusive products: the effects of everyday ambient illumination levels and contrast on older adults' near visual acuity.* Pages 803-817.

Current older adult capability data-sets fail to account for the effects of everyday environmental conditions on capability. This article details a study that investigates the effects of everyday ambient illumination conditions (overcast, 6000 lx; in-house lighting, 150 lx and street lighting, 7.5 lx) and contrast (90%, 70%, 50% and 30%) on the near visual acuity (VA) of older adults ($n = 38$, 65–87 years). VA was measured at a 1-m viewing distance using logarithm of minimum angle of resolution (LogMAR) acuity charts. Results from the study showed that for all contrast levels tested, VA decreased by 0.2 log units between the overcast and street lighting conditions. On average, in overcast conditions, participants could detect detail around 1.6 times smaller on the LogMAR charts compared with street lighting. VA also significantly decreased when contrast was reduced from 70% to 50%, and from 50% to 30% in each of the ambient illumination conditions.

Practitioner summary: This article presents an experimental study that investigates the impact of everyday ambient illumination levels and contrast on older adults' VA. Results show that both factors have a significant effect on their VA. Findings suggest that environmental conditions need to be accounted for in older adult capability data-sets/designs.

- **Keywords:** inclusive design, capability data, visual acuity, ambient illumination, contrast

Cheng-Jhe Lin & Changxu Wu. *Reactions, accuracy and response complexity of numerical typing on touch screens.* Pages 818-831.

Touch screens are popular nowadays as seen on public kiosks, industrial control panels and personal mobile devices. Numerical typing is one frequent task performed on touch screens, but this task on touch screen is subject to human errors and slow responses. This study aims to find innate differences of touch screens from standard physical keypads in the context of numerical typing by eliminating confounding issues. Effects of precise visual feedback and urgency of numerical typing were also investigated. The results showed that touch screens were as accurate as physical keyboards, but reactions were indeed executed slowly on touch screens as signified by both pre-motor reaction time and reaction time. Provision of precise visual feedback caused more errors, and the interaction between devices and urgency was not found on reaction time. To improve

usability of touch screens, designers should focus more on reducing response complexity and be cautious about the use of visual feedback.

Practitioner Summary: The study revealed that slower responses on touch screens involved more complex human cognition to formulate motor responses. Attention should be given to designing precise visual feedback appropriately so that distractions or visual resource competitions can be avoided to improve human performance on touch screens.

- **Keywords:** touch screen, numerical typing, human errors, response complexity, visual feedback

Patrick J. Lee, Ellen L. Lee & Wilson C. Hayes. *The ratio of thoracic to lumbar compression force is posture dependent.* Pages 832-841.

Despite the evidence suggesting that between 8% and 55% of manual labourers experience thoracic pain, research on spinal loading during occupational tasks has been almost invariably limited to the lumbar spine. In this study, we determined the ratio of thoracic to lumbar compression force and the relative risk of injury to each region in various postures. Compressive forces on the spine were calculated based on previously reported thoracic and lumbar intradiscal pressures and disc cross-sectional areas. Flexion postures were associated with an approximate doubling in lumbar compression force but only small increases (or even decreases) in thoracic compression. The ratio of thoracic to lumbar compression was above the tolerance ratio (i.e. the ratio of thoracic to lumbar compressive strength) during upright postures and below the tolerance ratio during flexion postures, indicating that upright postures may pose a greater relative risk of injury to the thoracic spine than to the lumbar spine.

Practitioner summary: Previously reported thoracic and lumbar *in vivo* disc pressures during various postures were compared. The ratio of thoracic and lumbar compression increased during upright postures and decreased in flexed postures, indicating that upright postures may pose a greater risk of injury to the thoracic spine than to the lumbar spine.

- **Keywords:** thoracic spine, lumbar spine, spinal compression, biomechanics, manual material handling

Marco Tarabini, Bortolino Saggin, Diego Scaccabarozzi, Davide Gaviraghi & Giovanni Moschioni. *Apparent mass distribution at the feet of standing subjects exposed to whole-body vibration.* Pages 842-855.

This study was carried out to investigate the influence of the body posture and of the foot support on the apparent mass distribution at the feet of standing subjects exposed to whole-body vibration. The apparent mass was measured at the driving point through a capacitive pressure sensor matrix, which allowed to separate the contributions of the different foot regions. The overall value was also determined using a conventional measurement system based on piezoelectric load cells. Ten male subjects performed 15 tests with three kinds of feet supports (flat rigid, anatomic rigid and flat soft) in five different postures. Static components of the pressure measurements were exploited to identify which fraction of the weight is supported by the rearfoot, the midfoot and the forefoot in the various test configurations. Factorial design of experiments on different response variables showed that the apparent mass is affected by the posture but not by the type of feet contact surface; conversely, the presence of insoles varies with the apparent mass distribution on the different feet parts.

Practitioner Summary: The response of standing subjects to whole-body vibration has always been considered as a global parameter measured at the driving point, neglecting the local phenomena occurring in different foot parts. We have experimentally identified

the apparent mass distribution of subjects in different standing postures and with different foot supports.

- **Keywords:** whole-body vibration, modelling physical response, acceleration exposures, back pain

Xinyao Hu & Xingda Qu. *Differentiating slip-induced falls from normal walking and successful recovery after slips using kinematic measures.* Pages 856-867.

Slip-induced falls are prevalent and serious in occupational settings. Fall detection can minimise the adverse consequences caused by falls. However, a limitation in the existing fall detection research is that the fall indicators were predetermined without any theoretical and experimental basis. This study aimed to determine the optimal fall indicators for fall detection research by experimentally examining a comprehensive set of kinematic measures. The body kinematic measures were compared among normal walking, successful recovery after slips and slip-induced falls. We identified the kinematic measures that differ between falls and the selected non-fall activities (i.e. successful recovery and normal walking), especially at the early stage of loss-of-balance due to slips. Findings obtained from this study can enhance the understanding of kinematic differences between slip-induced falls and non-fall activities, and such knowledge is particularly useful for developing fall detection models.

Practitioner Summary: Slips have been reported to be a major cause of accidental falls. Findings from this study can help determine the kinematic measures that can effectively and efficiently differentiate slip-induced falls from successful recovery and normal walking. Such knowledge can help develop effective strategies to prevent slip-induced falls.

- **Keywords:** falls, slips, fall detection, balance recovery, kinematics

Li-Hua Chen, Sun-Pui Ng, Winnie Yu, Jie Zhou & K. W. Frances Wan. *A study of breast motion using non-linear dynamic FE analysis.* Pages 868-878.

This paper presents a new method to simulate non-linear breast motion by using a three-dimensional (3D) dynamic finite element model (FEM). The model consists of a thorax with two breasts and three skin layers with specific mechanical properties. Using free breast vibration, the viscous damping ratios were ascertained to be 0.215 for an 80B size breast. The shear modulus for the breast was derived as the value that gave the minimum difference between the FEM-predicted results and the experimental data. A hyper-elastic neo-Hookean material model simulated the large deformation of breast tissue. The mode shapes of breast motions at different natural frequencies were established. The highest breast displacement amplitude ratio relative to the thorax was at 4 Hz. The study showed that FEM can predict breast displacement with sufficient accuracy and thereby provide the basis by which bras may be engineered more ergonomically in the future.

Practitioner Summary: To facilitate a theoretical analysis of breast motion to enable the design of more supportive bras, a dynamic FEM based on reliable non-linear properties of breast tissues has been developed. The methods and findings have potential widespread benefit for developing new products to promote women's health and comfort.

- **Keywords:** breast, finite element, dynamic, hyper-elastic behaviour, large deformation

Wonsup Lee, Kihyo Jung, Jeongrim Jeong, Jangwoon Park, Jayoung Cho, Heeun Kim, Seikwon Park & Heecheon You. *An anthropometric analysis of Korean male helicopter pilots for helicopter cockpit design. Pages 879-887.*

This study measured 21 anthropometric dimensions (ADs) of 94 Korean male helicopter pilots in their 20s to 40s and compared them with corresponding measurements of Korean male civilians and the US Army male personnel. The ADs and the sample size of the anthropometric survey were determined by a four-step process: (1) selection of ADs related to helicopter cockpit design, (2) evaluation of the importance of each AD, (3) calculation of required sample sizes for selected precision levels and (4) determination of an appropriate sample size by considering both the AD importance evaluation results and the sample size requirements. The anthropometric comparison reveals that the Korean helicopter pilots are larger (ratio of means = 1.01–1.08) and less dispersed (ratio of standard deviations = 0.71–0.93) than the Korean male civilians and that they are shorter in stature (0.99), have shorter upper limbs (0.89–0.96) and lower limbs (0.93–0.97), but are taller on sitting height, sitting eye height and acromial height (1.01–1.03), and less dispersed (0.68–0.97) than the US Army personnel.

Practitioner summary: The anthropometric characteristics of Korean male helicopter pilots were compared with those of Korean male civilians and US Army male personnel. The sample size determination process and the anthropometric comparison results presented in this study are useful to design an anthropometric survey and a helicopter cockpit layout, respectively.

- **Keywords:** anthropometric measurement, Korean male helicopter pilots, helicopter cockpit design, sample size determination