

Ergonomics– rok 2013, ročník 56

Číslo 7



Rose Challenger, Chris W. Clegg & Craig Shepherd. *Function allocation in complex systems: reframing an old problem.* Pages 1051-1069.

In this article, we offer a new, macroergonomics perspective on the long-debated issue of function allocation. We believe thinking in this domain needs to be realigned, moving away from the traditional microergonomics conceptualisation, concerned predominantly with task-based decisions, and towards a macroergonomics approach, viewing function allocation choices as central to effective systems design. We frame our arguments within a systems perspective, advocating that function allocation issues need to be on the agenda of all individuals with a wider interest in the human and organisational aspects of complex work systems, including people who commission, sponsor, design, implement and use such systems. We also argue that allocation decisions should form a transparent, explicit stage early in the systems design and development process, involve multiple stakeholders (including end-users), be evidence-based, framed within the language of risk and utilise iterative methods (e.g. scenarios planning techniques).

Practitioner Summary: This article presents a macroergonomics approach to function allocation, advocating its importance in effective systems design. Adopting a systems mindset, we argue function allocation should form an explicit stage early in the design process, involve multiple stakeholders, be evidence-based, framed within the language of risk and utilise iterative methods.

- **Keywords:** allocation of function, complex systems, socio-technical systems, human-machine systems

Qin Gao, Yang Wang, Fei Song, Zhizhong Li & Xiaolu Dong. *Mental workload measurement for emergency operating procedures in digital nuclear power plants.* Pages 1070-1085.

Mental workload is a major consideration for the design of emergency operation procedures (EOPs) in nuclear power plants. Continuous and objective measures are desired. This paper compares seven mental workload measurement methods (pupil size, blink rate, blink duration, heart rate variability, parasympathetic/sympathetic ratio, total power and (Goals, Operations, Methods, and Section Rules)-(Keystroke Level Model) GOMS-KLM-based workload index) with regard to sensitivity, validity and intrusiveness. Eighteen participants performed two computerised EOPs of different complexity levels,

and mental workload measures were collected during the experiment. The results show that the blink rate is sensitive to both the difference in the overall task complexity and changes in peak complexity within EOPs, that the error rate is sensitive to the level of arousal and correlate to the step error rate and that blink duration increases over the task period in both low and high complexity EOPs. Cardiac measures were able to distinguish tasks with different overall complexity. The intrusiveness of the physiological instruments is acceptable. Finally, the six physiological measures were integrated using group method of data handling to predict perceived overall mental workload.

Practitioner Summary: The study compared seven measures for evaluating the mental workload with emergency operation procedure in nuclear power plants. An experiment with simulated procedures was carried out, and the results show that eye response measures are useful for assessing temporal changes of workload whereas cardiac measures are useful for evaluating the overall workload.

- **Keywords:** mental workload, operation procedure, HRV, blinks, pupil dilation

Ido Morag & Gil Luria. *A framework for performing workplace hazard and risk analysis: a participative ergonomics approach.* Pages 1086-1100.

Despite the unanimity among researchers about the centrality of workplace analysis based on participatory ergonomics (PE) as a basis for preventive interventions, there is still little agreement about the necessary of a theoretical framework for providing practical guidance. In an effort to develop a conceptual PE framework, the authors, focusing on 20 studies, found five primary dimensions for characterising an analytical structure: (1) extent of workforce involvement; (2) analysis duration; (3) diversity of reporter role types; (4) scope of analysis and (5) supportive information system for analysis management. An ergonomics analysis carried out in a chemical manufacturing plant serves as a case study for evaluating the proposed framework. The study simultaneously demonstrates the five dimensions and evaluates their feasibility. The study showed that managerial leadership was fundamental to the successful implementation of the analysis; that all job holders should participate in analysing their own workplace and simplified reporting methods contributed to a desirable outcome.

Practitioner summary: This paper seeks to clarify the scope of workplace ergonomics analysis by offering a theoretical and structured framework for providing practical advice and guidance. Essential to successfully implementing the analytical framework are managerial involvement, participation of all job holders and simplified reporting methods.

- **Keywords:** participatory ergonomics, injuries prevention, hazards and risks analysis, reporting systems, management involvement

David Schuster, Javier Rivera, Brittany C. Sellers, Stephen M. Fiore & Florian Jentsch. *Perceptual training for visual search.* Pages 1101-1115.

People are better at visual search than the best fully automated methods. Despite this, visual search remains a difficult perceptual task. The goal of this investigation was to experimentally test the ways in which visual search performance could be improved through two categories of training interventions: perceptual training and conceptual training. To determine the effects of each training on a later performance task, the two types of trainings were manipulated using a between-subjects design (conceptual vs. perceptual × training present vs. training absent). Perceptual training led to speed and accuracy improvements in visual search. Issues with the design and administration of the conceptual training limited conclusions on its effectiveness but provided useful lessons for

conceptual training design. The results suggest that when the visual search task involves detecting heterogeneous or otherwise unpredictable stimuli, perceptual training can improve visual search performance. Similarly, careful consideration of the performance task and training design is required to evaluate the effectiveness of conceptual training.

Practitioner Summary: Visual search is a difficult, yet critical, task in industries such as baggage screening and radiology. This study investigated the effectiveness of perceptual training for visual search. The results suggest that when visual search involves detecting heterogeneous or otherwise unpredictable stimuli, perceptual training may improve the speed and accuracy of visual search.

- **Keywords:** visual search, signal detection, perception, conceptual training, perceptual training

Cosima Piepenbrock, Susanne Mayr, Iris Mund & Axel Buchner. *Positive display polarity is advantageous for both younger and older adults.* Pages 1116-1124.

The effect of display polarity on visual acuity and proofreading performance was investigated for younger and older adults. An advantage of positive polarity (dark characters on light background) over negative polarity (light characters on dark background) was expected for younger adults, but the effects on older adults were ambiguous. Light scatter due to residues in the senescent lens and vitreous humour could reverse the typical advantage of positive polarity. However, age-related changes lead to a decline in retinal illuminance. Brighter positive polarity displays should help to compensate for this decline and, accordingly, lead to better performance than darker negative polarity displays. Participants conducted a visual acuity test with black optotypes on white background or white optotypes on black background and performed a proofreading task in the same polarity. A positive polarity advantage was found for both age groups. The presentation in positive polarity is recommended for all ages.

Practitioner summary: In an ageing society, age-related vision changes need to be considered when designing digital displays. Visual acuity testing and a proofreading task revealed a positive polarity advantage for younger and older adults. Dark characters on light background lead to better legibility and are strongly recommended independent of observer's age.

- **Keywords:** display polarity, age, vision changes, display design

D. Roman-Liu, I. Grabarek, P. Bartuzi & W. Choromański. *The influence of mental load on muscle tension.* Pages 1125-1133.

We examined the differences in muscle tension and in physiological measures depending on the type of mental task. Fifteen participants performed tests for sustained attention, vigilance and maintaining posture only. We analysed electromyogram (EMG) measures of extensor digitorum (ED), flexor carpi ulnaris (FU), deltoideus (DE) and trapezius (TR), and heart rate (HR) and respiratory frequency (RF). Measures indicated higher values for mental tasks than for maintained posture only with significant differences in all measures. The following relationships were also significant: between DE and physiological measures (HR and RF), between ED and the amplitude of EMG of the other three muscles, between FU and TR and between HR and RF. The results of this study showed that the relationship between mental demands and muscle tension was mostly reflected by tension in the arm and shoulder girdle muscles and, to a lesser degree, in forearm muscles.

Practitioner Summary: We focused on physiological and muscle tension measures differentiating work according to the level of mental demands. Differences in sustained

attention, vigilance and maintaining posture only proved that mental demands were mostly reflected by tension in arm and shoulder girdle muscles and, to a lesser degree, in forearm muscles.

- **Keywords:** electromyography, mental demands, upper limb, shoulder, musculoskeletal load

Leena Korpinen, Rauno Pääkkönen & Fabriziomaria Gobba. *Self-reported neck symptoms and use of personal computers, laptops and cell phones among Finns aged 18–65. Pages 1134-1146.*

The purpose of this study was to investigate the possible relation between self-reported neck symptoms (aches, pain or numbness) and use of computers/cell phones. The study was carried out as a cross-sectional study by posting a questionnaire to 15,000 working-age persons, and 15.1% of all respondents (6121) reported that they very often experienced physical symptoms in the neck. The results showed that they also had many other symptoms very often, and 49% used a computer daily at work and 83.9% used cell phones. We compared physical/mental symptoms of persons with symptoms in the neck quite often or more, with others. We found significant differences in the physical/mental symptoms and use of cell phones and computers. The results suggest taking into account in the future that those persons' symptoms in the neck can be associated with use of cell phones or computers.

Practitioner Summary: We investigated the possible relation between neck symptoms and use of computers/cell phones. We found that persons, who very often had symptoms in the neck, had also other symptoms very often (e.g. exhaustion at work). Their use of information and communication technology (e.g. computers) can associate with their symptoms.

- **Keywords:** neck pain, physical symptoms, questionnaire, computer

Jung-Keun Park & Bryan Buchholz. *Effects of work surface height on muscle activity and posture of the upper extremity during simulated pipetting. Pages 1147-1158.*

In order to examine the effects of work surface height (WSH) on muscle activity, posture and discomfort during simulated pipetting, an experimental study was conducted using electromyography, electrogoniometry, video techniques and also qualitative data. The experimental design consisted of one independent variable (WSH with six heights) and 13 dependent variables. The levels of muscle strain and discomfort were significantly lower at the shoulder when the WSHs were low but thumb muscle activities and neck flexion levels were markedly higher at these WSHs compared to higher WSHs. To reduce shoulder strain, without raising thumb and neck strain beyond acceptable limits, the findings suggest that the height of a laboratory workbench should be at the level of the pipette tip when held in a standing position with the hand at elbow height. It was also found that pipetting should not be done in a seated posture.

Practitioner Summary: An experimental study was conducted to examine the effects of work surface height on upper extremity muscle activity, posture and discomfort during simulated pipetting. The findings suggest that the laboratory workbench height should be at the pipette-tip level when held in a standing position with the hand at elbow height.

- **Keywords:** work surface height, muscle activity, posture, discomfort, pipetting

Esa-Pekka Takala & Risto Toivonen. *Placement of forearm surface EMG electrodes in the assessment of hand loading in manual tasks.* Pages 1159-1166.

Surface electromyography (EMG) is commonly used to study the loading of the forearm. Pro-supination movements cause surface electrodes to move in relation to the underlying muscles. We studied the effects of different electrode locations and forearm postures on the association between the EMG signals and external hand load in a laboratory experiment. Eleven subjects performed simulated work tasks with the forearm in neutral, pronated or supinated postures and with systematic variation of external load. The tasks included isometric gripping, pushing and pulling, and lifting and lowering weights. Surface EMG was recorded by six pairs of electrodes located on the forearm. The associations were studied using multiple regression models. EMG activity varied according to the forearm posture, location of electrodes and type of simulated task. Variation was lowest with a through-forearm setting of electrodes. This setting also showed the highest correlation between external loads and the EMG activity [coefficient of determination (R^2) = 0.25–0.66].

Practitioner Summary: Moving of surface electrodes in relation to the underlying muscles interferes with the assessment of loading in ergonomic settings. This laboratory experiment showed that a through-forearm location of electrodes seems to be an optimal option in the assessment of forearm loading.

- **Keywords:** biomechanics, electromyography, forearm, surface electrodes, workload

Huiju Park, Donna Branson, Adriana Petrova, Semra Peksoz, Bert Jacobson, Aric Warren, Carla Goad & Panagiotis Kamenidis. *Impact of ballistic body armour and load carriage on walking patterns and perceived comfort.* Pages 1167-1179.

This study investigated the impact of weight magnitude and distribution of body armour and carrying loads on military personnel's walking patterns and comfort perceptions. Spatio-temporal parameters of walking, plantar pressure and contact area were measured while seven healthy male right-handed military students wore seven different garments of varying weight (0.06, 9, 18 and 27 kg) and load distribution (balanced and unbalanced, on the front and back torso). Higher weight increased the foot contact time with the floor. In particular, weight placement on the non-dominant side of the front torso resulted in the greatest stance phase and double support. Increased plantar pressure and contact area observed during heavier loads entail increased impact forces, which can cause overuse injuries and foot blisters. Participants reported increasingly disagreeable pressure and strain in the shoulder, neck and lower back during heavier weight conditions and unnatural walking while wearing unbalanced weight distributed loads. This study shows the potentially synergistic impact of wearing body armour vest with differential loads on body movement and comfort perception.

Practitioner Summary: This study found that soldiers should balance loads, avoiding load placement on the non-dominant side front torso, thus minimising mobility restriction and potential injury risk. Implications for armour vest design modifications can also be found in the results.

- **Keywords:** mobility, body armour, biomechanics, gait, load carriage

Asanka S. Rodrigo, Ravindra S. Goonetilleke & Shuping Xiong. *Load distribution to minimise pressure-related pain on foot: a model.* Pages 1180-1193.

The optimal force distribution to minimise pain or discomfort at the foot–shoe interface is still not known. Most shoe-related products attempt to distribute the load uniformly without much consideration to the bony and soft tissue regions. An experiment was conducted to first determine the pressure pain threshold (PPT) and tissue deformation on the plantar surface of the foot. Circular probes of areas 0.5, 1.0 and 2.0 cm² at indentation speeds of 0.5, 1 and 2 mm/s showed that PPT depends on the location stimulated, area of stimulation and the indentation speed. The results also showed that tissue stiffness is quite low for small deformations (< 4 mm), but significantly higher at large deformations (>4 mm). The stiffness at the larger deformation region was positively correlated with PPT ($r = 0.63, p < 0.001$). The data were further used to develop a model with PPT, deformation and stimulated area.

Practitioner Summary: Pressure at which there is an onset of pain is higher when a larger area of soft tissue is stimulated. Bony areas may be better suited to bear load on smaller areas to minimise pressure-related pain. Thus, manipulating supporting surface stiffness and surface contours can help minimise pain.

- **Keywords:** pain, foot, tissue deformation, pressure threshold, load distribution

B. Ayres, J. White, W. Hedger & J. Scurr. *Female upper body and breast skin temperature and thermal comfort following exercise.* Pages 1194-1202.

Slipping biomechanics was investigated on both non-contaminated and oil-contaminated surfaces during unconstrained straight-line walking. Breast support reduces breast pain and movement during exercise, however, an extra layer of clothing may affect thermoregulation. This preliminary study investigated female upper body and breast skin temperature and thermal comfort following short-duration exercise. Eight female participants with C-cup breasts had thermal images (infra-red camera, FLIR systems) of the bare breasts, the breasts in two sports bras (composite and polyester) and the abdomen, taken before and after 20 min of exercise at 28°C. Following exercise, bare-breast, bra and abdomen temperatures reduced by 0.61°C, 0.92°C and 2.06°C, respectively. The polyester sports bra demonstrated greater thermal comfort and enabled a greater change in skin temperature than the composite sports bra. It is concluded that following short-duration exercise, sports bras reduced the cooling ability of the breast. Material properties of the bras affect thermal comfort and post-exercise skin temperature; this should be an important consideration for sports bra manufacturers.

Practitioner summary: This study investigates the effect of sports bras on thermal regulation of the breast following exercise. Sports bras negatively affected the cooling ability of the skin on the breast, with the material properties of the bra affecting thermal comfort following exercise. These results present important considerations for sports bra manufacturers.

- **Keywords:** sports bra, thermoregulation, thermal comfort