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Mark S. Young, Karel A. Brookhuis, Christopher D. Wickens & Peter A. Hancock. *State of science : mental workload in ergonomics*. Pages 1-17.

Mental workload (MWL) is one of the most widely used concepts in ergonomics and human factors and represents a topic of increasing importance. Since modern technology in many working environments imposes ever more cognitive demands upon operators while physical demands diminish, understanding how MWL impinges on performance is increasingly critical. Yet, MWL is also one of the most nebulous concepts, with numerous definitions and dimensions associated with it. Moreover, MWL research has had a tendency to focus on complex, often safety-critical systems (e.g. transport, process control). Here we provide a general overview of the current state of affairs regarding the understanding, measurement and application of MWL in the design of complex systems over the last three decades. We conclude by discussing contemporary challenges for applied research, such as the interaction between cognitive workload and physical workload, and the quantification of workload 'redlines' which specify when operators are approaching or exceeding their performance tolerances. **Practitioner Summary:** The study of workload in ergonomics has risen in popularity since the 1980s. Applied problems, particularly in transport, have taken centre stage in recent years. New developments in neuroergonomics measurement techniques offer promise in quantifying both the interaction of physical and mental workload, as well as the elusive 'redline' performance limit for overload.

- **Keywords:** mental workload, attention, resources, measurement, applications

Priscilla C. Leider, Julitta S. Boschman, Monique H.W. Frings-Dresen & Henk F. van der Molen. *Effects of job rotation on musculoskeletal complaints and related work exposures: a systematic literature review*. Pages 18-32.

The aim of this systematic review was to summarise evidence on the effects of job rotation on musculoskeletal complaints, exposures related to musculoskeletal complaints and sustainable working life parameters. A total of 16 studies were included. No studies on sustainable working life parameters were found. The quality of the studies was assessed using a checklist; eight field studies and three laboratory studies of sufficient

quality were used to summarise the following evidence: one field study showed positive results and one field study showed negative results for musculoskeletal complaints, two field studies showed positive results and two field studies showed inconsistent results for exposures, and two field studies showed inconsistent results for musculoskeletal complaints and exposures. Two laboratory studies showed inconsistent results and one laboratory study showed no changes for exposures. In conclusion, there is currently inconsistent evidence for positive or negative effects of job rotation on musculoskeletal complaints and exposures related to musculoskeletal complaints. **Practitioner's Summary:** Currently, there is inconsistent evidence for recommending job rotation as a strategy for preventing musculoskeletal complaints. Exposures from all involved work activities and body regions should be identified and assessed first, to determine if job rotation provides increased exposure variation and/or beneficial changes in mean exposures related to musculoskeletal complaints.

- **Keywords:** job rotation, ergonomic intervention, exposure, musculoskeletal complaints, review

Anping Xie & Pascale Carayon. *A systematic review of human factors and ergonomics (HFE)-based healthcare system redesign for quality of care and patient safety.* Pages 33-49.

Healthcare systems need to be redesigned to provide care that is safe, effective and efficient, and meets the multiple needs of patients. This systematic review examines how human factors and ergonomics (HFE) is applied to redesign healthcare work systems and processes and improve quality and safety of care. We identified 12 projects representing 23 studies and addressing different physical, cognitive and organisational HFE issues in a variety of healthcare systems and care settings. Some evidence exists for the effectiveness of HFE-based healthcare system redesign in improving process and outcome measures of quality and safety of care. We assessed risk of bias in 16 studies reporting the impact of HFE-based healthcare system redesign and found varying quality across studies. Future research should further assess the impact of HFE on quality and safety of care, and clearly define the mechanisms by which HFE-based system redesign can improve quality and safety of care. **Practitioner Summary:** Existing evidence shows that HFE-based healthcare system redesign has the potential to improve quality of care and patient safety. Healthcare organisations need to recognise the importance of HFE-based healthcare system redesign to quality of care and patient safety, and invest resources to integrate HFE in healthcare improvement activities.

- **Keywords:** human factors and ergonomics, healthcare system redesign, quality of care, patient safety, systematic review, SEIPS model

Dechristian França Barbieri, Divya Srinivasan, Svend Erik Mathiassen, Helen Cristina Nogueira & Ana Beatriz Oliveira. *The ability of non-computer tasks to increase biomechanical exposure variability in computer-intensive office work.* Pages 50-64.

Postures and muscle activity in the upper body were recorded from 50 academics office workers during 2 hours of normal work, categorised by observation into computer work (CW) and three non-computer (NC) tasks (NC seated work, NC standing/walking work and breaks). NC tasks differed significantly in exposures from CW, with standing/walking NC tasks representing the largest contrasts for most of the exposure variables. For the majority of workers, exposure variability was larger in their present job than in CW alone, as measured by the job variance ratio (JVR), i.e. the ratio between min-min variabilities in the job and in CW. Calculations of JVRs for simulated jobs containing different proportions of CW showed that variability could, indeed, be increased by redistributing available tasks, but that substantial increases could only be achieved by

introducing more vigorous tasks in the job, *in casu* illustrated by cleaning. **Practitioner Summary:** Too little exposure variation is a general concern in computer-intensive office work. This study shows, using a novel metric, that available NC tasks can, indeed, increase variation compared to doing only CW, but also that a substantial increase in variation requires introducing more vigorous tasks such as cleaning.

- **Keywords:** task contrasts, exposure variation, posture, EMG

Katriina Viitasalo, Sampsa Puttonen, Eeva Kuosma, Jaana Lindström & Mikko Härmä. *Shift rotation and age – interactions with sleep-wakefulness and inflammation. Pages 65-74.*

The interaction of age with shift rotation in relation to sleep-wakefulness and inflammation were studied among male employees ($n = 772$). Cross-sectional analyses in day, two-shift and three-shift work with different shift rotations, as well as changes in leukocytes and hsCRP among three shift workers who changed their shift system during the 2.5-yr follow-up were completed. Shift work was associated with problems to fall asleep ($p < 0.001$) and feeling of the current working time being harmful to sleep and wakefulness ($p < 0.001$). Quickly forward-rotation shift workers considered their working time less harmful compared with slower backward-rotation shift workers. Age did not influence sleep in general, but older workers in the quickly forward-rotating three-shift system had less sleep complaints than their younger colleagues. The age differences in the inflammatory markers partly depended on the shift system. The results give some support that rapidly forward-rotating shift systems are more 'age-friendly' than backward-rotating shift systems. **Practitioner Summary:** In workplaces with varying shift systems, the possibility of elderly employees with health problems to change to a more 'age-friendly' shift schedule would enhance older workers' well-being and better coping with shift work.

- **Keywords:** shift work, shift schedule, age, sleep, inflammation

Charmayne M.L. Hughes, Chris Baber, Marta Bienkiewicz, Andrew Worthington, Alexa Hazell & Joachim Hermsdörfer. *The application of SHERPA (Systematic Human Error Reduction and Prediction Approach) in the development of compensatory cognitive rehabilitation strategies for stroke patients with left and right brain damage. Pages 75-95.*

Approximately 33% of stroke patients have difficulty performing activities of daily living, often committing errors during the planning and execution of such activities. The objective of this study was to evaluate the ability of the human error identification (HEI) technique SHERPA (Systematic Human Error Reduction and Prediction Approach) to predict errors during the performance of daily activities in stroke patients with left and right hemisphere lesions. Using SHERPA we successfully predicted 36 of the 38 observed errors, with analysis indicating that the proportion of predicted and observed errors was similar for all sub-tasks and severity levels. HEI results were used to develop compensatory cognitive strategies that clinicians could employ to reduce or prevent errors from occurring. This study provides evidence for the reliability and validity of SHERPA in the design of cognitive rehabilitation strategies in stroke populations. **Practitioner Summary:** This study evaluated SHERPA (Systematic Human Error Reduction and Prediction Approach) as a means for predicting errors during the performance of daily activities in left and right brain-damaged patients. Results demonstrate that SHERPA is a useful technique that can be employed in the design of cognitive rehabilitation strategies.

- **Keywords:** task analysis, human error identification, stroke, cognitive therapy

M. Pierrette, E. Parizet, P. Chevret & J. Chatillon. *Noise effect on comfort in open-space offices: development of an assessment questionnaire.* Pages 96-106.

It is currently accepted that noise is one of the most important annoyance factors in open-space offices. However, noise levels measured in open spaces of the tertiary sector rarely exceed 65 dB(A). It, therefore, appears necessary to develop a tool that can be used to assess the noise environment of these offices and identify the parameters to be taken into consideration when assessing the noise annoyance. This article presents a questionnaire to be filled by people working in such environment, and a case study in different open plan offices. The majority of the 237 respondents consider that the ambient noise level in their environment is high and that intelligible conversations between their colleagues represent the main source of noise annoyance. This annoyance was significantly correlated with their evaluation of sound intensity, which could not be represented by A-weighted level measurements. **Practitioner Summary:** This article presents a short questionnaire aimed to evaluate the employees' comfort in an open-plan office and to propose optimal modifications of the office. Answers collected from 237 respondents showed that intelligible conversations represent the main source of noise annoyance; moreover, overall noise level is not related to this annoyance.

- **Keywords:** office ergonomics, ergonomics tools and methods, perception, hearing, sound and noise

Po-Hung Lin. *Investigation of Chinese text entry performance for mobile display interfaces.* Pages 107-117.

This study examined the effects of panel type, frequency of use and arrangement of phonetic symbols on operation time, usability, visual fatigue and workload in text entry performance. Three types of panel (solid, touch and mixed), three types of frequency of use (low, medium and high) and two types of the arrangement of phonetic symbols (vertical and horizontal) were investigated through 30 college students in the experiment. The results indicated that panel type, frequency of use, arrangement of phonetic symbols and the interaction between panel type and frequency of use were significant factors on operation time. Panel type was also a significant factor on usability, and a touch panel and a solid panel showed better usability than a mixed panel. Furthermore, a touch panel showed good usability and the lowest workload and therefore it is recommended to use a touch panel with vertical phonetic arrangement in sending Chinese text messages. **Practitioner Summary:** This study found, from ergonomics considerations, that a touch panel showed good usability and it is recommended to use a touch panel with vertical phonetic arrangement in sending Chinese text messages. Mobile display manufacturers can use the results of this study as a reference for future keyboard design.

- **Keywords:** mobile display, text entry performance, panel type, frequency of use, arrangement of phonetic symbols

Michael W. Sonne & Jim R. Potvin. *A psychophysical study to determine maximum acceptable efforts for a thumb abduction task with high duty cycles.* Pages 118-127.

Potvin (2012, 'Predicting Maximum Acceptable Efforts for Repetitive Tasks: An Equation Based on Duty Cycle', *Human Factors: The Journal of the Human Factors and Ergonomics Society*, 54 (2), 175-188) developed an equation using psychophysical data to estimate

maximum acceptable efforts (MAEs) as a function of duty cycle (DC). However, only ~6%

of the data featured DCs ≥ 0.50 . The purpose of this study was to evaluate the MAE equation in the high DC range. We tested a repetitive thumb adduction task with DCs of 0.50, 0.70 and 0.90, at frequencies of both 2 and 6 per minute ($n = 6$ conditions). Participants were trained for 2 hours and tested for 1 hour on each condition. The MAE decreased with increasing DC, and MAEs at 2/min were higher than those at 6/min. When these current six means were added to the original psychophysical studies, the root-mean squared difference of the MAE equation decreased from 7.23% to 7.05% maximum voluntary contraction. The values from our study are also consistent with those demonstrating physiological evidence of fatigue during both continuous isotonic and high DC tasks. **Practitioner Summary:** The maximum acceptable effort (MAE) equation can be used by ergonomists to estimate acceptable forces and torques where both duty cycle (DC) is known and maximum strength data are available. Our psychophysical study provides evidence to validate the MAE equation for high DC tasks ($DC \geq 0.50$). In fact, the relationship between the equation and existing data is improved with the inclusion of our data.

- **Keywords:** psychophysics, maximum acceptable effort, duty cycle, fatigue

Divya Srinivasan, Afshin Samani, Svend Erik Mathiassen & Pascal Madeleine. *The size and structure of arm movement variability decreased with work pace in a standardised repetitive precision task.* Pages 128-139.

Increased movement variability has been suggested to reduce the risk of developing musculoskeletal disorders caused by repetitive work. This study investigated the effects of work pace on arm movement variability in a standardised repetitive pipetting task performed by 35 healthy women. During pipetting at slow and fast paces differing by 15%, movements of arm, hand and pipette were tracked in 3D, and used to derive shoulder and elbow joint angles. The size of cycle-to-cycle motor variability was quantified using standard deviations of several kinematics properties, while the structure of variability was quantified using indices of sample entropy and recurrence quantification analysis. When pace increased, both the size and structure of motor variability in the shoulder and elbow decreased. These results suggest that motor variability drops when repetitive movements are performed at increased paces, which may in the long run lead to undesirable outcomes such as muscle fatigue or overuse. **Practitioner Summary:** The size and structure of motor variability are associated with important outcomes in repetitive work, such as fatigue, pain and the risk of developing musculoskeletal disorders. Motor variability decreased when the pace of repetitive work was increased, indicating higher risks of developing undesirable outcomes such as muscle fatigue or overuse.

- **Keywords:** motor control, cyclic movements, Fitts' law, kinematics, linear and non-linear variability

Samira Golriz, Jeffrey J. Hebert, K. Bo Foreman & Bruce F. Walker. *The effect of hip belt use and load placement in a backpack on postural stability and perceived exertion: a within-subjects trial.* Pages 140-147.

The purpose of this study was to assess the effects of hip belt use and load placement in a backpack on perceived exertion and postural stability. Thirty participants were instructed to stand on a force plate and walk along a designated route under five conditions: unloaded, high-load placement, low-load placement, hip belt on and hip belt

off. The average velocity and sway area from the force plate were measured. Participants also rated their perceived stability and exertion. Compared to the unloaded condition, all loaded conditions significantly increased average velocity, sway area, perceived stability and exertion. Hip belt use did not affect average velocity and sway area; however, participants reported higher levels of stability and lower levels of exertion with hip belt use. Load placement did not affect average velocity, sway area, perceived stability or exertion. This study showed that wearing a backpack loaded to 20% of body weight reduced postural stability, while manipulation of load placement in a backpack did not affect subjective and objective measures of postural stability. Also, hip belt use only improved subjective measures of postural stability. **Practitioner Summary:** Load manipulation in a backpack did not affect stability and exertion. While hip belt use did not affect objective measures of stability, it helped participants to feel more stable and report less exertion. The findings are important for ergonomics backpack design and determining a proper way of packing and wearing a backpack.

- **Keywords:** postural stability, backpack, hip belt, load placement, exertion

Richard M. Kesler, Elizabeth T. Hsiao-Wecksler, Robert W. Motl, Rachel E. Klaren, Ipek Ensari & Gavin P. Horn. *A modified SCBA facepiece for accurate metabolic data collection from firefighters.* Pages 148-159.

To better assess the energy expenditure and exertion of firefighters during simulated firefighting activities, a commercial firefighter self-contained breathing apparatus (SCBA) facepiece was modified to interface with a portable metabolic monitoring device (Cosmed K4b²) while still functioning as a positive pressure SCBA air supply. To validate the device, standard National Fire Protection Association 1981 SCBA function tests were conducted and 14 subjects performed variable-workload assessments using all combinations of two test devices (Cosmed K4b² and metabolic cart) and two masks (modified SCBA facepiece and stock manufacturer-supplied breath collection). Metabolic data collected with the Cosmed K4b² via the modified facepiece were found to be accurate when compared to a ParvoMedics Truemax 2400 metabolic cart (average per cent difference: 4.6%). This modified facepiece design is suitable for use in metabolic studies requiring the utilisation of an SCBA system. Furthermore, the well-established overestimation of oxygen consumption from the Cosmed K4b² system was replicated. **Practitioner Summary:** The nature of a firefighters' self-contained breathing apparatus (SCBA) prevents collection of respiratory metabolic data while the firefighter consumes air from the SCBA. This study introduces and validates a modified SCBA facepiece design integrating metabolic data collection tools with firefighting SCBA allowing for data collection across various firefighting activities.

- **Keywords:** oxygen uptake, gas analysis, firefighting, self-contained breathing apparatus, respiration

Zeuwts Linus, Ducheyne Fabian, Vansteenkiste Pieter, D'Hondt Eva, Cardon Greet & Lenoir Matthieu. *Associations between cycling skill, general motor competence and body mass index in 9-year-old children.* Pages 160-171.

Learning to ride a bicycle is an important milestone in a child's life. Unfortunately, young traffic casualties remain overrepresented in traffic reports, with single-bicycle crashes as principal cause in children. This correlational, cross-sectional study focuses on the association between cycling skills and two intrinsic characteristics: general motor competence and body mass index (BMI). Therefore, general motor competence, BMI and practical cycling competence were measured in 9-year-old children ($n = 40$). Significant correlations were found between cycling skills and general motor competence ($r = 0.434, p \leq 0.01$), and between cycling skills and BMI ($r = -0.400, p \leq 0.05$). A

multiple regression analysis revealed that children's general motor quotient and BMI together predicted 19% of cycling skill score. These findings indicate that general motor competence and bicycle skills are not independent of each other stressing the importance of young children's characteristics when actively participating in traffic. In addition, BMI might be negatively associated with the development of cycling skills in children.

Practitioner Summary: The association between cycling skills, general motor competence and body mass index (BMI) was examined in 9-year-old children. Significant correlations between cycling skills and general motor competence showed the importance of general motor development for bicycle and traffic skill acquisition.

- **Keywords:** bicycling, gross motor competence, overweight, children