This paper presents the case for the need for ‘Action Research’ (AR) approaches to gain understanding of how ergonomics considerations can best be integrated into the design of new work systems. The AR researchers work collaboratively with other stakeholders to solve a real-world problem: gaining insight into the problem and factors influencing solution building from an embedded position in the development process. This experience is interpreted in terms of available theory and can support further theory development. This non-experimental approach can help provide practical new approaches for integrating ergonomics considerations into real work system design processes. The AR approach suffers from a lack of acceptance by conventionally trained scientists. This paper aims to help overcome this weakness by developing the underlying theory and rationale for using AR approaches in ergonomics research. We propose further development of hybrid approaches which incorporate other evaluation techniques to extend the knowledge gains from AR projects.

**Practitioner Summary:** Researchers should engage directly with organisations in ergonomics projects so that they can better understand the challenges and needs of practitioners who are trying to apply available scientific knowledge in their own unique context. Such ‘Action Research’ could help develop theory and approaches useful to improve mobilisation and application of ergonomics knowledge in organisations.

- **Keywords:** proactive human factors, work system design, science methodology, ergonomics intervention research

**W.P. Neumann & J. Village. Ergonomics action research II: a framework for integrating HF into work system design. Pages 1140-1156.**

This paper presents a conceptual framework that can support efforts to integrate human factors (HF) into the work system design process, where improved and cost-effective application of HF is possible. The framework advocates strategies of broad stakeholder participation, linking of performance and health goals, and process focussed change tools that can help practitioners engage in improvements to embed HF into a firm's work system design process. Recommended tools include business process mapping of the design process, implementing design criteria, using cognitive mapping to connect to
managers’ strategic goals, tactical use of training and adopting virtual HF (VHF) tools to support the integration effort. Consistent with organisational change research, the framework provides guidance but does not suggest a strict set of steps. This allows more adaptability for the practitioner who must navigate within a particular organisational context to secure support for embedding HF into the design process for improved operator wellbeing and system performance.

**Practitioner Summary**: There has been little scientific literature about how a practitioner might integrate HF into a company’s work system design process. This paper proposes a framework for this effort by presenting a coherent conceptual framework, process tools, design tools and procedural advice that can be adapted for a target organisation.

- **Keywords**: organisational development, work system design, ergonomics intervention, proactive ergonomics, participatory acroergonomics, meta-ergonomics


The introduction of simulators for the practice of endoscopic-surgery sensori-motor skills opens a wide range of design options. An obvious one is augmented visual information early in practice, in particular a direct view of the site instead of the endoscopic view. We studied the effects of such augmented visual information on the simulated ablation of tissue with straight, horizontal and parallel cuts. Direct view had an immediate beneficial effect on performance as compared with endoscopic-view practice. However, in subsequent tests with endoscopic view the benefits disappeared and turned into costs for some aspects of performance, e.g., duration. This finding highlights for a simulated surgical task that optimisation of practice by a performance criterion may not result in optimisation by a transfer criterion.

**Practitioner Summary**: Endoscopic surgery represents a challenge for human sensori-motor skills, but new simulator-based training methods give leeway for optimisation. A candidate is augmented visual feedback, in particular a direct rather than endoscopic view of the site. However, performance becomes dependent on the augmented feedback so that the costs outweigh the benefits.

- **Keywords**: simulation, augmented feedback, resection, transfer


Many workers experience combined physical and mental demands in their jobs, yet the contribution of these demands to the development of musculoskeletal disorders is unclear. The purpose of this study was to investigate muscle- and task-dependent responses to concurrent demands during intermittent static work. Twenty-four participants performed shoulder, wrist, and torso exertions at three levels of physical workload (PWL) in the absence (control) and presence (concurrent) of a mental arithmetic task. Compared to the control, concurrent demand conditions resulted in decreased muscle activity (4–9% decrease), increased cardiovascular load (2–4% increase), and impaired motor co-ordination (9–24% increase in force fluctuation). Furthermore, these outcomes were more prominent at higher PWL levels and within postural (shoulder and torso) muscles. Mental task performance exhibited greater
interference with the physical task at low and high PWL levels. Thus, it may be important to consider these muscle- and task-specific interactions of concurrent demands during job design to address worker health and performance issues.

**Practitioner Summary:** Occupational tasks place both physical and mental demands on workers. These demands can adversely affect physiological responses and performance, and are muscle- and task-dependent. Findings from this research may facilitate the development of ergonomics interventions, such as task redesign and tool/workstation design, that may help reduce risk of workplace injuries.

- **Keywords:** physical workload, mental workload, physiological responses, performance


Numerical typing is an important perceptual-motor task whose performance may vary with different pacing, finger strategies and urgency of situations. Queuing network-model human processor (QN-MHP), a computational architecture, allows performance of perceptual-motor tasks to be modelled mathematically. The current study enhanced QN-MHP with a top-down control mechanism, a close-loop movement control and a finger-related motor control mechanism to account for task interference, endpoint reduction, and force deficit, respectively. The model also incorporated neuromotor noise theory to quantify endpoint variability in typing. The model predictions of typing speed and accuracy were validated with Lin and Wu's (2011) experimental results. The resultant root-mean-squared errors were 3.68% with a correlation of 95.55% for response time, and 35.10% with a correlation of 96.52% for typing accuracy. The model can be applied to provide optimal speech rates for voice synthesis and keyboard designs in different numerical typing situations.

**Practitioner Summary:** An enhanced QN-MHP model was proposed in the study to mathematically account for the effects of pacing, finger strategies and internalised urgency on numerical typing performance. The model can be used to provide optimal pacing for voice synthesise systems and suggested optimal numerical keyboard designs under urgency.

- **Keywords:** cognitive modelling, numerical typing, numerical keyboard design, typing error

Leanna M. Horton, Maury A. Nussbaum & Michael J. Agnew. *Effects of rotation frequency and task order on localised muscle fatigue and performance during repetitive static shoulder exertions.* Pages 1205-1217.

Though widely considered to reduce physical exposures and increase exposure variation, there is limited evidence that rotating between tasks is effective in reducing the risk of work-related musculoskeletal disorders (WMSDs). The purpose of this study was to assess the effects of rotation, specifically focusing on rotation frequency and task order, on muscle fatigue and performance when rotating between tasks that load the same muscle group. Twelve participants completed six experimental sessions during which repetitive static shoulder abduction tasks were performed at two exertion levels for one hour either with or without rotation. Compared to only performing a higher or lower exertion task, rotating between the two tasks decreased and increased fatigue, respectively. Increasing rotation frequency adversely affected task performance, and task
order had a minor effect on muscle fatigue. These rotation parameters may be important considerations when implementing rotation in the workplace.

**Practitioner Summary:** Rotation is widely used and assumed to reduce the risk of WMSDs, yet little research supports that it is effective in doing so. Results here show that specific aspects of a rotation scheme may influence muscle fatigue and task performance, though further research is needed under more realistic task conditions.

- **Keywords:** rotation frequency, task order, muscle fatigue, performance, shoulder

**Erica Beaucage-Gauvreau, Geneviève A. Dumas & Mohamed Lawani.**
*Trunk postural demands of occupational activities of some merchant pregnant women in Benin, West Africa. Pages 1218-1228.*

Strenuous physical work puts expectant mothers at risk of experiencing back pain during the gestational months. Pregnant women in Benin perform physically demanding occupational tasks that include the lifting and carriage of heavy loads on their heads for commercial activities. A large percentage of pregnant subjects (58%) reported having back pain episodes since the start of their pregnancy. However, the mean Oswestry score of the affected participants was relatively low with a mean score of 0.2 (SD: 0.12), on a scale from 0 to 1. An evaluation of the postural demands of the occupational activities of these women revealed that they performed on average 328 trunk flexions at angles exceeding 60°, with 66 of these flexions sustained for more than 4 s, during the average 7.9 h where trunk postures were recorded. They also spent on average 36% of the recording time at trunk flexion angles larger than 20°. These results show that the merchant pregnant women in the Porto-Novo area in Benin are at great risk for developing back disorders during pregnancy.

**Practitioner Summary:** Results will make a first contribution to the literature by identifying the stressful postures adopted during a typical day. The findings of this study can help in the development of preventative concepts and postural modification techniques to decrease the occurrence of back pain during pregnancy for women in Benin.

- **Keywords:** Africa, occupational activities, trunk posture, inclinometer, back pain, pregnancy

**J.A. Hess, R.L. Mizner, L. Kincl & D. Anton.**
*Alternatives to lifting concrete masonry blocks onto rebar: biomechanical and perceptual evaluations. Pages 1229-1242.*

This study examined the use of and barriers to H-block and high lift grouting, two alternatives to lifting concrete masonry blocks onto vertical rebar. Peak and cumulative shoulder motions were evaluated, as well as adoption barriers: H-block cost and stakeholder perceptions. Results indicated that using the alternatives significantly decreased peak shoulder flexion ($p < 0.001$). A case study indicated that building cost was higher with H-block, but the difference was less than 2% of the total cost. Contractors and specifiers reported important differences in perceptions, work norms, and material use and practices. For example, 48% of specifiers reported that use of high lift grouting was the contractor's choice, while 28% of contractors thought it must be specified. Use of H-block or high-lift grouting should be considered as methods to reduce awkward upper extremity postures. Cost and stakeholders' other perceptions present barriers that are important considerations when developing diffusion strategies for these alternatives.
Practitioner Summary: This study provides information from several perspectives about ergonomic controls for a high risk bricklaying task, which will benefit occupational safety experts, health professionals and ergonomists. It adds to the understanding of shoulder stresses, material cost and stakeholder perceptions that will contribute to developing effective diffusion strategies.

- Keywords: ergonomics, bricklaying, shoulder injury, stakeholder perceptions, biomechanics, diffusion of innovation


The purpose of this study was to investigate the effects of personal protective equipment (PPE) on cardiovascular and metabolic responses during incremental exercise, and to determine if PPE affects the relationship between heart rate (HR) and oxygen uptake when expressed as the chronotropic index (CI). Ten male participants performed graded exercise tests under three conditions: control (CON), (PPE) and weighted vest (WV) (same weight as PPE). Time to exhaustion was significantly longer in the CON compared to the other conditions ($p < 0.01$). Submaximal oxygen uptake and HR were significantly lower in the CON compared to the PPE and WV conditions. The CI (CON, 32.2 ± 4.5; PPE, 31.7 ± 5.7; WV, 32.6 ± 4.9) was similar in all three conditions. This study has shown that additional weight and encapsulating clothing leads to elevations in HR and oxygen uptake compared to a control condition, however, the CI remains unaffected.

Practitioner Summary: Firefighters wear personal protective equipment that is designed to protect the wearer; however it also imposes a physiological burden. It is known that work in firefighting PPE increases cardiovascular and metabolic strain. This study has shown that PPE does not alter the relationship between heart rate and oxygen uptake.

- Keywords: firefighting, personal protective equipment, heart rate, oxygen uptake, chronotropic index

Sibylle Pennig, Julia Quehl & Vinzent Rolny. Effects of aircraft cabin noise on passenger comfort. Pages 1252-1265.

The effects of cabin noise on subjective comfort assessments were systematically investigated in order to reveal optimisation potentials for an improved passenger noise acceptance. Two aircraft simulation studies were conducted. An acoustic laboratory test facility provided with loudspeaker systems for realistic sound presentations and an aircraft cabin simulator (Dornier Do 728) with a high degree of ecological validity were used. Subjects were exposed to nine different noise patterns (three noise levels ranging from 66 to 78 dB(A) combined with three different frequency spectra). Regression analysis demonstrated a significant increase of passengers' acceptance with lower noise levels and significant effects of different frequency spectra determined by seat position in the aircraft cabin (front, middle, rear). Acoustic cabin design should therefore consider measures beyond noise level reduction altering noise characteristics to improve passengers' comfort and well-being in the aircraft cabin.

Practitioner Summary: To improve passenger comfort in the aircraft with respect to cabin noise, passengers' reactions to specific noise conditions were systematically investigated. Two laboratory studies showed significant dose-response relationships
between sound pressure level and subjective comfort ratings which differed due to the noise at specific seat positions in the aircraft.

- **Keywords:** aircraft cabin noise, comfort, well-being, sound pressure level, frequency spectrum

**Brianna Larsen & Brad Aisbett. Subjective job task analyses for physically demanding occupations: What is best practice? Pages 1266-1277.**

Workers in physically demanding occupations (PDOs) are frequently subjected to physical selection tests. To avoid legal ramifications, workplaces must be able to show that any personnel selection procedures reflect the inherent requirements of the job. A job task analysis (JTA) is fundamental in determining the work tasks required for employees. To date, there are no published instructions guiding PDO researchers on how to conduct job task analyses. Job task analysis research for non-PDOs offers some insight into the expected reliability and validity of data obtained on the most prevalent task domains in job analysis (importance, frequency, time spent and difficulty). This review critiques such research, and the existing published material on JTA of PDOs, and provides recommendations for future research and practice.

**Practitioner Summary:** There are no published guidelines for physically demanding occupation (PDO) researchers conducting job task analysis (JTA). Given the legal consequences of improperly conducted JTA, scientifically valid instructions for JTA practitioners are required. This review critiques existing research which analyses reliabilities of JTA data, and provides guidelines for PDO researchers conducting JTA.

- **Keywords:** physical selection tests, inherent requirements, task domains, reliability, validity

**Robin Burgess-Limerick, Christine M. Zupanc & Guy Wallis. Directional control–response compatibility of joystick steered shuttle cars. Pages 1278-1283.**

Shuttle cars are an unusual class of vehicle operated in underground coal mines, sometimes in close proximity to pedestrians and steering errors may have very serious consequences. A directional control–response incompatibility has previously been described in shuttle cars which are controlled using a steering wheel oriented perpendicular to the direction of travel. Some other shuttle car operators are seated perpendicular to the direction of travel and steer the car via a seat mounted joystick. A virtual simulation was utilised to determine whether the steering arrangement in these vehicles maintains directional control–response compatibility. Twenty-four participants were randomly assigned to either a condition corresponding to this design (consistent direction), or a condition in which the directional steering response was reversed while driving in-bye (visual field compatible). Significantly less accurate steering performance was exhibited by the consistent direction group during the in-bye trials only. Shuttle cars which provide the joystick steering mechanism described here require operators to accommodate alternating compatible and incompatible directional control–response relationships with each change of car direction.

**Practitioner Summary:** A virtual simulation of an underground coal shuttle car demonstrates that the design incorporates a directional control–response incompatibility when driving the vehicle in one direction. This design increases the probability of operator error, with potential adverse safety and productivity consequences
• **Keywords:** steering, joystick, directional compatibility