In this paper, we analyse two approaches that attempt to address how a human factors and ergonomics (HFE) perspective can contribute to the sustainability of the human race. We outline the principles, purposes and fields of application of ergoeconomy and green ergonomics, and thereafter deal with their context of emergence, and the overlaps in purpose, and principles. Shared values are deduced and related to socio-technical principles for systems’ design. Social responsibility and environmental/ecospheric responsibility are the leading threads of ergoeconomy and green ergonomics, giving rise to the values of: respect for human rights, respect for the Earth, respect for ethical decision-making, appreciation of complexity, respect for transparency and openness, and respect for diversity. We discuss the consequences of considering these values in HFE theory and practice. Practitioner summary: Through the analysis of ergoeconomy and green ergonomics, this qualitative interpretative study presents the importance of values in the shift towards sustainability from a human factors and ergonomics perspective, contributing to the design of more sustainable socio-technical systems and HFE practices.

Keywords: ergonomics, ergoeconomy, green ergonomics, sustainability, values

This study aims to determine whether indirect touch device can be used to interact with graphical objects displayed on another screen in an air traffic control (ATC) context. The introduction of such a device likely requires an adaptation of the sensory-motor system. The operator has to simultaneously perform movements on the horizontal plane while assessing them on the vertical plane. Thirty-six right-handed participants performed movement training with either constant or variable practice and with or without visual feedback of the displacement of their actions. Participants then performed a test phase without visual feedback. Performance improved in both practice conditions, but accuracy

Keywords: usability, trainability, indirect touch interaction.
was higher with visual feedback. During the test phase, movement time was longer for those who had practiced with feedback, suggesting an element of dependency. However, this ‘cost’ of feedback did not extend to movement accuracy. Finally, participants who had received variable training performed better in the test phase, but accuracy was still unsatisfactory. We conclude that continuous visual feedback on the stylus position is necessary if tablets are to be introduced in ATC. **Practitioner Summary:** We investigated the possibility of integrating a tablet computer as an input device in air traffic control. While we found that practice globally improved pointing performance, we concluded that the presence of continuous visual feedback on the stylus position is necessary to guarantee selection efficiency.

- **Keywords:** air traffic control, tablet computer, aiming movements, visual feedback, training, control strategies

**Paul M. Salmon, Michael G. Lenne, Guy H. Walker, Neville A. Stanton & Ashleigh Filtness. Using the Event Analysis of Systemic Teamwork (EAST) to explore conflicts between different road user groups when making right hand turns at urban intersections. pages 1628-1642.**

Collisions between different types of road users at intersections form a substantial component of the road toll. This paper presents an analysis of driver, cyclist, motorcyclist and pedestrian behaviour at intersections that involved the application of an integrated suite of ergonomics methods, the Event Analysis of Systemic Teamwork (EAST) framework, to on-road study data. EAST was used to analyse behaviour at three intersections using data derived from an on-road study of driver, cyclist, motorcyclist and pedestrian behaviour. The analysis shows the differences in behaviour and cognition across the different road user groups and pinpoints instances where this may be creating conflicts between different road users. The role of intersection design in creating these differences in behaviour and resulting conflicts is discussed. It is concluded that currently intersections are not designed in a way that supports behaviour across the four forms of road user studied. Interventions designed to improve intersection safety are discussed. **Practitioner Summary:** Intersection safety currently represents a key road safety issue worldwide. This paper presents a novel application of a framework of ergonomics methods for studying differences in road user behaviour at intersections. The findings support development of interventions that consider all road users as opposed to one group in isolation.

- **Keywords:** intersections, road safety, EAST, systems analysis, drivers, cyclists, motorcyclists, pedestrian

**Bryan Reimer, Bruce Mehler, Jonathan Dobres, Joseph F. Coughlin, Steve Matteson, David Gould, Nadine Chahine & Vladimir Levantovsky. Assessing the impact of typeface design in a text-rich automotive user interface. pages 1643-1658.**

Text-rich driver–vehicle interfaces are increasingly common in new vehicles, yet the effects of different typeface characteristics on task performance in this brief off-road based glance context remains sparsely examined. Subjects completed menu selection tasks while in a driving simulator. Menu text was set either in a ‘humanist’ or ‘square grotesque’ typeface. Among men, use of the humanist typeface resulted in a 10.6% reduction in total glance time as compared to the square grotesque typeface. Total response time and number of glances showed similar reductions. The impact of typeface was either more modest or not apparent for women. Error rates for both males and females were 3.1% lower for the humanist typeface. This research suggests that optimised typefaces may mitigate some interface demands. Future work will need to assess whether other typeface characteristics can be optimised to further reduce
demand, improve legibility, increase usability and help meet new governmental
distraction guidelines. Practitioner Summary: Text-rich in-vehicle interfaces are
increasingly common, but the effects of typeface on task performance remain sparsely
studied. We show that among male drivers, menu selection tasks are completed with
10.6% less visual glance time when text is displayed in a ‘humanist’ typeface, as
compared to a ‘square grotesque’.

- Keywords: typography, driving, distraction, display, legibility

Pingping Liu, Weijun Li, Buxin Han & Xingshan Li. Effects of anomalous
characters and small stroke omissions on eye movements during the
reading of Chinese sentences. pages 1659-1669.

We investigated the influence of typographical errors (typos) on eye movements and
word recognition in Chinese reading. Participants' eye movements were tracked as they
read sentences in which the target words were presented (1) normally, (2) with
the initial stroke of the first characters removed (the omitted stroke condition) or (3) the first
characters replaced by anomalous characters (the anomalous character condition). The
results indicated that anomalous characters caused longer fixation durations and shorter
outgoing forward saccade lengths than the correct words. This finding is consistent with
the prediction of the theory of the processing-based strategy. Additionally, anomalous
characters strongly disrupted lexical processing and whole sentence comprehension, but
small stroke omissions did not. Implications of the effect of processing difficulty on
forward saccade targeting for models of eye movement control during Chinese reading
are discussed. Practitioner Summary: A better understanding of the effects of different
types of spelling errors on eye movements and sentence reading could provide valuable
evidence to highlight the importance of correct spelling. We find that readers' oculomotor
control system may be flexible and able to adapt to unusual presentation effectively.

- Keywords: eye movements, typographical errors, saccade length, Chinese readi

Cosima Piepenbrock, Susanne Mayr & Axel Buchner. Smaller pupil size
and better proofreading performance with positive than with negative
polarity displays. pages 1670-1677.

The ‘positive polarity advantage’ describes the fact that reading performance is better for
dark text on light background (positive polarity) than for light text on dark background
(negative polarity). We investigated the underlying mechanism by assessing pupil size
and proofreading performance when reading positive and negative polarity texts. In
particular, we tested the display luminance hypothesis which postulates that the typically
greater brightness of positive compared to negative polarity displays leads to smaller
pupil sizes and, hence, a sharper retinal image and better perception of detail. Indeed,
pupil sizes were smaller and proofreading performance was better with positive than with
negative polarity displays. The results are compatible with the hypothesis that the
positive polarity advantage is an effect of display luminance. Limitations of the study are
being discussed. Practitioner Summary: Digital displays are ubiquitous. Understanding
of the mechanisms underlying the perception of text is important for good display design.
The hypothesis that bright positive polarity displays leads to small pupils and a sharp
retinal image that improves reading cannot be rejected and is thus maintained. Positive
polarity displays are recommended.

- Keywords: display polarity, pupil size, eye tracking, display design, screen
  luminance

Marina Ciccarelli, Leon Straker, Svend Erik Mathiassen & Clare Pollock.
Posture variation among office workers when using different information
and communication technologies at work and away from work. pages 1678-1686

Office workers perform tasks using different information and communication technologies (ICT) involving various postures. Adequate variation in postures and muscle activity is generally believed to protect against musculoskeletal complaints, but insufficient information exists regarding the effect on postural variation of using different ICT. Thus, this study among office workers aimed to determine and compare postures and postural variation associated with using distinct types of ICT. Upper arm, head and trunk postures of 24 office workers were measured with the Physiometer® over a whole day in their natural work and away-from-work environments. Postural variation was quantified using two indices: APDF(90-10) and EVA(ud). Various ICT had different postural means and variation. Paper-based tasks had more non-neutral, yet also more variable postures. Electronics-based tasks had more neutral postures, with less postural variability. Tasks simultaneously using paper- and electronics-based ICT had least neutral and least variable postures. Tasks without ICT usually had the most posture variability. Interspersing tasks involving different ICT could increase overall exposure variation among office workers and may thus contribute to musculoskeletal risk reduction.

Practitioner Summary: This study in office workers assessed posture variation, which is believed to protect against musculoskeletal complaints. Electronics-based tasks had more neutral upper body postures but less posture variation than other tasks. Combining tasks based on different technologies could increase postural variation in and outside the job for office workers.

• Keywords: ICT, posture, exposure variation analysis, APDF(90-10)


The purpose of this study was to determine the influence of seat height and foot position in the sagittal plane on L5-S1 joint load. Fourteen healthy male adults stood up from a chair with three different seat heights and positions of the feet in the sagittal plane. L5-S1 net joint torque, mechanical work, range of motion and electromyographic activity of the erector spinae muscle were measured. L5-S1 net joint work increased by about 50% from high to low seat position. The mean and peak L5-S1 net joint torques increased about 30% from foot-back to foot-neutral position. These results were reinforced by a greater integrated electromyography signal from the erector spinae from high to low seat position and from foot-back to foot-neutral position. A high chair and placement of the feet behind the knees may be advisable to lessen lumbar load during sit-to-stand movements.

Practitioner Summary: This study evaluated the effect of seat height and foot position on L5-S1 joint work and erector spinae activation during sit-to-stand movements. A high seat with the feet positioned further back decreased L5-S1 joint torque and erector spinae activation. These outcomes may help to reduce spine load during sit-to-stand movements.

• Keywords: L5-S1 joint, joint work, electromyography, biomechanics

Linda M. Rose, W. Patrick Neumann, Göran M. Hägg & Göran Kenttä. Fatigue and recovery during and after static loading. pages 1696-1710.

Subjectively assessed endurance time (ET), resumption time (RT) and perceived discomfort, pain or fatigue (PD), and objectively measured maximum force-exerting capacity were investigated for varying loads and durations of a pushing task with two repeated trials. Beyond the main results quantifying how the load scenario affected ET, RT and PD, three additional results are of note: (1) although the maximum pushing force did not change between trials, shorter ET, longer RT and higher PD indicated
accumulation of fatigue in Trial 2; (2) the PD ratings showed a trend with a linear increase during loading and a curvilinear decrease during recovery; and (3) the RT and the load level for different relative loading times were found to have an unexpected U-shaped relationship, indicating lowest fatigue at the intermediate load level. These results can be used to model a more sustainable and productive work-recovery ratio. **Practitioner Summary:** Sufficient recovery during a work-shift is important for sustainable work. This paper presents data from an empirical study on how fatigue reactions and recovery needs vary with load level and loading time and with one repeated loading. The results enable the modelling of work-recovery ratios to ensure adequate recovery during work-shifts.

- **Keywords:** resumption time, perceived discomfort/pain/fatigue, force, subjective assessment


The human response to vibration is typically studied using linear estimators of the frequency response function, although different literature works evidenced the presence of non-linear effects in whole-body vibration response. This paper analyses the apparent mass of standing subjects using the conditioned response techniques in order to understand the causes of the non-linear behaviour. The conditioned apparent masses were derived considering models of increasing complexity. The multiple coherence function was used as a figure of merit for the comparison between the linear and the non-linear models. The apparent mass of eight male subjects was studied in six configurations (combinations of three vibration magnitudes and two postures). The contribution of the non-linear terms was negligible and was endorsed to the change of modal parameters during the test. Since the effect of the inter-subject variability was larger than that due to the increase in vibration magnitude, the biodynamic response should be more meaningfully modelled using a linear estimator with uncertainty rather than looking for a non-linear modelling. **Practitioner Summary:** Causes of the non-linear body response to whole-body vibration are not clear. The biodynamic response of standing subjects (computed using the conditioned response techniques) evidenced that the non-linearity is due to the modal parameter changes during the test, but its effect is negligible in comparison with the inter-subject variability.

- **Keywords:** whole-body vibration, non-linearity, apparent mass, modelling physical response, acceleration exposures

Yu Huang & Michael J. Griffin. *The discomfort produced by noise and whole-body vertical vibration presented separately and in combination.* pages 1724-1738.

This study investigated the prediction of the discomfort caused by simultaneous noise and vibration from the discomfort caused by noise and the discomfort caused by vibration when they are presented separately. A total of 24 subjects used absolute magnitude estimation to report their discomfort caused by seven levels of noise (70–88 dBA SEL), 7 magnitudes of vibration (0.146–2.318 ms$^{-1.75}$) and all 49 possible combinations of these noise and vibration stimuli. Vibration did not significantly influence judgements of noise discomfort, but noise reduced vibration discomfort by an amount that increased with increasing noise level, consistent with a ‘masking effect’ of noise on judgements of vibration discomfort. A multiple linear regression model or a root-sums-of-squares model predicted the discomfort caused by combined noise and vibration, but the root-sums-of-squares model is more convenient and provided a more accurate prediction of the discomfort produced by combined noise and vibration. **Practitioner Summary:** The total discomfort produced by combined noise and vibration, $\psi_c$, can be well predicted...
from the root-sums-of-squares of the noise discomfort, $\psi_{\text{sn}}$, and the vibration discomfort, $\psi_{\text{sv}}$, when each stimulus is presented alone (i.e. $\psi_c = [\psi_{\text{sn}}^2 + \psi_{\text{sv}}^2]^{0.5}$).

- **Keywords:** whole-body vibration, hearing, sound and noise, transport ergonomics, vehicle ergonomics, general ergonomics

**Erika M. Pliner, Naira H. Campbell-Kyureghyan & Kurt E. Beschorner. Effects of foot placement, hand positioning, age and climbing biodynamics on ladder slip outcomes. pages 1739-1749.**

Ladder falls frequently cause severe injuries; yet the factors that influence ladder slips/falls are not well understood. This study aimed to quantify (1) the effects of restricted foot placement, hand positioning, climbing direction and age on slip outcomes, and (2) differences in climbing styles leading to slips versus styles leading to non-slips. Thirty-two occupational ladder users from three age groups (18–24, 25–44 and 45–64 years) were unexpectedly slipped climbing a vertical ladder, while being assigned to different foot placement conditions (unrestricted vs. restricted toe clearance) and different hand positions (rails vs. rungs). Constraining foot placement increased the climber's likelihood of slipping ($p < 0.01$), while younger and older participants slipped more than the middle-aged group ($p < 0.01$). Longer double stance time, dissimilar and more variable foot and body positioning were found in styles leading to a slip. Maintaining sufficient toe clearance and targeting ladder safety training to younger and older workers may reduce ladder falls. **Practitioner Summary:** Ladder falls frequently cause severe occupational fall injuries. This study aims to identify safer ladder climbing techniques and individuals at risk of falling. The results suggest that ladders with unrestricted toe clearance and ladder climbing training programmes, particularly for younger and older workers, may reduce ladder slipping risk.

- **Keywords:** ladder falls, climbing biomechanics, aging, slips, trips and falls

**W. Todd Rogers, David Docherty & Stewart Petersen. Establishment of performance standards and a cut-score for the Canadian Forces Firefighter Physical Fitness Maintenance Evaluation (FF PFME). pages 1750-1759.**

The Bookmark method for setting cut-scores was used to re-set the cut-score for the Canadian Forces Firefighter Physical Fitness Maintenance Evaluation (FF PFME). The time required to complete 10 tasks that together simulate a first-response firefighting emergency was accepted as a measure of work capacity. A panel of 25 Canadian Forces firefighter supervisors set cut-scores in three rounds. Each round involved independent evaluation of nine video work samples, where the times systematically increased from 400 seconds to 560 seconds. Results for Round 1 were discussed before moving to Round 2 and results for Round 2 were discussed before moving to Round 3. Accounting for the variability among panel members at the end of Round 3, a cut-score of 481 seconds (mean Round 3 plus 2 SEM) was recommended. Firefighters who complete the FF PFME in 481 seconds or less have the physical capacity to complete first-response firefighting work. **Practitioner Summary:** Task-simulation tests are commonly used to evaluate physical fitness for duty in emergency response occupations such as firefighting. This paper describes the novel use of the Bookmark method where a panel of expert judges approved performance standards and set a cut-score for physical fitness of Canadian Forces firefighters.

- **Keywords:** firefighting, task simulation test, standard setting, Bookmark method

Many occupations require the use of personal protective equipment (PPE) but the added metabolic demands are unknown for certain professions. The purpose of this study was to quantify metabolic and perceptual differences between activity with and without the PPE ensemble required for police officers. Twelve participants were asked to complete experimental and control exercise sessions consisting of three modes of exercise (walking, jogging and stepping). A significant main effect ($p < 0.01$) for gear was found for heart rate (beats per minute) and VO$_2$ (L/min) between conditions. Dependent $t$-tests revealed significant differences for perceived effort, discomfort and session rating of perceived exertion between trials. Medium to large effect sizes for all variables with significant main effects between modes ($p < 0.01$, $\eta^2 = 0.51–0.96$, $1-\beta = 0.98–1.0$, $d = 0.42–2.7$) were observed. These findings help to increase awareness of how PPE affects metabolic demands and perception of discomfort during exercise. **Practitioner Summary:** This study determined that the safety and protective equipment worn by police officers increases energy expenditure and adds a feeling of effort to exercise. Better design of equipment, use of fitness programmes or yearly assessments may help to alleviate some of this added stress.

- **Keywords:** metabolic demand, personal protective equipment, work physiology, law enforcement