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Helen P. N. Hughes, Chris W. Clegg, Lucy E. Bolton & Lauren C. Machon.
Systems scenarios: a tool for facilitating the socio-technical design of work systems. Pages: 1319-1335.

The socio-technical systems approach to design is well documented. Recognising the benefits of this approach, organisations are increasingly trying to work with systems, rather than their component parts. However, few tools attempt to analyse the complexity inherent in such systems, in ways that generate useful, practical outputs. In this paper, we outline the 'System Scenarios Tool' (SST), which is a novel, applied methodology that can be used by designers, end-users, consultants or researchers to help design or re-design work systems. The paper introduces the SST using examples of its application, and describes the potential benefits of its use, before reflecting on its limitations. Finally, we discuss potential opportunities for the tool, and describe sets of circumstances in which it might be used. **Practitioner Summary:** The paper presents a novel, applied methodological tool, named the 'Systems Scenarios Tool'. We believe this tool can be used as a point of reference by designers, end-users, consultants or researchers, to help design or re-design work systems. Included in the paper are two worked examples, demonstrating the tool's application.

- **Keywords:** Work organisation, socio-technical systems, system performance modelling, cost-benefit analysis, ergonomics tools and methods

Sarah-Louise Donovan, Paul M. Salmon, Michael G. Lenné & Tim Horberry. ***Safety leadership and systems thinking: application and evaluation of a Risk Management Framework in the mining industry.*** Pages: 1336-1350.

Safety leadership is an important factor in supporting safety in high-risk industries. This article contends that applying systems-thinking methods to examine safety leadership can support improved learning from incidents. A case study analysis was undertaken of a large-scale mining landslide incident in which no injuries or fatalities were incurred. A multi-method approach was adopted, in which the Critical Decision Method, Rasmussen's Risk Management Framework and Accimap method were applied to examine the safety leadership decisions and actions which enabled the safe outcome. The approach enabled

Rasmussen's predictions regarding safety and performance to be examined in the safety leadership context, with findings demonstrating the distribution of safety leadership across leader and system levels, and the presence of vertical integration as key to supporting the successful safety outcome. In doing so, the findings also demonstrate the usefulness of applying systems-thinking methods to examine and learn from incidents in terms of what 'went right'. The implications, including future research directions, are discussed. **Practitioner Summary:** This paper presents a case study analysis, in which systems-thinking methods are applied to the examination of safety leadership decisions and actions during a large-scale mining landslide incident. The findings establish safety leadership as a systems phenomenon, and furthermore, demonstrate the usefulness of applying systems-thinking methods to learn from incidents in terms of what 'went right'. Implications, including future research directions, are discussed.

- **Keywords:** Safety leadership, systems-thinking, safe performance, learning from incidents

L. Reinerman-Jones, D. J. Barber, J. L. Szalma & P. A. Hancock. *Human interaction with robotic systems: performance and workload evaluations*. Pages: 1351-1368.

We first tested the effect of differing tactile informational forms (i.e. directional cues vs. static cues vs. dynamic cues) on objective performance and perceived workload in a collaborative human-robot task. A second experiment evaluated the influence of task load and informational message type (i.e. single words vs. grouped phrases) on that same collaborative task. In both experiments, the relationship of personal characteristics (attentional control and spatial ability) to performance and workload was also measured. In addition to objective performance and self-report of cognitive load, we evaluated different physiological responses in each experiment. Results showed a performance-workload association for directional cues, message type and task load. EEG measures however, proved generally insensitive to such task load manipulations. Where significant EEG effects were observed, right hemisphere amplitude differences predominated, although unexpectedly these latter relationships were negative. Although EEG measures were partially associated with performance, they appear to possess limited utility as measures of workload in association with tactile displays. **Practitioner Summary:** As practitioners look to take advantage of innovative tactile displays in complex operational realms like human-robotic interaction, associated performance effects are mediated by cognitive workload. Despite some patterns of association, reliable reflections of operator state can be difficult to discern and employ as the number, complexity and sophistication of these respective measures themselves increase.

- **Keywords:** Objective performance, subjective response, physiological reactions, tactile signalling, human-robot interaction

Prithima R. Mosaly, Lukasz M. Mazur & Lawrence B. Marks. *Quantification of baseline pupillary response and task-evoked pupillary response during constant and incremental task load*. Pages: 1369-1375.

The methods employed to quantify the baseline pupil size and task-evoked pupillary response (TEPR) may affect the overall study results. To test this hypothesis, the objective of this study was to assess variability in baseline pupil size and TEPR during two basic working memory tasks: constant load of 3-letters memorisation-recall (10 trials), and incremental load memorisation-recall (two trials of each load level), using two commonly used methods (1) change from trail/load specific baseline, (2) change from constant baseline. Results indicated that there was a significant shift in baseline between the trials for constant load, and between the load levels for incremental load. The TEPR was independent of shifts in baseline using method 1 only for constant load, and method 2 only for higher levels of incremental load condition. These important findings suggest

that the assessment of both the baseline and methods to quantify TEPR are critical in ergonomics application, especially in studies with small number of trials per subject per condition. **Practitioner Summary:** Quantification of TEPR can be affected by shifts in baseline pupil size that are most likely affected by non-cognitive factors when other external factors are kept constant. Therefore, quantification methods employed to compute both baseline and TEPR are critical in understanding the information processing of humans in practical ergonomics settings.

- **Keywords:** Cognitive workload, task evoked pupillary response (TEPR), baseline pupil size, working memory

Ho-Sang Lee, Jung-Yong Kim, Murali Subramaniam, Sangho Park & Seung-Nam Min. *Evaluation of quantitative glare technique based on the analysis of bio-signals.* Pages: 1376-1383.

This laboratory study evaluated the effect of glare source (halogen, HID and LED) and its illumination levels (0.7, 2 and 5 lx) using a quantitative methodology. Pupil diameter and electroencephalography were measured using FaceLab and Biopac systems, respectively. The discomfort glare was assessed subjectively with Borg's CR-10 scale. Twenty healthy subjects participated. Pupil size was significantly affected by the headlamp type and illumination condition. Pupil size was smaller when exposed to the LED headlamp than other headlamps (Halogen > HID > LED). In addition, when the illumination increased, pupil size decreased (0.7 lx > 2 lx > 5 lx). Also, driver's discomfort increased when pupil size was small, and theta waves were high. This discomfort may cause reduced attention and safety of the driver. These results can be applied to design and development of headlamps. Further investigation is necessary with adopted methodology to evaluate other headlamps in different illumination conditions. **Practitioner Summary:** This study evaluated pupil size and electroencephalography under different glare source (halogen, HID and LED) and illumination levels (0.7, 2 and 5 lx). Driver's discomfort increased when pupil size was small, and theta waves were high. This discomfort may cause reduced attention and safety of the driver.

- **Keywords:** Discomfort glare, pupil size, psychological, illumination, headlamp type

Aoife Synnott, Wim Dankaerts, Jan Seghers, Helen Purtil & Kieran O'Sullivan. *The effect of a dynamic chair on seated energy expenditure.* Pages: 1384-1392.

Dynamic sitting approaches have been advocated to increase seated energy expenditure with the view of lessening the sedentary nature of the task. This study compared energy expenditure (EE) and overall body discomfort on a novel dynamic chair with a standard office chair. Fifteen pain-free participants completed a DVD viewing task on both chairs in a randomised order. Energy expenditure and discomfort were collected simultaneously. Linear mixed models were used to analyse steady-state EE recorded on each of the chairs. Differences in discomfort were analysed using Wilcoxon Signed Rank Tests. Sitting on the novel dynamic chair significantly ($p = 0.005$) increased energy expenditure compared to a standard office chair. The discomfort experienced was mild overall, but was significantly greater on the dynamic chair ($p = 0.004$). Whilst the EE was seen to be significantly higher on the dynamic chair, the MET values are still below 1.5 METS. Thus, the use of a dynamic chair does not seem to be the most effective measure to prevent sedentary behaviour. **Practitioner Summary:** Sitting on a dynamic chair increased energy expenditure compared to sitting on a standard office chair among pain-free participants. Whilst the EE was seen to be significantly higher on the dynamic chair, the MET values are still below 1.5 METS (low level EE).

- **Keywords:** Sitting, sedentary, energy expenditure, office ergonomics

Diana De Carvalho, Diane Grondin & Jack Callaghan. *The impact of office chair features on lumbar lordosis, intervertebral joint and sacral tilt angles: a radiographic assessment.* Pages: 1393-1404.

Background: The purpose of this study was to determine which office chair feature is better at improving spine posture in sitting. **Method:** Participants (n = 28) were radiographed in standing, maximum flexion and seated in four chair conditions: control, lumbar support, seat pan tilt and backrest with scapular relief. Measures of lumbar lordosis, intervertebral joint angles and sacral tilt were compared between conditions and sex. **Results:** Sitting consisted of approximately 70% of maximum range of spine flexion. No differences in lumbar flexion were found between the chair features or control. Significantly more anterior pelvic rotation was found with the lumbar support (p = 0.0028) and seat pan tilt (p < 0.0001). Males had significantly more anterior pelvic rotation and extended intervertebral joint angles through L1–L3 in all conditions (p < 0.0001). **Conclusion:** No one feature was statistically superior with respect to minimising spine flexion, however, seat pan tilt resulted in significantly improved pelvic posture. **Practitioner Summary:** Seat pan tilt, and to some extent lumbar supports, appear to improve seated postures. However, sitting, regardless of chair features used, still involves near end range flexion of the spine. This will increase stresses to the spine and could be a potential injury generator during prolonged seated exposures.

- **Keywords:** Office chair, spine, low back pain, sitting, design

Deepti Sood, Maury A. Nussbaum, Kris Hager & Helen C. Nogueira. *Predicted endurance times during overhead work: influences of duty cycle and tool mass estimated using perceived discomfort.* Pages: 1405-1414.

A need for overhead work remains in several industries and such work is an important risk factor for shoulder musculoskeletal problems. In this study, we evaluated the effects of duty cycle and tool mass on endurance times during overhead work. A psychophysical approach was used, via a new methodology that was implemented to more efficiently estimate endurance times (rather than through direct measurements). Participants performed a simulated overhead task in specified combinations of tool mass and duty cycle. Both duty cycle and tool mass have substantial effects on the development of fatigue and estimated endurance times, though the former was more substantial and an interactive effect was evident. Gender differences were not substantial, except when using the largest tool mass. We recommend that, for two-hour periods of overhead work, tool masses greater than 1.25 kg should be avoided, as should duty cycles greater than 50%. **Practitioner Summary:** The current results may facilitate enhanced design and evaluation of overhead work tasks. In addition, the new estimation approach that was employed may enhance the efficiency of future studies using a psychophysical approach (ie using extrapolation of patterns of reported discomfort to predict longer term outcomes).

- **Keywords:** Overhead work, perceived discomfort, fatigue, gender, psychophysics, guideline

Itay Ketko, Meir Plotnik, Ran Yanovich, Amit Gefen & Yuval Heled. *Wheeled assistive device for load carriage – the effects on human gait and biomechanics.* Pages: 1415-1424.

Soldiers are often required to carry loads which impose biomechanical strain on the human body. This can adversely affect physical performances. Recently, wheel-based devices (WBD) were designed to reduce the load on the soldier. In the present study, a prototype of this newly developed WBD was evaluated. Thirteen volunteers performed

three exercise protocols on a treadmill as follows: (1) no load; (2) carrying 40% of their bodyweight with a backpack or; (3) with the WBD. Data acquisition included: gait parameters, vertical ground reaction forces (VGRF) and contact pressure acting on the shoulder. Biomechanical analysis showed that the WBD decreased the contact pressure on the shoulder and the VGRF. However, greater gait variability, in terms of cycle-to-cycle gait line generation, was observed, which might point to a difficulty in maintaining stability while walking. The study suggests that WBD has a potential to reduce the biomechanical strain on the soldier while carrying heavy loads. Future potential adjustments for the development of a better WBD-based solution are suggested. **Practitioner Summary:** The present research observed the potential biomechanical advantages of using a wheel-based device designed to reduce the load on the soldier. It contributed to a lower mechanical force on the soldier's body, yet causing modulations in gait control. Future design adjustments should be made to optimise the platform.

- **Keywords:** Soldier, backpack, gait variability, pressure, ground reaction forces

Lisa A. Zukowski, Chris J. Hass, Orit Shechtman, Evangelos A. Christou & Mark D. Tillman. *The effect of wheelchair propulsion style on changes in time spent in extreme wrist orientations after a bout of fatiguing propulsion.* Pages: 1425-1434.

This study compared how wheelchair propulsion styles affect changes in percentage of time spent in extreme wrist orientations, which have been associated with median nerve injury, after a fatiguing bout of propulsion. Twenty novice, non-disabled adult males learned arcing (ARC) and semicircular (SEMI) propulsion styles and utilised each to perform a wheelchair fatigue protocol. ARC and SEMI did not significantly differ in terms of changes after the fatigue protocol in percentage of time spent in extreme flexion/extension or radial/ulnar deviation at the push phase beginning or end. A pattern was observed, although not significant, of greater increases in percentage of time spent in extreme wrist extension and ulnar deviation during the push phase beginning and ulnar deviation during the push phase end while utilising SEMI relative to ARC. This study evinces that individual differences are greater than observed changes in extreme wrist orientations for both propulsion styles. **Practitioner Summary:** How wheelchair propulsion styles change with fatigue in terms of extreme wrist orientations was examined. This study evinces that individual differences are greater than observed changes in extreme wrist orientations for both propulsion styles and point towards the need for future research on individual differences utilising propulsion styles.

- **Keywords:** Wheelchairs, overuse injuries, fatigue, wrist kinematic

Jiao Jiao, Yi Li, Lei Yao, Yajun Chen, Yueping Guo, Stephen H. S. Wong, Frency S. F. Ng & Junyan Hu. *Effects of body-mapping-designed clothing on heat stress and running performance in a hot environment.* Pages: 1435-1444.

To investigate clothing-induced differences in human thermal response and running performance, eight male athletes participated in a repeated-measure study by wearing three sets of clothing (CloA, CloB, and CloC). CloA and CloB were body-mapping-designed with 11% and 7% increased capacity of heat dissipation respectively than CloC, the commonly used running clothing. The experiments were conducted by using steady-state running followed by an all-out performance running in a controlled hot environment. Participants' thermal responses such as core temperature (T_c), mean skin temperature (\bar{T}_{sk}), heat storage (S), and the performance running time were measured. CloA resulted in shorter performance time than CloC (323.1 ± 10.4 s vs. 353.6 ± 13.2 s, $p = 0.01$), and induced the lowest \bar{T}_{sk} , smallest ΔT_c , and smallest S in the resting and running phases. This study indicated that clothing made with different heat dissipation

capacities affects athlete thermal responses and running performance in a hot environment. **Practitioner Summary:** A protocol that simulated the real situation in running competitions was used to investigate the effects of body-mapping-designed clothing on athletes' thermal responses and running performance. The findings confirmed the effects of optimised clothing with body-mapping design and advanced fabrics, and ensured the practical advantage of developed clothing on exercise performance.

- **Keywords:** Sportswear, running exercise, thermal responses, core temperature, heat dissipation

Gilvan V. da Silva, Manny Halpern & Claire C. Gordon. *Anthropometry of Brazilian Air Force pilots*. Pages: 1445-1457.

Anthropometric data are essential for the design of military equipment including sizing of aircraft cockpits and personal gear. Currently, there are no anthropometric databases specific to Brazilian military personnel. The aim of this study was to create a Brazilian anthropometric database of Air Force pilots. The methods, protocols, descriptions, definitions, landmarks, tools and measurements procedures followed the instructions outlined in Measurer's Handbook: US Army and Marine Corps Anthropometric Surveys, 2010–2011 – NATICK/TR-11/017. The participants were measured countrywide, in all five Brazilian Geographical Regions. Thirty-nine anthropometric measurements related to cockpit design were selected. The results of 2133 males and 206 females aged 16–52 years constitute a set of basic data for cockpit design, space arrangement issues and adjustments, protective gear and equipment design, as well as for digital human modelling. Another important implication is that this study can be considered a starting point for reducing gender bias in women's career as pilots. **Practitioner Summary:** This paper describes the first large-scale anthropometric survey of the Brazilian Air Force pilots and the development of the related database. This study provides critical data for improving aircraft cockpit design for ergonomics and comprehensive pilot accommodation, protective gear and uniform design, as well as digital human modelling.

- **Keywords:** Anthropometry, cockpit design, flight deck, pilot accommodation, Brazilian Air Force