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P.A. Hancock, B.D. Sawyer & S. Stafford. *The effects of display size on performance.* Pages 337-354.

We examined the systematic effects of display size on task performance as derived from a standard perceptual and cognitive test battery. Specifically, three experiments examined the influence of varying viewing conditions on response speed, response accuracy and subjective workload at four differing screen sizes under three different levels of time pressure. Results indicated a ubiquitous effect for time pressure on all facets of response while display size effects were contingent upon the nature of the viewing condition. Thus, performance decrement and workload elevation were evident only with the smallest display size under the two most restrictive levels of time pressure. This outcome generates a lower boundary threshold for display screen size for this order of task demand. Extrapolations to the design and implementation of all display sizes and forms of cognitive and psychomotor demand are considered. **Practitioner Summary:** This work specifies the effect of display size on operator performance. It presents a threshold for an acceptable level of response time and accuracy contingent upon time pressure imposed and display size presented. The procedure provides vital information for all future designers and users of displays.

- **Keywords:** display size, time pressure, response capacity, speed, accuracy

Catrin Hasse & Carmen Bruder. *Eye-tracking measurements and their link to a normative model of monitoring behavior.* Pages 355-367.

Increasing automation necessitates operators monitoring appropriately (OMA) and raises the question of how to identify them in future selections. A normative model was developed providing criteria for the identification of OMA. According to this model, the monitoring process comprises distinct monitoring phases (orientation, anticipation, detection and recheck) in which attention should be focused on relevant areas. The current study tests the normative model on the basis of eye tracking. The eye-tracking data revealed increased concentration on relevant areas during the orientation and anticipation phase in comparison to the other phases. For the assessment of monitoring behaviour in the context of personnel selection, this implies that the anticipation and orientation phases should be considered separately as they appear to be more important

in the context of monitoring than the other phases. **Practitioner Summary:** A normative model was developed for the assessment of monitoring behaviour. Using the eye-tracking method, this model was tested with applicants for an Air Traffic Controller training programme. The results are relevant for the future selection of human operators, who will have to monitor highly automated systems.

- **Keywords:** automation, monitoring, attention, eye tracking, aviation, personnel selection

Steve N.H. Tsang & Alan H.S. Chan. *Tracking and discrete dual task performance with different spatial stimulus–response mappings.* Pages 368-382.

The effect of spatial compatibility on dual-task performance for various display–control configurations was studied using a tracking task and a discrete four-choice response task. A total of 36 participants took part in this study, and they were asked to perform the primary tracking task while at the same time to respond to an occasional signal. Different levels of compatibility between the stimuli and responses of the discrete response task were found to lead to different degrees of influence on the tracking task. However, degradation of performance was observed for both tasks, which was probably due to resource competition for the visual and spatial resources required for simultaneous task operation and required for bimanual responses. No right–left prevalence effect for the spatial compatibility task was observed in this study, implying that the use of unimanual two-finger responses may not provide the right conditions for a significant effect in the horizontal right–left dimension. **Practitioner Summary:** The effect of spatial compatibility in multiple display–control configurations was examined in a dual-task paradigm. The analyses of keen competition for visual and spatial resources in processing the dual tasks under different degrees of stimulus–response compatibility provide useful ergonomics design implications and recommendations for visual interfaces requiring frequent visual scanning.

- **Keywords:** multiple resources, spatial compatibility, displays and controls, tracking

Maria Luz, Dietrich Manzey, Susanne Modemann & Gero Strauss. *Less is sometimes more : a comparison of distance-control and navigated-control concepts of image-guided navigation support for surgeons.* Pages 383-393.

Image-guided navigation (IGN) systems provide automation support of intra-operative information analysis and decision-making for surgeons. Previous research showed that navigated-control (NC) systems which represent high levels of decision-support and directly intervene in surgeons' workflow provide benefits with respect to patient safety and surgeons' physiological stress but also involve several cost effects (e.g. prolonged surgery duration, reduced secondary-task performance). It was hypothesised that less automated distance-control (DC) systems would provide a better solution in terms of human performance consequences. $N = 18$ surgeons performed a simulated mastoidectomy with NC, DC and without IGN assistance. Effects on surgical performance, physiological effort, workload and situation awareness (SA) were compared. As expected, DC technology had the same benefits as the NC system but also led to less unwanted side effects on surgery duration, subjective workload and SA. This suggests that IGN systems just providing information analysis support are overall more beneficial than higher automated decision-support. **Practitioner Summary:** This study investigates human performance consequences of different concepts of IGN support for surgeons. Less automated DC systems turned out to provide advantages for patient safety and

surgeons' stress similar to higher automated NC systems with, at the same time, reduced negative consequences on surgery time and subjective workload.

- **Keywords:** image-guided navigation, human-automation interaction, healthcare ergonomics, stages and levels of automation

Jessica Schiro, Pierre Loslever, François Gabrielli & Philippe Pudlo. *Inter and intra-individual differences in steering wheel hand positions during a simulated driving task.* Pages 394-410.

This paper describes an experimental study focusing onto the way drivers use the steering wheel while performing a 2D tracking task. The stimulus during this task was a steering wheel angle signal recorded in real situations involving turns and straight lines performed at about 30 km/h. The hand positions of 20 volunteers were recorded in 6 steering scenarios involving 7 road geometries using a 3D motion capture system. The hand movement data were analysed via a descriptive/inferential procedure: each hand was considered using nine indicators – eight membership value averages linked to eight fuzzy angle windows and a frequency value related to the *off* steering wheel position – while the indicators were investigated using multiple correspondence analysis and non-parametric global and post-hoc tests. Results showed that inter-individual differences were larger than intra-individual differences. Considering $2 \times 9 = 18$ windows, the inter-individual differences mainly appeared during two main kinds of steering hand strategies: *with versus without* crossing hands, the latter being the most often used (17 among 20 participants). The intra-individual data showed that some drivers maintained a nearly identical strategy for all road geometries, while other drivers changed their hand position with the direction and/or maximum angle value of the turn. **Practitioner Summary:** Understanding hand position strategy could be used to design steering wheel assistance in relation to a driver's physical resources with a view to adapting the steering wheel to disabled drivers.

- **Keywords:** motion analysis, driving, steering wheel, hand-positioning strategies, driving simulator

Fanxing Meng, Cristy Ho, Rob Gray & Charles Spence. *Dynamic vibrotactile warning signals for frontal collision avoidance: towards the torso versus towards the head.* Pages 411-425.

Three experiments were conducted to assess the effectiveness of dynamic vibrotactile warning signals with different spatial patterns and to compare dynamic towards-torso and towards-head vibrotactile warnings in a simulated driving task. The results revealed that embedding additional stimuli between the participant's hands and waist in the towards-torso cues (Experiment 1) and increasing the spatial distance between adjacent stimuli in the towards-head cues (Experiment 2) did not result in any further benefits in braking response times (BRTs). The triple towards-head cues resulting from the sequential operation of three pairs of stimuli on the torso gave rise to a significant advantage over the static cues; however, it did not outperform the dynamic towards-torso cues with just two pairs of stimuli. Taken together, these results demonstrated the promise of dynamic vibrotactile warnings (especially, the towards-torso warnings) in terms of the future design of more effective rear-end collision warnings. **Practitioner Summary:** Three experiments assessed the effectiveness of dynamic towards-torso and towards-head vibrotactile warning signals in a simulated driving task. The results demonstrated the promise of dynamic vibrotactile warnings (especially, the towards-torso vibrotactile warnings) in terms of the future design of more effective frontal collision warnings.

- **Keywords:** haptic, tactile, driving, brake reaction time, interface design, frontal collision warning

Michael Brown, Robert Houghton, Sarah Sharples & Jeremy Morley. *The attribution of success when using navigation aids.* Pages 426-433.

Attitudes towards geographic information technology is a seldom explored research area that can be explained with reference to established theories of attribution. This article reports on a study of how the attribution of success and failure in pedestrian navigation varies with level of automation, degree of success and locus of control. A total of 113 participants took part in a survey exploring reflections on personal experiences and vignettes describing fictional navigation experiences. A complex relationship was discovered in which success tends to be attributed to skill and failure to the navigation aid when participants describe their own experiences. A reversed pattern of results was found when discussing the navigation of others. It was also found that navigation success and failure are associated with personal skill to a greater extent when using paper maps, as compared with web-based routing engines or satellite navigation systems.

Practitioner Summary: This article explores the influences on the attribution of success and failure when using navigation aids. A survey was performed exploring interpretations of navigation experiences. Level of success, self or other as navigator and type of navigation aid used are all found to influence the attribution of outcomes to internal or external factors.

- **Keywords:** personal navigation, attribution, trust in automation, human factors, attitudes and behaviour

Robert J. Houghton, Chris Baber, Neville A. Stanton, Daniel P. Jenkins & Kirsten Revell. *Combining network analysis with Cognitive Work Analysis : insights into social organisational and cooperation analysis.* Pages 434-449.

Cognitive Work Analysis (CWA) allows complex, sociotechnical systems to be explored in terms of their potential configurations. However, CWA does not explicitly analyse the manner in which person-to-person communication is performed in these configurations. Consequently, the combination of CWA with Social Network Analysis provides a means by which CWA output can be analysed to consider communication structure. The approach is illustrated through a case study of a military planning team. The case study shows how actor-to-actor and actor-to-function mapping can be analysed, in terms of centrality, to produce metrics of system structure under different operating conditions. **Practitioner Summary:** In this paper, a technique for building social network diagrams from CWA is demonstrated. The approach allows analysts to appreciate the potential impact of organisational structure on a command system.

- **Keywords:** systems design, sociotechnical systems, Cognitive Work Analysis, network analysis, visualisation

Einar Jebens, Asgeir Mamen, Jon Ingulf Medbø, Oddvar Knudsen & Kaj Bo Veiersted. *Are elderly construction workers sufficiently fit for heavy manual labour?* Pages 450-462.

This study analysed the work ability of elderly construction workers. Forty male construction workers, 20 young (age < 33 yrs) and 20 senior (age > 44 yrs) workers, were tested regarding aerobic power (VO_{2max}) and muscle strength. The aerobic demand of a number of tasks in construction work was measured and compared with the workers' aerobic power. VO_{2max} was higher for the young, and they performed better on most muscle strength tests. The measurements showed that about half of the senior workers had to use more than 30% of their maximum oxygen uptake on some tasks. In conclusion, because elderly construction workers decline in physical fitness, they are more exposed to overload when performing heavy manual work than are their younger

peers. Increasing their individual fitness or adjusting their workload may be important for staying in the workforce for such workers. **Practitioner Summary:** Construction workers must occasionally perform strenuous work tasks that may endanger their safety. This was more often the case for elderly workers investigated here. Elderly workers should therefore be particularly observant of their physical fitness, and should possibly train during leisure time to improve their fitness.

- **Keywords:** elderly workers, strenuous work, aerobic power, field-testing

Kjerstin Vogel & Jörgen Eklund. *On physiological demands and sustainability in meat cutting.* Pages 463-479.

Meat cutters' work has been investigated by several researchers. However, knowledge about the physiological demands of meat cutting is almost lacking. The aim of this explorative study was to assess physiological demands in meat cutting, to compare them with International Labour Organization (ILO) recommendations for acceptable workload and to discuss the findings in relation to individual and work-related factors. In accordance with the ILO recommendations, work was categorised as sustainable or non-sustainable based on critical relative aerobic strain (RAS) levels. Twenty-one beef and pork cutters participated in the study, which included workload measurements, assessment of workplace and individual factors. Thirteen meat cutters were categorised as having non-sustainable and eight as having sustainable work. Results suggest that the workload is higher in beef cutting than in pork cutting, and that longer work experience is related to lower RAS. Other factors contributing to the physical workload are discussed.

Practitioner Summary: Meat-cutting work may exceed recommended physical workload levels. Beef cutting is physically more demanding than pork cutting. Furthermore, factors such as years in the profession, knife sharpness, work pace, wage system, working technique, maximum oxygen uptake level and muscular strength should be considered when planning actions regarding the workload for meat cutters.

- **Keywords:** RAS, heart rate, workload, MSDs, oxygen consumption

Ryan B. Graham, Catherine L.W. Smallman, Ross H. Miller & Joan M. Stevenson. *A dynamical systems analysis of assisted and unassisted anterior and posterior hand-held load carriage.* Pages 480-491.

oad carriage is recognised as a primary occupational factor leading to slip and fall injuries, and therefore assessing balance maintenance during such tasks is critical in assessing injury risk. Ten males completed 55 strides under five carriage conditions: (1) unassisted anterior, (2) unassisted posterior, (3) assisted anterior, (4) assisted posterior and (5) unloaded gait (UG). Kinematic data were recorded from markers affixed to landmarks on the right side of each participant, in order to calculate segment angles for the foot, shank, thigh and pelvis. Continuous relative phase (CRP) variability was calculated for each segment pair and local dynamic stability was calculated for each segment in all three movement planes. In general, irrespective of the assistive device or movement plane, anterior load carriage was most stable (lower CRP variability and maximum finite-time Lyapunov exponents). Moreover, load carriage was less dynamically stable than UG, displaying the importance of objectively investigating safe load carriage practices. **Practitioner Summary:** Dynamical systems analyses were used to comprehensively evaluate the stability of various hand-held load carriage methods. In general, anterior load carriage was significantly more stable than posterior load carriage, Mover's assistive device had small but beneficial effects on stability, and load carriage was less stable than UG.

- **Keywords:** load carriage, assistive device, dynamical systems analysis, continuous relative phase variability, Lyapunov exponents

Megan Phillips, Babak Bazrgari & Robert Shapiro. *The effects of military body armour on the lower back and knee mechanics during toe-touch and two-legged squat tasks.* Pages 492-503.

While effective in the prevention of otherwise lethal injuries, military body armour (BA) has been suggested to reduce warfighter's performance and increase injury-related musculoskeletal conditions. Providing the significant role of joint biomechanics in both performance and risk of injury, the immediate and prolonged effects of wearing BA on biomechanics of the lower back and knee during toe-touch (TT) and two-legged squat (TLS) tasks were investigated. The immediate effects of BA were an increase of >40 ms

($p \leq 0.02$) in flexion duration of the dominant joint and an ~ 1 s ($p \leq 0.02$) increase in

overall task duration as well as an $\sim 18\%$ ($p = 0.03$) decrease in the lumbopelvic rhythm

ratio near the mid-range of trunk flexion. In general the prolonged duration of wearing BA (i.e. 45 min of walking) was not found to cause more changes in our measures than walking without BA. **Practitioner Summary:** The effects of wearing military BA on biomechanics of the lower back and knee during TT and TLS tasks were investigated. The immediate effects of BA were increased flexion duration, increased overall trial duration and decreased lumbopelvic rhythm near the mid-range of trunk flexion.

- **Keywords:** military body armour, prolonged walking, performance, risk of injury, military ergonomics

Michael Hamilton, Lesley Strawderman, Brendon Hale & Kari Babski-Reeves. *Effects of BMI and task parameters on postural sway during simulated small parts assembly.* Pages 504-512.

Postural stability is critical for ensuring a safe workplace. Employees with poor stability are more prone to falls and injuries while at work. In this study, postural sway of participants in different obesity categories was evaluated while performing an assembly workstation task. The study included three workstations: those designed for the 5th, 50th and 95th percentile workers based on anthropometric data tables. Force plates were used to study the differences in postural sway in both the medial-lateral and anterior-posterior directions. The results revealed that the obese class 1 and obese class 2 groups' anterior-posterior sway was significantly larger than that of the normal weight groups while performing assembly work tasks. Also, pace type (self-paced or time-paced) and workstation (5th, 50th and 95th percentile) significantly affected the postural sway. The postural sway was not affected by gender differences. Workstations should be designed to accommodate the increased postural sway of obese workers. **Practitioner Summary:** It is known that body mass index (BMI) affects postural sway. In this study, we examine the impact of BMI on postural sway at various workstation configurations. The postural sway was significantly larger in participants with larger BMIs.

- **Keywords:** postural sway, postural stability, BMI, obesity

Yu-Chi Lee & Mao-Jiun Wang. *Taiwanese adult foot shape classification using 3D scanning data.* Pages 513-523.

This study classifies the foot shapes of Taiwanese using 3D foot scanning data from 2000 males and 1000 females. Nine foot dimensions relative to foot length and absolute

measures in the common foot length categories were applied to compare the gender differences. Using foot breadth in % foot length (% FL), ball of foot length in % FL and arch height in % FL as feature parameters, three foot shape types for males and females can be classified. Significant gender differences were found in seven of the nine foot dimensions. Females had greater ball of foot length than males (0.2% FL). When comparing feet of the same foot length, males had greater breadth, girth and height dimensions than females, except for toe height. In addition, ethnic differences in foot shape were also observed. The findings can provide very useful information for building gender-specific shoe lasts and designing footwear insoles. **Practitioner Summary:** 3D foot scanning data of 2000 males and 1000 females were classified into three different foot shapes for males and females, respectively. Gender and ethnic differences on foot shape were also compared. The findings can provide very useful information for gender-specific shoe last design and footwear production.

- **Keywords:** foot shape classification, 3D foot scanning, foot anthropometry, gender differences, ethnic differences

H.I. Castellucci, P.M. Arezes, J.F.M. Molenbroek & C. Viviani. *The effect of secular trends in the classroom furniture mismatch : support for continuous update of school furniture standards.* Pages 524-534.

In order to create safer schools, the Chilean authorities published a Standard regarding school furniture dimensions. The aims of this study are twofold: to verify the existence of positive secular trend within the Chilean student population and to evaluate the potential mismatch between the anthropometric characteristics and the school furniture dimensions defined by the mentioned standard. The sample consists of 3078 subjects. Eight anthropometric measures were gathered, together with six furniture dimensions from the mentioned standard. There is an average increase for some dimensions within the Chilean student population over the past two decades. Accordingly, almost 18% of the students will find the seat height to be too high. Seat depth will be considered as being too shallow for 42.8% of the students. It can be concluded that the Chilean student population has increased in stature, which supports the need to revise and update the data from the mentioned Standard. **Practitioner Summary:** Positive secular trend resulted in high levels of mismatch if furniture is selected according to the current Chilean Standard which uses data collected more than 20 years ago. This study shows that school furniture standards need to be updated over time.

- **Keywords:** school, furniture, standard, secular trend, mismatch

Maria Suong Tjønnås, Hilde Færevik, Mariann Sandsund & Randi E. Reinertsen. *The dry-heat loss effect of melt-spun phase change material fibres.* Pages 535-542.

Phase change materials (PCM) have the ability to store latent heat when they change phases, a property that gives clothing that incorporates PCM its cooling effect. This study investigated the effect of dry-heat loss (cooling) of a novel melt-spun PCM fibre on the basis of the area covered, mass, the latent heat of fusion and melting temperature, compared to a known PCM clothing product. PCM fibres with melting temperatures of 28.4 and 32.0°C and PCM packs with melting temperatures of 28.0 and 32.0°C were studied. The results showed that the PCM fibres had a larger initial peak cooling effect than that of the PCM packs. The duration of the cooling effect of PCM fibres was primarily dependent on the PCM mass and the latent heat of fusion capacity, and secondly on the covered area and melting temperature of the PCM. **Practitioner Summary:** This study investigates the cooling effect of PCM fibres on a thermal manikin. The PCM fibres had a high but short-lasting cooling effect. This study contributes to the knowledge of how the body's temperature regulation may be affected by the cooling properties of clothing that incorporates PCM.

- **Keywords:** melt-spun phase change material fibres, covering area, mass, heat of fusion, phase change temperature, thermal manikin