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#### **Chao-Ming Wang & Ching-Hua Huang. *A study of usability principles and interface design for mobile e-books.* Pages 1253-1265.**

This study examined usability principles and interface designs in order to understand the relationship between the intentions of mobile e-book interface designs and users' perceptions. First, this study summarised 4 usability principles and 16 interface attributes, in order to conduct usability testing and questionnaire survey by referring to Nielsen (1993), Norman (2002), and Yeh (2010), who proposed the usability principles. Second, this study used the interviews to explore the perceptions and behaviours of user operations through senior users of multi-touch prototype devices. The results of this study are as follows: (1) users' behaviour of operating an interactive interface is related to user prior experience; (2) users' rating of the visibility principle is related to users' subjective perception but not related to user prior experience; however, users' ratings of the ease, efficiency, and enjoyment principles are related to user prior experience; (3) the interview survey reveals that the key attributes affecting users' behaviour of operating an interface include aesthetics, achievement, and friendliness. **Practitioner Summary:** This study conducts experiments to explore the effects of users' prior multi-touch experience on users' behaviour of operating a mobile e-book interface and users' rating of usability principles. Both qualitative and quantitative data analyses were performed. By applying protocol analysis, key attributes affecting users' behaviour of operation were determined.

- **Keywords:** mobile e-books, usability principles, interface design, multi-touch devices

#### **Gemma J.M. Read, Paul M. Salmon, Michael G. Lenné & Daniel P. Jenkins. *Designing a ticket to ride with the Cognitive Work Analysis Design Toolkit.* Pages 1266-1286.**

Cognitive work analysis has been applied in the design of numerous sociotechnical systems. The process used to translate analysis outputs into design concepts, however, is not always clear. Moreover, structured processes for translating the outputs of ergonomics methods into concrete designs are lacking. This paper introduces the Cognitive Work Analysis Design Toolkit (CWA-DT), a design approach which has been

developed specifically to provide a structured means of incorporating cognitive work analysis outputs in design using design principles and values derived from sociotechnical systems theory. This paper outlines the CWA-DT and describes its application in a public transport ticketing design case study. Qualitative and quantitative evaluations of the process provide promising early evidence that the toolkit fulfils the evaluation criteria identified for its success, with opportunities for improvement also highlighted.

**Practitioner summary:** The Cognitive Work Analysis Design Toolkit has been developed to provide ergonomics practitioners with a structured approach for translating the outputs of cognitive work analysis into design solutions. This paper demonstrates an application of the toolkit and provides evaluation findings.

- **Keywords:** cognitive work analysis, sociotechnical systems theory, system design, ticketing system design, participatory design

**Susanne Barth, Jan Maarten Schraagen & Martin Schmettow. *Network measures for characterising team adaptation processes*. Pages 1287-1302.**

The aim of this study was to advance the conceptualisation of team adaptation by applying social network analysis (SNA) measures in a field study of a paediatric cardiac surgical team adapting to changes in task complexity and ongoing dynamic complexity. Forty surgical procedures were observed by trained human factors researchers, and communication processes amongst team members were recorded. Focusing on who talked to whom, team communication structures, in response to changing task demands, were characterised by various network measures. Results showed that in complex procedures, the communication patterns were more decentralised and flatter. Also, in critical transition phases of the procedure, communication was characterised by higher information sharing and participation. We discuss implications for team adaptation theory and teamwork observation methods. **Practitioner Summary:** The reasons for this study were to advance our conceptualisation of team adaptation processes and to further quantify team observation methods. We found that the surgical team studied adapted to complexity of surgical procedures by adopting flatter communication patterns. We quantified team observation methods by applying SNA techniques.

- **Keywords:** teamwork, adaptability, social network analysis, surgery, task complexity

**Qin Gao, Wenzhu Yu, Xiang Jiang, Fei Song, Jiajie Pan & Zhizhong Li. *An integrated computer-based procedure for teamwork in digital nuclear power plants*. Pages 1303-1313.**

Computer-based procedures (CBPs) are expected to improve operator performance in nuclear power plants (NPPs), but they may reduce the openness of interaction between team members and harm teamwork consequently. To support teamwork in the main control room of an NPP, this study proposed a team-level integrated CBP that presents team members' operation status and execution histories to one another. Through a laboratory experiment, we compared the new integrated design and the existing individual CBP design. Sixty participants, randomly divided into twenty teams of three people each, were assigned to the two conditions to perform simulated emergency operating procedures. The results showed that compared with the existing CBP design, the integrated CBP reduced the effort of team communication and improved team transparency. The results suggest that this novel design is effective to optimise team process, but its impact on the behavioural outcomes may be moderated by more factors, such as task duration. **Practitioner Summary:** The study proposed and evaluated a team-level integrated computer-based procedure, which presents team members' operation status and execution history to one another. The experimental results show

that compared with the traditional procedure design, the integrated design reduces the effort of team communication and improves team transparency.

- **Keywords:** teamwork, computer-based procedures, shared information about team members, nuclear power plants

**Wai Yoong, Ayemon Khin, Navin Ramlal, Bogadi Loabile & Stephen Forman. *Interruptions and distractions in the gynaecological operating theatre: irritating or dangerous?* Pages 1314-1319.**

Distractions and interference can include visual (e.g. staff obscuring monitors), audio (e.g. noise, irrelevant communication) and equipment problems. Level of distraction is usually defined as I: relatively inconsequential; II: > one member of the surgical team affected; III: the entire surgical team affected. The aim of this study was to observe the frequency and impact of distracting events and interruptions on elective gynaecology cases. Data from 35 cases were collected from 10 consecutive operating sessions. Mean number of interruptions was 26 episodes/case, while mean number of level II/III distractions was 17 episodes/case. Ninety per cent of interruptions occur in the first 30 minutes of the procedure and 80.9% lead to level II/III distraction. Although no complications were directly attributable to the observed distractions, the mean prolongation of operating time was 18.46 minutes/case. Understanding their effects on theatre environment enables appropriate measures to be taken so that theatre productivity and patient safety are optimised. **Practitioner Summary:** This observational study of 35 elective cases shows a mean interruption rate of 26 episodes/case with 80.9% affecting > one member of operating team, leading to mean prolongation of 18.46 minutes/case. Theatre staff should be aware of these findings and appropriate measures taken to optimise theatre productivity and patient safety.

- **Keywords:** distractions, interruptions, gynaecology

**Jingyu Zhang, Jiazhong Yang & Changxu Wu. *From trees to forest : relational complexity network and workload of air traffic controllers.* Pages 1320-1336.**

In this paper, we propose a relational complexity (RC) network framework based on RC metric and network theory to model controllers' workload in conflict detection and resolution. We suggest that, at the sector level, air traffic showing a centralised network pattern can provide cognitive benefits in visual search and resolution decision which will in turn result in lower workload. We found that the network centralisation index can account for more variance in predicting perceived workload and task completion time in both a static conflict detection task (Study 1) and a dynamic one (Study 2) in addition to other aircraft-level and pair-level factors. This finding suggests that linear combination of aircraft-level or dyad-level information may not be adequate and the global-pattern-based index is necessary. Theoretical and practical implications of using this framework to improve future workload modelling and management are discussed. **Practitioner Summary:** We propose a RC network framework to model the workload of air traffic controllers. The effect of network centralisation was examined in both a static conflict detection task and a dynamic one. Network centralisation was predictive of perceived workload and task completion time over and above other control variables.

- **Keywords:** relational complexity network, air traffic control, workload, network centralisation

**Victoria A. Banks & Neville A. Stanton. *Contrasting models of driver behaviour in emergencies using retrospective verbalisations and network analysis.* Pages 1337-1346.**

Automated assistance in driving emergencies aims to improve the safety of our roads by avoiding or mitigating the effects of accidents. However, the behavioural implications of such systems remain unknown. This paper introduces the driver decision-making in emergencies (DDMiEs) framework to investigate how the level and type of automation may affect driver decision-making and subsequent responses to critical braking events using network analysis to interrogate retrospective verbalisations. Four DDMiE models were constructed to represent different levels of automation within the driving task and its effects on driver decision-making. Findings suggest that whilst automation does not alter the decision-making pathway (e.g. the processes between hazard detection and response remain similar), it does appear to significantly weaken the links between information-processing nodes. This reflects an unintended yet emergent property within the task network that could mean that we may not be improving safety in the way we expect. **Practitioner Summary:** This paper contrasts models of driver decision-making in emergencies at varying levels of automation using the Southampton University Driving Simulator. Network analysis of retrospective verbalisations indicates that increasing the level of automation in driving emergencies weakens the link between information-processing nodes essential for effective decision-making.

- **Keywords:** automation, driver decision-making, network analysis, retrospective verbalisation

**Peter M. van Leeuwen, Carla Gómez i Subils, Arnau Ramon Jimenez, Riender Happee & Joost C.F. de Winter. *Effects of visual fidelity on curve negotiation, gaze behaviour and simulator discomfort*. Pages 1347-1364.**

Technological developments have led to increased visual fidelity of driving simulators. However, simplified visuals have potential advantages, such as improved experimental control, reduced simulator discomfort and increased generalisability of results. In this driving simulator study, we evaluated the effects of visual fidelity on driving performance, gaze behaviour and subjective discomfort ratings. Twenty-four participants drove a track with 90° corners in (1) a high fidelity, textured environment, (2) a medium fidelity, non-textured environment without scenery objects and (3) a low-fidelity monochrome environment that only showed lane markers. The high fidelity level resulted in higher steering activity on straight road segments, higher driving speeds and higher gaze variance than the lower fidelity levels. No differences were found between the two lower fidelity levels. In conclusion, textures and objects were found to affect steering activity and driving performance; however, gaze behaviour during curve negotiation and self-reported simulator discomfort were unaffected. **Practitioner Summary:** In a driving simulator study, three levels of visual fidelity were evaluated. The results indicate that the highest fidelity level, characterised by a textured environment, resulted in higher steering activity, higher driving speeds and higher variance of horizontal gaze than the two lower fidelity levels without textures.

- **Keywords:** driving simulation, simulator fidelity, curve negotiation, eye-movements, simulator discomfort

**Germán Gálvez-García. *A comparison of techniques to mitigate Simulator Adaptation Syndrome*. Pages 1365-1371.**

We investigated the effectiveness of galvanic cutaneous stimulation (GCS) and auditory stimulation in mitigating simulator adaptation syndrome (SAS). Fifteen drivers (9 men; *M* age = 23.2 years) participated in a driving simulation experiment comparing three different stimulation conditions (GCS, auditory stimulation and no stimulation as a base line condition) in curves on a virtual urban circuit. GCS and auditory stimulation decreased SAS by reducing head sway. Both sources of stimulation can be recommended as countermeasures against SAS. We encourage the use of stimuli which influence the balancing ability to the design of future simulator protocols and devices to mitigate SAS.

**Practitioner Summary:** We have provided evidence on the effectiveness of two different stimuli as countermeasures against simulator adaptation syndrome (SAS). We concluded that the positive impact of body sway might play a role in SAS and therefore encourage the use of stimuli which influence the balancing ability to mitigate the symptoms of SAS.

- **Keywords:** simulator adaptation syndrome, driving task, simulator sickness questionnaire, galvanic cutaneous stimulation, auditory stimulation

**Min-Ju Liao & Shan-Hung Wang. *Exploring the role of stimulus code–response modality compatibility on the spatial Stroop effect.* Pages 1372-1387.**

This study investigated the compatibility of stimulus codes and response modalities and how it mediated the spatial Stroop effect. Stimulus code (word, arrow and moving dots), response modality (voice, keypress and mouse movement), directional information (left and right) and physical location (centre, left and right) of the stimulus were manipulated. Participants responded to the directional information of the stimulus. Spatial interference was expected when the stimulus' directional information and physical location were incongruent. Results showed that more compatible pairings for the three response modalities were word–voice, arrow–keypress and arrow–movement. Incongruent spatial location delayed the reaction time for all response modalities with the word, speeded up the vocal and keypress responses with the moving dots, and had no effect with the arrow. Arrow was thus recommended for conveying directional information on interfaces. This study demonstrated that spatial interference was mediated by the stimulus code, response modality and their compatibility. **Practitioner Summary:** This study manipulated three stimulus codes and three response modalities to examine how stimulus–response compatibility mediated the spatial Stroop effect. Spatial interference appeared with the word and moving dots, but not arrow stimulus, for vocal, keypress and mouse responses. Arrow was therefore recommended to convey directional information on an interface.

- **Keywords:** stimulus code–response modality compatibility, spatial Stroop effect

**Divya Srinivasan, Svend Erik Mathiassen, Afshin Samani & Pascal Madeleine. *The combined influence of task accuracy and pace on motor variability in a standardised repetitive precision task.* Pages 1388-1397.**

Thirty-five healthy women, experienced in pipetting, each performed four pipetting sessions at different pace and accuracy levels relevant to occupational tasks. The size and structure of motor variability of shoulder and elbow joint angles were quantified using cycle-to-cycle standard deviations of several kinematics properties, and indices based on sample entropy and recurrence quantification analysis. Decreasing accuracy demands increased both the size and structure of motor variability. However, when simultaneously lowering the accuracy demand and increasing pace, motor variability decreased to values comparable to those found when pace alone was increased without changing accuracy. Thus, motor variability showed some speed-accuracy trade-off, but the pace effect dominated the accuracy effect. Hence, this trade-off was different from that described for end-point performance by Fitts' law. The combined effect of accuracy and pace and the resultant decrease in motor variability are important to consider when designing sustainable work systems comprising repetitive precision tasks. **Practitioner summary:** Variability in movements and/or muscle activities between repeats of the same repetitive task is associated with important occupational outcomes, including fatigue, discomfort and pain. This study showed that simultaneously decreasing accuracy and increasing pace in short-cycle repetitive work led to decreased motor variability in arm movements, indicating less favourable ergonomics conditions.

- **Keywords:** cyclic movements, Fitts' law, kinematics, linear and nonlinear variability, motor control, speed-accuracy trade-off

**Aaron M. Kociolek & Peter J. Keir. *Development of a kinematic model to predict finger flexor tendon and subsynovial connective tissue displacement in the carpal tunnel.* Pages 1398-1409.**

Finger flexor tendinopathies and carpal tunnel syndrome are histologically characterised by non-inflammatory fibrosis of the subsynovial connective tissue (SSCT) in the carpal tunnel, which is indicative of excessive and repetitive shear forces between the finger flexor tendons and SSCT. We assessed flexor digitorum superficialis (FDS) tendon and adjacent SSCT displacements with colour Doppler ultrasound as 16 healthy participants completed long finger flexion/extension movements captured by a motion capture system. FDS tendon displacements fit a second-order regression model based on metacarpophalangeal and proximal interphalangeal joint flexion angles ( $R^2 = 0.92 \pm 0.01$ ). SSCT displacements were  $33.6 \pm 1.7\%$  smaller than FDS tendon displacements and also fit a second-order regression model ( $R^2 = 0.89 \pm 0.01$ ). FDS tendon and SSCT displacement both correlated with finger joint thickness, enabling participant-specific anthropometric scaling. We propose the current regression models as an ergonomic method to determine relative displacements between the finger flexor tendons and SSCT. **Practitioner Summary:** Relative displacements between the finger flexor tendons and SSCT provide insight into gliding and friction in the carpal tunnel. Our regression models represent a move towards mechanistic-based ergonomic risk assessment of the wrist/hand. This is a natural evolution of ergonomic methods based on tendon-joint interaction.

- **Keywords:** finger, repetitive motion, relative displacement, tendon travel, shear injury

**Adedoyin Abiodun Adeleye & Olusegun Gabriel Akanbi. *Hand cumulative trauma disorders in Nigerian custom tailors: the need for redesign of manual scissors.* Pages 1410-1423.**

Cutting scissors are important working tools for Nigerian custom tailors (CTs) but its usage apparently does not meet the ergonomics need of these artisans. A survey was carried out amongst CTs using questionnaires to obtain their background social-occupational demographics and observation methods to study their work performance, use of scissors and any cumulative trauma disorder (CTD) in their hands. Thicknesses of various fabrics were measured and comparison between Western world's custom tailoring job and the Nigerian type was done. The results showed some CTD risk factors with finger contusions on the 71 CTs evaluated. The right-hand contusions were traced to the constant usage of unpadded manual scissors with ungloved hands. Disparity between Western and Nigerian tailoring practice may account for the high occurrence of disorders in Nigerian CTs. Since hand dimensions are crucial in the design of hand tools, it is therefore concluded that hand anthropometry of Nigerian CTs and soft padding of manual scissors may mitigate CTD burdens on CTs' hands. **Practitioner summary:** Cumulative trauma disorders on the hands of low-income Nigerian CTs needed investigation. This was done via self-assessment and observational methods of the artisans' work system. Frequent usage of unpadded manual scissors with un-gloved hands cause and exacerbate the problem. Hand anthropometry of users is crucial in scissors manufacturing.

- **Keywords:** cumulative trauma disorders, contusions, custom-tailors, scissors, ergonomics

**Boyi Hu & Xiaopeng Ning. *The influence of lumbar extensor muscle fatigue on lumbar–pelvic coordination during weightlifting.* Pages 1424-1432.**

Lumbar muscle fatigue is a potential risk factor for the development of low back pain. In this study, we investigated the influence of lumbar extensor muscle fatigue on lumbar–pelvic coordination patterns during weightlifting. Each of the 15 male subjects performed five repetitions of weightlifting tasks both before and after a lumbar extensor muscle fatiguing protocol. Lumbar muscle electromyography was collected to assess fatigue. Trunk kinematics was recorded to calculate lumbar–pelvic continuous relative phase (CRP) and CRP variability. Results showed that fatigue significantly reduced the average lumbar–pelvic CRP value (from 0.33 to 0.29 rad) during weightlifting. The average CRP variability reduced from 0.17 to 0.15 rad, yet this change was statistically not significant. Further analyses also discovered elevated spinal loading during weightlifting after the development of lumbar extensor muscle fatigue. Our results suggest that frequently experienced lumbar extensor muscle fatigue should be avoided in an occupational environment. **Practitioner Summary:** Lumbar extensor muscle fatigue generates more in-phase lumbar–pelvic coordination patterns and elevated spinal loading during lifting. Such increase in spinal loading may indicate higher risk of back injury. Our results suggest that frequently experienced lumbar muscle fatigue should be avoided to reduce the risk of LBP.

- **Keywords:** lumbar extensor muscle fatigue, lumbar–pelvic coordination, continuous relative phase, low back pain

**Taofeng Ye & Xiao Pan. *A convenient prediction model for complete recovery time after exhaustion in high-intensity work.* Pages 1433-1444.**

We aimed to propose a convenient model for predicting complete recovery time (CRT) after exhaustion in high-intensity work. Before participating in the laboratory test, each of the 47 young adult subjects provided demographic information and filled out the perceived functional ability (PFA) and physical activity rating (PA-R) questionnaires. All subjects were required to perform one cycling test (at 70% maximum working capacity). Subjects continued cycling until exhaustion and then sat and recovered until their heart rates (HR) returned to baseline values. We found that CRT was significantly correlated with relative body mass index, the PFA score, PA-R score and maximum heart rate ( $HR_{max}$ ). Accordingly, a prediction model for CRT was proposed. Furthermore, by replacing  $HR_{max}$  with age-predicted maximal HR, we obtained a more convenient prediction model that was independent of any physiological indexes that can only be obtained by subject testing. **Practitioner Summary:** High-intensity work is associated with higher perceived fatigue, which can be alleviated after a rest period. Instead of complex laboratory testing, questionnaires were used to derive a convenient prediction model for CRT after exhaustion. Ergonomics should be incorporated into work–rest schedule planning to improve efficiency and safety.

- **Keywords:** complete recovery time, high-intensity work, prediction model, questionnaires

**Ville Ilmarinen, Juhani Ilmarinen, Pekka Huuhtanen, Veikko Louhevaara & Ove Näsman. *Examining the factorial structure, measurement invariance and convergent and discriminant validity of a novel self-report measure of work ability : work ability – personal radar.* Pages 1445-1460.**

For identification of groups and domains for work ability promotion, brief self-report measure, work ability – personal radar (WA-PR), based on the ‘the house of work ability’

model is presented and psychometrically evaluated in the structural equation framework using data from technological sector ( $N = 3754$ ). The house model had acceptable fit to the data. In addition, factor loadings in the model were invariant across groups, demonstrating metric invariance of the WA-PR. Scalar invariance of WA-PR was fully demonstrated across men and women, and partially demonstrated across age and employee groups. Comparisons between groups revealed lower levels of health and functional capacity, but higher levels of four other WA-PR dimensions in older employees. In addition, all house structures showed convergence with alternative work ability measures. WA-PR demonstrated potential for effective measurement of multiple work ability dimensions from employees' perspective. It provides means for efficient location of relevant domains and focus groups for work ability promotion. **Practitioner Summary:** A novel approach to multidimensional work ability measurement was developed to tackle the challenges of work ability promotion. The properties of the instrument were psychometrically evaluated in structural equation modelling framework. Instrument demonstrated potential for locating relevant domains and focus groups for work ability promotions at workplaces and organisations.

- **Keywords:** work ability, measurement, self-report, invariance, validity

**K.J. Glitz, U. Seibel, U. Rohde, W. Gorges, A. Witzki, C. Piekarski & D. Leyk. *Reducing heat stress under thermal insulation in protective clothing : microclimate cooling by a 'physiological' method. Pages 1461-1469.***

Heat stress caused by protective clothing limits work time. Performance improvement of a microclimate cooling method that enhances evaporative and to a minor extent convective heat loss was tested. Ten male volunteers in protective overalls completed a work-rest schedule (130 min; treadmill: 3 × 30 min, 3 km/h, 5% incline) with or without an additional air-diffusing garment (climatic chamber: 25°C, 50% RH, 0.2 m/s wind). Heat loss was supported by ventilating the garment with dry air (600 l/min, <<5% RH, 25°C). Ventilation leads ( $M \pm SD$ ,  $n = 10$ , ventilated vs. non-ventilated) to substantial strain reduction (max. HR:  $123 \pm 12$  b/min vs.  $149 \pm 24$  b/min) by thermal relief (max. core temperature:  $37.8 \pm 0.3^\circ\text{C}$  vs.  $38.4 \pm 0.4^\circ\text{C}$ , max. mean skin temperature:  $34.7 \pm 0.8^\circ\text{C}$  vs.  $37.1 \pm 0.3^\circ\text{C}$ ) and offers essential extensions in performance and work time under thermal insulation. **Practitioner Summary:** Heat stress caused by protective clothing limits work time. Performance can be improved by a microclimate cooling method that supports evaporative and to a minor extent convective heat loss. Sweat evaporation is the most effective thermoregulatory mechanism for heat dissipation and can be enhanced by insufflating dry air into clothing.

- **Keywords:** protective clothing, heat stress, microclimate cooling, sweat evaporation