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Hardy A. van de Ven, Ute Bültmann, Michiel P. de Looze, Wendy Koolhaas, Thomas Kantermann, Sandra Brouwer, Jac J.L. van der Klink. *Need for recovery among male technical distal on-call workers. Pages 1927-1938.*

The objectives of this study were to (1) examine whether need for recovery differs between workers (i) not on-call, (ii) on-call but not called and (iii) on-call and called, and (2) investigate the associations between age, health, work and social characteristics with need for recovery for the three scenarios (i–iii). Cross-sectional data of $N = 169$ Dutch distal on-call workers were analysed with multivariate logistic regression. Need for recovery differed significantly between the three scenarios (i–iii), with lowest need for recovery for scenario (i) 'not on-call' and highest need for recovery for scenario (iii) 'on-call and called'. Poor mental health and high work–family interference were associated with higher need for recovery in all three scenarios (i–iii), whereas high work demands was only associated with being on-call (ii and iii). The results suggest that the mere possibility of being called affects the need for recovery, especially in workers reporting poor mental health, high-work demands and work–family interference. **Practitioner summary:** On-call work is a scarcely studied but demanding working time arrangement. We examined need for recovery and its associations with age, health, work and social characteristics among distal on-call workers. The results suggest that the mere possibility of being called can affect worker well-being and need for recovery.

- **Keywords:** work schedule tolerance, health, work–family interference, age

Gabriella Eriksson, Christopher J.D. Patten, Ola Svenson, Lars Eriksson. *Estimated time of arrival and debiasing the time saving bias. Pages 1939-1946.*

The time saving bias predicts that the time saved when increasing speed from a high speed is overestimated, and underestimated when increasing speed from a slow speed. In a questionnaire, time saving judgements were investigated when information of estimated time to arrival was provided. In an active driving task, an alternative meter indicating the inverted speed was used to debias judgements. The simulated task was to first drive a distance at a given speed, and then drive the same distance again at the

speed the driver judged was required to gain exactly 3 min in travel time compared with the first drive. A control group performed the same task with a speedometer and saved less than the targeted 3 min when increasing speed from a high speed, and more than 3 min when increasing from a low speed. Participants in the alternative meter condition were closer to the target. The two studies corroborate a time saving bias and show that biased intuitive judgements can be debiased by displaying the inverted speed. **Practitioner Summary:** Previous studies have shown a cognitive bias in judgements of the time saved by increasing speed. This simulator study aims to improve driver judgements by introducing a speedometer indicating the inverted speed in active driving. The results show that the bias can be reduced by presenting the inverted speed and this finding can be used when designing in-car information systems.

- **Keywords:** time saving bias, debiasing, inverted speed, estimated time of arrival, heuristic

Hsiu-Feng Wang. *To space or not space? Interword spacing effects on Chinese children's reading materials.* Pages 1947-1959.

This study investigated different Chinese on-screen text layouts to see if they improved the reading speed and comprehension of Taiwanese children. A number of different experimental treatments were used. These were: interword spacing (unspaced, semi-spaced and fully-spaced), text difficulty (easy and difficult) and text direction (vertical and horizontal). The experiment involved 84 children aged between 10 and 11 years old. In the experiment the children were asked to read articles. The time they took to read these articles was recorded. The children also partook in comprehension tests to determine how much they had understood about the articles they had read. The results showed that horizontal text was read more quickly than vertical text and was better comprehended. The results also showed that fully-spaced difficult text was read more quickly than semi-spaced difficult text, and unspaced difficult text was also better comprehended. **Practitioner Summary:** This experiment was conducted to explore the affects of interword spacing, text direction and text difficulty on the reading speeds and comprehension of on-screen traditional Chinese characters by Taiwanese children. It found that fully-spaced, horizontal text was the quickest and most comprehensible to read, regardless of text difficulty.

- **Keywords:** text layout, interword spacing, text direction, text difficulty, children's reading materials

Jerred Holt, Kevin B. Bennett , John M. Flach. *Emergent features and perceptual objects: re-examining fundamental principles in analogical display design.* Pages 1960-1973.

Two sets of design principles for analogical visual displays, based on the concepts of emergent features and perceptual objects, are described. An interpretation of previous empirical findings for three displays (bar graph, polar graphic, alphanumeric) is provided from both perspectives. A fourth display (configural coordinate) was designed using principles of ecological interface design (i.e. direct perception). An experiment was conducted to evaluate performance (accuracy and latency of state identification) with these four displays. Numerous significant effects were obtained and a clear rank ordering of performance emerged (from best to worst): configural coordinate, bar graph, alphanumeric and polar graphic. These findings are consistent with principles of design based on emergent features; they are inconsistent with principles based on perceptual objects. Some limitations of the configural coordinate display are discussed and a redesign is provided. **Practitioner Summary:** Principles of ecological interface design, which emphasise the quality of very specific mappings between domain, display and observer constraints, are described; these principles are applicable to the design of all analogical graphical displays.

- **Keywords:** cognitive systems engineering, analogical visual displays, ecological interface design, system state identification, direct perception, emergent features, perceptual objects, decision support, semantic mapping, display design

Inseok Lee, Won-Gue Hwang. *Effects of personal experiences on the interpretation of the meaning of colours used in the displays and controls in electric control panels. Pages 1974-1982.*

A survey was conducted to examine how personal experiences affect the interpretation of the meaning of display and control colours on electric control panels (ECPs). In Korea, the red light on ECPs represents a normal state of operation, while the green light represents a stopped state of operation; this appears to contradict the general stereotypes surrounding these colours. The survey results indicated that the participants who had experience in using ECPs interpreted the colour meaning differently from the other participant group. More than half of the experienced participants regarded the coloured displays and controls as they were designed, while most participants in the other group appeared to interpret the colours in accordance with the stereotypes. It is presumed that accidents related to human errors can occur when non-experienced people use the ECPs, which are easily accessible in many buildings. **Practitioner Summary:** A survey was conducted to investigate how personal experiences affect the interpretation of the function meanings of coloured lights on electrical control panels. It was found that the interpretation varies according to personal experiences, which can induce accidents related to human errors while operating electrical equipment.

- **Keywords:** stereotype of colour, colour display and control, push-button switch, electric control panels, personal experience

Alan H.S. Chan, Errol R. Hoffmann. *Circular displays: control/display arrangements and stereotype strength with eight different display locations. Pages 1983-1995.*

Two experiments are reported that were designed to investigate control/display arrangements having high stereotype strengths when using circular displays. Eight display locations relative to the operator and control were tested with rotational and translational controls situated on different planes according to the Frame of Reference Transformation Tool (FORT) model of Wickens et al. (2010). (Left. No, Right! Development of the Frame of Reference Transformation Tool (FORT), Proceedings of the Human Factors and Ergonomics Society 54th Annual Meeting, 54: 1022–1026). In many cases, there was little effect of display locations, indicating the importance of the Worryingham and Beringer (1998. Directional stimulus–response compatibility: a test of three alternative principles. *Ergonomics*, 41(6), 864–880) Visual Field principle and an extension of this principle for rotary controls (Hoffmann and Chan (2013). The Worryingham and Beringer ‘visual field’ principle for rotary controls. *Ergonomics*, 56(10), 1620–1624). The initial indicator position (12, 3, 6 and 9 o'clock) had a major effect on control/display stereotype strength for many of the six controls tested. Best display/control arrangements are listed for each of the different control types (rotational and translational) and for the planes on which they are mounted. Data have application where a circular display is used due to limited display panel space and applies to spacecraft, robotics operators, hospital equipment and home appliances. **Practitioner Summary:** Circular displays are often used when there is limited space available on a control panel. Display/control arrangements having high stereotype strength are listed for four initial indicator positions. These arrangements are best for design purposes.

- **Keywords:** display/control, stereotype strength, circular displays

Alan H.S. Chan, Errol R. Hoffmann. *Effect of display location on control-display stereotype strength for translational and rotational controls with linear displays.* Pages 1996-2015.

Experiments were designed to investigate the effects of control type and display location, relative to the operator, on the strength of control/display stereotypes. The Worryingham and Beringer Visual Field principle and an extension of this principle for rotary controls (Hoffmann E.R., and Chan A.H.S. 2013). "The Worryingham and Beringer 'Visual Field' Principle for Rotary Controls. *Ergonomics.*" 56 (10): 1620–1624) indicated that, for a number of different control types (rotary and lever) on different planes, there should be no significant effect of the display location relative to the seated operator. Past data were surveyed and stereotype strengths listed. Experiments filled gaps where data are not available. Six different control types and seven display locations were used, as in the Frame of Reference Transformation Tool (FORT) model of Wickens et al. (Wickens, C.D., Keller, J.W., and Small, R.L. (2010). "Left. No, Right! Development of the Frame of Reference Transformation Tool (FORT)." *Proceedings of the Human Factors and Ergonomics Society 54th Annual Meeting September 2010*, 54: 1022–1026). Control/display arrangements with high stereotype strengths were evaluated yielding data for designers of complex control/display arrangements where the control and display are in different planes and for where the operator is moving. It was found possible to predict display/control arrangements with high stereotype strength, based on past data. **Practitioner Summary:** Controls and displays in complex arrangements need to have high compatibility. These experiments provide arrangements for six different controls (rotary and translational) and seven different display locations relative to the operator.

- **Keywords:** control/display design, stereotype strength, principles for prediction

ShuQin Wen, Stewart Petersen, Rachel McQueen, Jane Batcheller. *Modelling the physiological strain and physical burden of chemical protective coveralls.* Pages 2016-2031.

This study determined the impact of selected chemical protective coveralls (CPC) on physiological responses and comfort sensations. Fifteen males exercised at approximately 6 METS in three CPC (Tyvek®, Gulf and Tychem®) and a control garment. Physiological strain was characterised by core and skin temperatures, heart rate, $\dot{V}O_2$, perceived exertion, hotness and wetness. Physical burden was characterised by restriction to movement, $\dot{V}O_2$ and RPE. The highest levels of physiological strain and physical burden were found in Tychem®, and the lowest in control. Seven statistical regression models were developed through correlation and multiple regression analyses between the human responses and the results from previously conducted fabric and garment property testing. These models showed that physical burden was increased by adding weight and/or restricting movement. Oxygen consumption was best predicted by clothing weight and fabric bending hysteresis. Fabric evaporative resistance and thickness were the two best predictors of physiological and perceptual responses. **Practitioner Summary:** Traditional evaluation of chemical protective coveralls (CPC) involves testing at the fabric and garment levels and rarely is based on human trials. This study integrates information from fabric, garment and human trials to better understand physiological strain and physical comfort during prolonged exercise in CPC.

- **Keywords:** chemical protective clothing, physiological strain, physical burden, comfort

Anthony Walker, Toby Keene, Christos Argus, Matthew Driller, Joshua H. Guy, Ben Rattray. *Immune and inflammatory responses of Australian firefighters after repeated exposures to the heat.* Pages 2032-2039.

When firefighters work in hot conditions, altered immune and inflammatory responses may increase the risk of a cardiac event. The present study aimed to establish the time course of such responses. Forty-two urban firefighters completed a repeat work protocol in a heat chamber ($100 \pm 5^\circ\text{C}$). Changes to leukocytes, platelets, TNF α , IL-6, IL-10, LPS and CRP were evaluated immediately post-work and also after 1 and 24 h of rest. Increases in core temperatures were associated with significant increases in leukocytes, platelets and TNF α directly following work. Further, platelets continued to increase at 1 h ($+31.2 \pm 31.3 \times 10^9 \text{ l}$, $p < 0.01$) and remained elevated at 24 h ($+15.9 \pm 19.6 \times 10^9 \text{ l}$, $p < 0.01$). Sustained increases in leukocytes and platelets may increase the risk of cardiac events in firefighters when performing repeat work tasks in the heat. This is particularly relevant during multi-day deployments following natural disasters. **Practitioner Summary:** Firefighters regularly re-enter fire affected buildings or are redeployed to further operational tasks. Should work in the heat lead to sustained immune and inflammatory changes following extended rest periods, incident controllers should plan appropriate work/rest cycles to minimise these changes and any subsequent risks of cardiac events.

- **Keywords:** occupational stress, inflammation, immune response, safety, cardiac risk

Philippe-Antoine Dubé, Daniel Imbeau, Denise Dubeau, Isabelle Auger, Mario Leone. Prediction of work metabolism from heart rate measurements in forest work: some practical methodological issues. Pages 2040-2056.

Individual heart rate (HR) to workload relationships were determined using 93 submaximal step-tests administered to 26 healthy participants attending physical activities in a university training centre (laboratory study) and 41 experienced forest workers (field study). Predicted maximum aerobic capacity (MAC) was compared to measured MAC from a maximal treadmill test (laboratory study) to test the effect of two age-predicted maximum HR Equations ($220 - \text{age}$ and $207 - 0.7 \times \text{age}$) and two clothing insulation levels (0.4 and 0.91 clo) during the step-test. Work metabolism (WM) estimated from forest work HR was compared against concurrent work VO_2 measurements while taking into account the HR thermal component. Results show that MAC and WM can be accurately predicted from work HR measurements and simple regression models developed in this study (1% group mean prediction bias and up to 25% expected prediction bias for a single individual). Clothing insulation had no impact on predicted MAC nor age-predicted maximum HR equations. **Practitioner summary:** This study sheds light on four practical methodological issues faced by practitioners regarding the use of HR methodology to assess WM in actual work environments. More specifically, the effect of wearing work clothes and the use of two different maximum HR prediction equations on the ability of a submaximal step-test to assess MAC are examined, as well as the accuracy of using an individual's step-test HR to workload relationship to predict WM from HR data collected during actual work in the presence of thermal stress.

- **Keywords:** heart rate, work metabolism, prediction bias, maximum aerobic capacity, forest work

Chia-Hsiung Chen, David P. Azari, Yu Hen Hu, Mary J. Lindstrom, Darryl Thelen, Thomas Y. Yen, Robert G. Radwin. The accuracy of conventional 2D video for quantifying upper limb kinematics in repetitive motion occupational tasks. Pages 2057-2066.

Marker-less 2D video tracking was studied as a practical means to measure upper limb kinematics for ergonomics evaluations. Hand activity level (HAL) can be estimated from

speed and duty cycle. Accuracy was measured using a cross-correlation template-matching algorithm for tracking a region of interest on the upper extremities. Ten participants performed a paced load transfer task while varying HAL (2, 4, and 5) and load (2.2 N, 8.9 N and 17.8 N). Speed and acceleration measured from 2D video were compared against ground truth measurements using 3D infrared motion capture. The median absolute difference between 2D video and 3D motion capture was 86.5 mm/s for speed, and 591 mm/s² for acceleration, and less than 93 mm/s for speed and 656 mm/s² for acceleration when camera pan and tilt were within ± 30 degrees. Single-camera 2D video had sufficient accuracy (< 100 mm/s) for evaluating HAL. **Practitioner Summary:** This study demonstrated that 2D video tracking had sufficient accuracy to measure HAL for ascertaining the American Conference of Government Industrial Hygienists Threshold Limit Value[®] for repetitive motion when the camera is located within ± 30 degrees off the plane of motion when compared against 3D motion capture for a simulated repetitive motion task.

- **Keywords:** repetitive motion, hand activity level, marker-less video tracking, work-related musculoskeletal disorders, exposure assessment

Jenna Dibblee, Portia Worthy, Philip Farrell, Markus Hetzler, Susan Reid, Joan Stevenson, Steven Fischer. *Evaluating a prototype device designed to alleviate night vision goggle induced neck strain among military personnel.* Pages 2067-2077.

The purpose of this study was verify the design of a novel Helmet System Support Device (HSSD) that can be used by military aircrew to help intervene on and reduce the high prevalence of neck trouble. Twelve healthy participants repeated simulated helicopter aircrew tasks on 3 separate days. On each day they wore a different helmet configuration, where measures of performance, perceived demand/preference and muscular demand were recorded. The results showed that vigilance tasks were performed over 10% faster with the HSSD configuration compared to wearing the normal helmet configuration. Participants were able to maintain static (endurance) postures for 28% longer, and use of the HSSD helped to prevent neck muscle fatigue in the most demanding task. The results of this design verification study indicate that the HSSD may be a realistic, feasible near-term solution to intervene on the high prevalence of neck trouble among rotary-wing aircrew. **Practitioner Summary:** This paper verifies the effectiveness of the Helmet System Support Device (HSSD) as an on-body personal protective device to help control exposures associated with aircrew neck trouble. The HSSD reduced perceived demand, reduced cumulative muscle activity in select muscles and provided improved fatigue resistance, meeting its desired design objectives.

- **Keywords:** ergonomic design, neck trouble, biomechanics, aircrew, helmet

Neville A. Stanton, Ling Rothrock, Catherine Harvey, Linda Sorensen. *Investigating information-processing performance of different command team structures in the NATO Problem Space.* Pages 2078-2100.

The structure of command teams is a significant factor on their communications and ability to process, and act upon, information. The NATO Problem Space was used in this study to represent three of the main dimensions in the battle-space environment: familiarity, rate of change, and strength of information position. Results show that the five common team structures (chain, Y, circle, wheel and all-connected) did not generally perform as predicted in team literature. Findings suggest that under dynamic and highly variable conditions, high levels of synchronisation and trust should be present. On the other hand, synchronisation and trust are less important in hierarchical, highly centralised structures, because team members are more willing to accept the authority of a single leader and this tight control ensures that these teams can perform well as long

as the Problem Space is familiar, information is explicit and the environment does not change. **Practitioner Summary:** Some types of team structures are better suited to particular constraints of the battle-space than others. This research has shown that the much touted all-connected structure is often the worst performing structure and that the traditional hierarchy of command and control has much merit in the digital information age.

- **Keywords:** NATO Problem Space, team information processing, team structures