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Jan Dul, Ralph Bruder, Peter Buckle, Pascale Carayon, Pierre Falzon, William S. Marras, John R. Wilson & Bas van der Doelen. *A strategy for human factors/ergonomics: developing the discipline and profession.* Pages 377-395.

Human factors/ergonomics (HFE) has great potential to contribute to the design of all kinds of systems with people (work systems, product/service systems), but faces challenges in the readiness of its market and in the supply of high-quality applications. HFE has a unique combination of three fundamental characteristics: (1) it takes a systems approach (2) it is design driven and (3) it focuses on two closely related outcomes: performance and well-being. In order to contribute to future system design, HFE must demonstrate its value more successfully to the main stakeholders of system design. HFE already has a strong value proposition (mainly well-being) and interactivity with the stakeholder group of 'system actors' (employees and product/service users). However, the value proposition (mainly performance) and relationships with the stakeholder groups of 'system experts' (experts from technical and social sciences involved in system design), and 'system decision makers' (managers and other decision makers involved in system design, purchase, implementation and use), who have a strong power to influence system design, need to be developed. Therefore, the first main strategic direction is to strengthen the demand for high-quality HFE by increasing awareness among powerful stakeholders of the value of high-quality HFE by *communicating with stakeholders, by building partnerships and by educating stakeholders*. The second main strategic direction is to strengthen the application of high-quality HFE by *promoting the education of HFE specialists, by ensuring high-quality standards of HFE applications and HFE specialists, and by promoting HFE research excellence* at universities and other organisations. This strategy requires cooperation between the HFE community at large, consisting of the International Ergonomics Association (IEA), local (national and regional) HFE societies, and HFE specialists. We propose a joint world-wide HFE development plan, in which the IEA takes a leadership role.

Practitioner Summary: Human factors/ergonomics (HFE) has much to offer by addressing major business and societal challenges regarding work and product/service systems. HFE potential, however, is underexploited. This paper presents a strategy for the HFE community to strengthen demand and application of high-quality HFE, emphasising its key elements: systems approach, design driven, and performance and well-being goals.

- **Keywords:** human factors/ergonomics discipline, human factors/ergonomics profession, future of ergonomics, work systems, product/service systems, performance

Garg, J. Kapellusch, K. Hegmann, J. Wertsch, A. Merryweather, G. Deckow-Schaefer, E.J. Malloy & the WISTAH Hand Study Research Team. *The Strain Index (SI) and Threshold Limit Value (TLV) for Hand Activity Level (HAL): risk of carpal tunnel syndrome (CTS) in a prospective cohort. Pages 396-414.*

A cohort of 536 workers was enrolled from 10 diverse manufacturing facilities and was followed monthly for six years. Job physical exposures were individually measured. Worker demographics, medical history, psychosocial factors, current musculoskeletal disorders (MSDs) and nerve conduction studies (NCS) were obtained. Point and lifetime prevalence of carpal tunnel syndrome (CTS) at baseline (symptoms + abnormal NCS) were 10.3% and 19.8%. During follow-up, there were 35 new CTS cases (left, right or both hands). Factors predicting development of CTS included: job physical exposure (American conference of governmental industrial hygienists Threshold Limit Value (ACGIH TLV) for Hand Activity Level (HAL) and the Strain Index (SI)), age, BMI, other MSDs, inflammatory arthritis, gardening outside of work and feelings of depression. In the adjusted models, the TLV for HAL and the SI were both significant per unit increase in exposure with hazard ratios (HR) increasing up to a maximum of 5.4 ($p = 0.05$) and 5.3 ($p = 0.03$), respectively; however, similar to other reports, both suggested lower risk at higher exposures. Data suggest that the TLV for HAL and the SI are useful metrics for estimating exposure to biomechanical stressors.

Practitioner Summary: This study was conducted to determine how well the TLV for HAL and the SI predict risk of CTS using a prospective cohort design with survival analysis. Both the TLV for HAL and the SI were found to predict risk of CTS when adjusted for relevant covariates.

- **Keywords:** epidemiology, ergonomics, cohort, carpal tunnel syndrome, Strain Index, TLV for HAL

J. Village, C. Trask, Y. Chow, J.B. Morrison, M. Koehoorn & K. Teschke. *Assessing whole body vibration exposure for use in epidemiological studies of back injuries: measurements, observations and self-reports. Pages 415-424.*

Improved assessment of whole body vibration exposure is needed for epidemiological studies investigating the causes of low back disorders. Vibration was measured on 54 worker-days in five heavy industries, with data collected on observed and self-reported driving conditions, demographics, and vehicle characteristics. Variables significant at $p < 0.1$ in simple linear regressions (20 of 34) were retained for mixed effects multiple regressions to determine the best prediction of rms vibration level and 8-h equivalent vibration exposure. Vibration was measured, on average, for 205 min per work shift (SD 105). Means and standard deviations in $m \cdot s^{-2}$ were: x-axis 0.35 (0.19); y-axis 0.34 (0.28); z-axis 0.54 (0.23); vector sum 0.90 (0.49); and 8-h equivalent vector sum 0.70 (0.37). The final three regression models retained only 2 or 3 of the 34 variables (driving speed (<20 km/h and/or 20–40 km/h) and industry and/or vehicle type and explained up to 60% of the variance ($R^2 = 0.26-0.6$).

Practitioner summary: The purpose of the project was to create a model that can predict whole body vibration exposure from a number of observed or self-reported variables. This could eliminate the need for costly and time-consuming field measurements of WBV in epidemiological studies. Despite a large number of variables

included in the model (34) and 54 worker-days of WBV measurement, the final models contained only two or three variables, and explained 60% of the variance. While this is an improvement over use of job title in epidemiological studies, it still leaves a considerable amount of WBV variance unexplained.

- **Keywords:** whole-body vibration, exposure assessment, determinants modelling, heavy equipment, epidemiology

Bongkyoo Choi, Alicia Kurowski, Meg Bond, Dean Baker, Els Clays, Dirk De Bacquer & Laura Punnett. *Occupation-differential construct validity of the Job Content Questionnaire (JCQ) psychological job demands scale with physical job demands items: a mixed methods research. Pages 425-439.*

The construct validity of the Job Content Questionnaire (JCQ) psychological demands scale in relationship to physical demands has been inconsistent. This study aims to test quantitatively and qualitatively whether the scale validity differs by occupation. Hierarchical clustering analyses of 10 JCQ psychological and physical demands items were conducted in 61 occupations from two datasets: one of non-faculty workers at a university in the United States (6 occupations with 208 total workers) and the other of a Belgian working population (55 occupations with 13,039 total workers). The psychological and physical demands items overlapped in 13 of 61 occupation-stratified clustering analyses. Most of the overlaps occurred in physically-demanding occupations and involved the two psychological demands items, 'work fast' and 'work hard'. Generally, the scale reliability was low in such occupations. Additionally, interviews with eight university workers revealed that workers interpreted the two psychological demands items differently by the nature of their tasks. The scale validity was occupation-differential.

Practitioner Summary: The JCQ psychological job demands scale as a job demand measure has been used worldwide in many studies. This study indicates that the wordings of the 'work fast' and 'work hard' items of the scale need to be reworded enough to differentiate mental and physical job demands as intended, 'psychological.'

- **Keywords:** clustering analysis, reliability, interview, the United States, Belgium

Kirsten Nabe-Nielsen, Anne Helene Garde, Birgit Aust & Finn Diderichsen. *Increasing work-time influence: consequences for flexibility, variability, regularity and predictability. Pages 440-449.*

This quasi-experimental study investigated how an intervention aiming at increasing eldercare workers' influence on their working hours affected the flexibility, variability, regularity and predictability of the working hours. We used baseline ($n = 296$) and follow-up ($n = 274$) questionnaire data and interviews with intervention-group participants ($n = 32$). The work units in the intervention group designed their own intervention comprising either implementation of computerised self-scheduling (subgroup A), collection of information about the employees' work-time preferences by questionnaires (subgroup B), or discussion of working hours (subgroup C). Only computerised self-scheduling changed the working hours and the way they were planned. These changes implied more flexible but less regular working hours and an experience of less predictability and less continuity in the care of clients and in the co-operation with colleagues. In subgroup B and C, the participants ended up discussing the potential consequences of more work-time influence without actually implementing any changes.

Practitioner Summary: Employee work-time influence may buffer the adverse effects of shift work. However, our intervention study suggested that while increasing the

individual flexibility, increasing work-time influence may also result in decreased regularity of the working hours and less continuity in the care of clients and co-operation with colleagues.

- **Keywords:** flexibility, nurses, self-scheduling, shift work, workplace interventions

Satoru Inoue, Kazuo Furuta, Keiichi Nakata, Taro Kanno, Hisae Aoyama & Mark Brown. *Cognitive process modelling of controllers in en route air traffic control. Pages 450-464.*

In recent years, various efforts have been made in air traffic control (ATC) to maintain traffic safety and efficiency in the face of increasing air traffic demands. ATC is a complex process that depends to a large degree on human capabilities, and so understanding how controllers carry out their tasks is an important issue in the design and development of ATC systems. In particular, the human factor is considered to be a serious problem in ATC safety and has been identified as a causal factor in both major and minor incidents. There is, therefore, a need to analyse the mechanisms by which errors occur due to complex factors and to develop systems that can deal with these errors. From the cognitive process perspective, it is essential that system developers have an understanding of the more complex working processes that involve the cooperative work of multiple controllers. Distributed cognition is a methodological framework for analysing cognitive processes that span multiple actors mediated by technology. In this research, we attempt to analyse and model interactions that take place in en route ATC systems based on distributed cognition. We examine the functional problems in an ATC system from a human factors perspective, and conclude by identifying certain measures by which to address these problems. This research focuses on the analysis of air traffic controllers' tasks for en route ATC and modelling controllers' cognitive processes.

Practitioner Summary: This research focuses on an experimental study to gain a better understanding of controllers' cognitive processes in air traffic control. We conducted ethnographic observations and then analysed the data to develop a model of controllers' cognitive process. This analysis revealed that strategic routines are applicable to decision making.

- **Keywords:** cognitive task analysis, human modelling, experimental approach, air traffic control, ethnomethodology

Mathieu Deroo, Jean-Michel Hoc & Franck Mars. *Influence of risk expectation on haptically cued corrective manoeuvres during near lane departure. Pages 465-475.*

Some driving devices are designed to prevent road departures. One such device, motor priming (MP), provides small pulses to the steering wheel towards the lane centre, without correcting the trajectory itself. Compared with the other lane departure warning systems, its higher efficacy has been demonstrated; it is hypothesised that this relies on the action of haptic cues at the sensorimotor level (Navarro, J., Mars, F., and Hoc, J.M., 2007. Lateral control assistance for car drivers: a comparison of motor priming and warning systems. *Human Factors*, 49 (5), 950–960). The way in which corrective manoeuvres, primed by MP, can be influenced by processes that operate at higher levels of cognitive control, such as risk evaluation, is an issue. Results showed that MP improved all indicators of steering efficiency, starting with reaction times. Risk expectation and situation analysis did not influence reaction times but came into play soon after the corrective manoeuvre was initiated. Thus, although MP triggered the response at the sensorimotor level, higher levels of cognition (symbolic control) quickly modulated the execution of the corrective manoeuvre.

Practitioner Summary: This paper showed that corrective manoeuvres following directional pulses on the steering wheel (motor priming) are modulated by risk expectation. The conclusion may be of interest for designers of haptics-based automation such as lane departure warning and lane keeping assistance systems.

- **Keywords:** human-machine cooperation, driving assistance device, cognitive control, steering behaviour

Namal Thibbotuwawa, Errol R. Hoffmann & Ravindra S. Goonetilleke. *Open-loop and feedback-controlled mouse cursor movements in linear paths.* Pages 476-488.

Path length (A), path width (W) and movement direction (θ) are identified as the main factors affecting visually-controlled movement times in linear paths. Effects of A and W are well described by Drury's (1971). Drury, C. G. 1971. Movements with lateral constraint. *Ergonomics*, 14 (2) : 293 – 305 .

[Taylor & Francis Online], [Web of Science ®]

View all references. Movements with lateral constraint. *Ergonomics*, 14 (2), 293–305.) model in which movement time is linearly related to the ratio of A/W . At low A/W values, departure from linearity has been identified but not investigated in detail. Data are presented for both open-loop and feedback-controlled movements in linear paths at 0, 60 and 150° movement directions. Movement amplitude and path width were varied over a wide range to determine the effects of A and (A/W) on movement time. Movements were found to be made ballistically or in open-loop mode when the ratio (A/W) was less than about 8 to 10 and the movement times were linearly related to \sqrt{A} for all angles of movement. Feedback-controlled movements followed Drury's law; ballistic movements had movement speed linear with \sqrt{A} .

Practitioner Summary: Many tasks require manoeuvring equipment or devices through a path of limited width. These movements can be made with or without feedback control, depending on the path constraints. The conditions for the two forms of movement are determined in this research.

- **Keywords:** constrained path, Drury's law, hand movement, movement time, movement speed, ballistic move, feedback control, visual control, open-loop control

Fan Gao. *Power grip force is modulated in repeated elbow movement.* Pages 489-499.

The objective of this study was to quantitatively investigate the modulation of power grip force under repeated elbow movement and its relation to muscle cocontraction and potential risk of developing cumulative trauma disorders (CTD). Thirteen right-handed participants without any neuromuscular disorders were recruited. Participants were instructed to hold a digital dynamometer in the hand with three levels of grip forces (20%, 40% and 60% of the maximum grip force) and perform repeated arm movement in the sagittal plane at three speeds (slow, self-paced and fast) with the upper arm voluntarily held by side by the participant. With the increase of motion rate and target force level, the grip force fluctuation, finger flexor muscle activities, elbow muscles cocontraction and apparent stiffness were significantly increased ($p < 0.01$). This study suggests that the power grip coupled with fast arm movement be avoided as much as possible in the workplace.

Practitioner Summary: Power grip is usually accompanied with arm movement in workplaces and the increased physical demand might result in higher muscle activities and potentially higher risk of repetitive musculoskeletal injuries.

- **Keywords:** power grip, sEMG (surface electromyography), repeated elbow movement, cocontraction, grip force

Stewart Bruce-Low, Dave Smith, Scott Burnet, James Fisher, Gary Bissell & Leonie Webster. *One lumbar extension training session per week is sufficient for strength gains and reductions in pain in patients with chronic low back pain ergonomics. Pages 500-507.*

Chronic low back pain (CLBP) is the leading cause of absenteeism from the workplace and research into exercise interventions to address this problem is required. This study investigated training frequency for participants with CLBP. Participants either trained once a week (1 × week, $n = 31$), or twice a week (2 × week, $n = 20$) or did not (control group, $n = 21$). Participants were isometric strength tested in weeks 1 and 12 and trained dynamically either 1×week (80% of maximum) or 2×week (80% and 50%). The results (pre vs. post) showed significant increases in maximal strength, range of motion and reductions in pain for both training groups. Pain scores for the 1 × week and 2 × week both reached minimal clinical improvement change unlike the control group. Thus, one lumbar extension training session per week is sufficient for strength gains and reductions in pain in low back pain in CLBP patients.

Practitioner Summary: CLBP is the leading cause of absenteeism from the workplace. The present study using a modified randomised control trial design investigated exercise training frequency for participants with CLBP. One lumbar extension training session per week is sufficient for strength gains and reductions in low back pain in CLBP patients.

- **Keywords:** occupational, exercise therapy, back pain

Wouter M. Bergmann Tiest, N. Dolfine Kusters, Astrid M.L. Kappers & Hein A.M. Daanen. *Phase change materials and the perception of wetness. Pages 508-512.*

Phase change materials (PCMs) are increasingly incorporated in textiles in order to serve as a thermal buffer when humans change from a hot to a cold environment and the reverse. Due to the absence of wetness sensors in the skin, cooling of the skin may be perceived as a sensation of wetness instead of cold. In order to investigate if this phenomenon occurs when manipulating textiles, nine subjects were asked to touch or manipulate PCM-treated and untreated fabrics. In 75% of the cases, the subjects indicated that the treated material felt wetter than the untreated material independent of the way the textiles were manipulated. We conclude that incorporating PCMs in textiles may lead to a feeling of wetness which might be uncomfortable. Therefore, we recommend investigating a change in cooling properties to minimise this feeling.

Practitioner Summary: This article describes a psychophysical experiment into the sensation of wetness of textiles treated with phase change materials. It was found that in 75% of the cases, subjects found the treated fabric to feel wetter than the untreated. This may affect the comfort of wearing clothes made of these textiles.

- **Keywords:** coldness, wetness, perception, touch