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D. Golightly & N. Dadashi. *The characteristics of railway service disruption: implications for disruption management*. Pages: 307-320.

Rail disruption management is central to operational continuity and customer satisfaction. Disruption is not a unitary phenomenon – it varies by time, cause, location and complexity of coordination. Effective, user-centred technology for rail disruption must reflect this variety. A repertory grid study was conducted to elicit disruption characteristics. Construct elicitation with a group of experts (n = 7) captured 26 characteristics relevant to rail disruption. A larger group of operational staff (n = 28) rated 10 types of rail incident against the 26 characteristics. The results revealed distinctions such as business impact and public perception, and the importance of management of the disruption over initial detection. There were clear differences between those events that stop the traffic, as opposed to those that only slow the traffic. The results also demonstrate the utility of repertory grid for capturing the characteristics of complex work domains. **Practitioner Summary:** The aim of the paper is to understand how variety in rail disruption influences socio-technical design. It uses repertory grid to identify and prioritise 26 constructs, and group 10 disruption types, identifying critical factors such as whether an incident stops or merely slows the service, and business reputation.

- **Keywords:** Railways, disruption, repertory grid, expertise, socio-technical systems design

Vicki Antrobus, Gary Burnett & Claudia Krehl. *Driver-passenger collaboration as a basis for human-machine interface design for vehicle navigation systems*. Pages: 321-332.

Human Factors concerns exist with vehicle navigation systems, particularly relating to the effects of current Human-Machine Interfaces (HMIs) on driver disengagement from the environment. A road study was conducted aiming to provide initial input for the development of intelligent HMIs for in-vehicle systems, using the traditional collaborative navigation relationship between the driver and passenger to inform future design. Sixteen drivers navigated a predefined route in the city of Coventry, UK with the assistance of an existing vehicle navigation system (SatNav), whereas a further 16

followed the navigational prompts of a passenger who had been trained along the same route. Results found that there were no significant differences in the number of navigational errors made on route for the two different methods. However, drivers utilising a collaborative navigation approach had significantly better landmark and route knowledge than their SatNav counterparts. Analysis of individual collaborative transcripts revealed the large individual differences in descriptor use by passengers and reference to environmental landmarks, illustrating the potential for the replacement of distance descriptors in vehicle navigation systems. Results are discussed in the context of future HMIs modelled on a collaborative navigation relationship. **Practitioner Summary:** Current navigation systems have been associated with driver environmental disengagement, this study uses an on-road approach to look at how the driver–passenger collaborative relationship and dialogue can inform future navigation HMI design. Drivers navigating with passenger assistance demonstrated enhanced landmark and route knowledge over drivers navigating with a SatNav.

- **Keywords:** In-vehicle navigation systems, adaptive interfaces, landmarks, collaboration

Zhen Zhou & Michael J. Griffin. *Response of the seated human body to whole-body vertical vibration: biodynamic responses to mechanical shocks*. Pages: 333-346.

The biodynamic response of the seated human body has been investigated with 20 males exposed to upward and downward shocks at 13 fundamental frequencies (1–16 Hz) and 18 magnitudes (up to ±8.3 ms^{-2}). For 1- and 2- degree-of-freedom models, the stiffness and damping coefficients were obtained by fitting seat acceleration waveforms predicted from the measured force to the measured seat acceleration waveform. Stiffness and damping coefficients were also obtained in the frequency domain with random vibration. The optimum stiffness and damping coefficients varied with the magnitude and the frequency of shocks. With both upward and downward shocks, the resonance frequency of the models decreased from 6.3 to 4 Hz as the vibration dose values of the shocks increased from 0.05 to 2.0 $ms^{-1.75}$. The stiffness and damping obtained from responses to shocks were correlated with, and similar to, the stiffness and damping obtained with random vibration. **Practitioner Summary:** When modelling the dynamic response of the seated human body to vertical acceleration less than 1 g, the relation between force and acceleration can be well represented by a single degree-of-freedom model although the optimum stiffness and damping depend on the magnitude and frequency of sinusoidal, random or shock motion.

- **Keywords:** Biodynamics, mechanical shocks, apparent mass, force, nonlinearity

Zhen Zhou & Michael J. Griffin. *Response of the seated human body to whole-body vertical vibration: discomfort caused by mechanical shocks*. Pages: 347-357.

The frequency dependence of discomfort caused by vertical mechanical shocks has been investigated with 20 seated males exposed to upward and downward shocks at 13 fundamental frequencies (1–16 Hz) and 18 magnitudes (±0.12 to ±8.3 ms^{-2}). The rate of growth of discomfort with increasing shock magnitude depended on the fundamental frequency of the shocks, so the frequency dependence of equivalent comfort contours (for both vertical acceleration and vertical force measured at the seat) varied with shock magnitude. The rate of growth of discomfort was similar for acceleration and force, upward and downward shocks, and lower and higher magnitude shocks. The frequency dependence of discomfort from shocks differs from that of sinusoidal vibrations having the same fundamental frequencies. This arises in part from the frequency content of the shock. Frequency weighting W_b in BS 6841:1987 and ISO 2631-1:1997 provided reasonable estimates of the discomfort caused by the shocks investigated in this study.

Practitioner Summary: No single frequency weighting can accurately predict the discomfort caused by mechanical shocks over wide ranges of shock magnitude, but vibration dose values with frequency weighting W_b provide reasonable estimates of discomfort caused by shocks similar to those investigated in this study with peak accelerations well below 1 g.

- **Keywords:** Ride comfort, mechanical shocks, shock magnitude, force

Julien Jacquier-Bret, Philippe Gorce, Genaro Motti Lilian & Nadine Vigouroux. *Biomechanical analysis of upper limb during the use of touch screen: motion strategies identification*. Pages: 358-365.

This present work focused on the upper limb joint coordination during the achievement of puzzles on touch screen. A 5-inch and 10-inch devices were used to perform 9 and 16 pieces puzzles dragged with digits. The conclusions showed an increase in joint solicitation with the number of piece and the touch screen size. Moreover, three interactions strategies proved to be an evidence: the 'wrist strategy' preferentially implying wrist flexion/extension, the 'elbow strategy' preferentially implying the elbow flexion/extension and the 'neutral strategy' mobilising equally the two joints. From an ergonomic point of view, the data about how the upper limb segments are mobilised while interacting with the screen could be relevant to increase the adaptability of the devices to the user, including users with motor impairments. **Practitioner Summary:** Information about the biomechanical organisation of movement during interaction with touch devices appears relevant in order to develop applications adapted to the motor capacities of users. From the analysis of joint angles when performing several times a puzzle with healthy subjects, three motor strategies were highlighted.

- **Keywords:** Biomechanics, upper limb, human–computer interaction, touch screen

Vincenzo Occhionero, Rinaldo Ghersi, Lucio Prandini, Leena Korpinen & Fabriziomaria Gobba. *The biomechanical overload of the upper limb: a neglected occupational hazard in animal facility operators*. Pages: 366-374.

Data on biomechanical overload of the upper limb in animal facility operators are currently scanty. We decided to study this risk in a university animal facility. Eleven different tasks performed by operators were identified. For each of them, the biomechanical overload of the upper limb was evaluated by applying 4 different methods frequently used, hypothesising a task duration of 4 and 8 h. Then two 'typical' real working days of the examined facility were reconstructed, and the risk for operators was calculated using the OCRA Index, Checklist and Mini-Checklist. Considering the specific tasks, the results show some difference among methods, but the overall results show an acceptable/slight risk of biomechanical overload of the upper limb in animal facility operators during typical working days. **Practitioner Summary:** Upper limb biomechanical overload (UL-BO) is a neglected risk in animal facilities. In a university facility, 11 different tasks were identified, and 2 typical working days were analysed. Even if some task at increased risk may exist, during typical working days, the overall results show that the risk of UL-BO in operators can be considered usually acceptable or, at worst, slight.

- **Keywords:** Biomechanical overload, upper limb, animal facility, musculoskeletal disorders

Raffaele Spinelli, Giovanni Aminti & Fabio De Francesco. *Postural risk assessment of mechanised firewood processing*. Pages: 375-383.

The study assessed the postural risk of mechanised firewood processing with eight machines, representing the main technology solutions available on the market. Assessment was conducted with the Ovako Working posture Analysis System (OWAS) on 1000 still frames randomly extracted from videotaped work samples. The postural risk associated with firewood processing was variable and associated with technology type. Simple, manually operated new machines incurred a higher postural risk compared with semi- or fully automatic machines. In contrast, new semi-automatic and automatic machines were generally free from postural risk. In all cases, attention should be paid to postural risk that may occur during blockage resolution. The study did not cover the postural risk of firewood processing sites as a whole. The study provided useful information for selecting firewood processing machinery and for improving firewood machinery design, as part of a more articulate strategy aimed at enhancing the safety of firewood processing work sites. **Practitioner Summary:** The postural risk associated with mechanised firewood processing (eg cutting and splitting) depends on the type of equipment. Postural risk is highest (OWAS Action Category 2) with new in-line machines, designed for operation by a single worker. Fully automatic machines present minimum postural risk, except during blockage resolution.

- **Keywords:** WMSD, OWAS, biomass, forestry, logging

Myeongkyu Kim & Donghun Lee. *Development of an IMU-based foot-ground contact detection (FGCD) algorithm*. Pages: 384-403.

It is well known that, to locate humans in GPS-denied environments, a lower limb kinematic solution based on Inertial Measurement Unit (IMU), force plate, and pressure insoles is essential. The force plate and pressure insole are used to detect foot-ground contacts. However, the use of multiple sensors is not desirable in most cases. This paper documents the development of an IMU-based FGCD (foot-ground contact detection) algorithm considering the variations of both walking terrain and speed. All IMU outputs showing significant changes on the moments of foot-ground contact phases are fully identified through experiments in five walking terrains. For the experiment on each walking terrain, variations of walking speeds are also examined to confirm the correlations between walking speed and the main parameters in the FGCD algorithm. As experimental results, FGCD algorithm successfully detecting four contact phases is developed, and validation of performance of the FGCD algorithm is also implemented. **Practitioner Summary:** In this research, it was demonstrated that the four contact phases of Heel strike (or Toe strike), Full contact, Heel off and Toe off can be independently detected regardless of the walking speed and walking terrain based on the detection criteria composed of the ranges and the rates of change of the main parameters measured from the Inertial Measurement Unit sensors.

- **Keywords:** Foot-ground contact, detection criterion, IMU, walking speed, walking terrains, gait analysis

Xingyu Chen & Xingda Qu. *Influence of affective auditory stimuli on balance control during static stance*. Pages: 404-409.

The main purpose of this study was to examine the effects of affective auditory stimuli on balance control during static stance. Twelve female and 12 male participants were recruited. Each participant completed four upright standing trials including three auditory stimuli trials and one baseline trial (ie no auditory stimuli). The three auditory stimuli trials corresponded to the pleasant, neutral and unpleasant sound conditions. Center of pressure (COP) measures were used to quantify balance control performance. It was found that unpleasant auditory stimuli were associated with larger COP amplitude in the AP direction compared to the rest testing conditions. There were no significant interaction effects between 'auditory stimuli' and gender. These findings suggested that some specificities presented by auditory stimuli are important for balance control, and the

effects of auditory stimuli on balance control were dependent on their affective components. **Practitioner Summary:** Findings from this study can aid in better understanding of the relationship between auditory stimuli and balance control. In particular, unpleasant auditory stimuli were found to result in poorer balance control and higher fall risks. Therefore, to prevent fall accidents, interventions should be developed to reduce exposures to unpleasant sound.

- **Keywords:** Falls, balance control, affective auditory stimuli, center of pressure

Hui-Lien Chien & Tung-Wu Lu. *Effects of shoe heel height on the end-point and joint kinematics of the locomotor system when crossing obstacles of different heights*. Pages: 410-420.

High-heeled shoes increase the risk of falling during walking, especially in the presence of obstacles. The study aimed to compare the end-point (foot/shoe) trajectories and joint angles of the lower extremities in 12 healthy females crossing obstacles of different heights while barefoot and when wearing narrow-heeled shoes (heel heights: 3.9, 6.3 and 7.3 cm). During obstacle-crossing, young females in narrow-heeled shoes maintained the same leading toe-clearance as when barefoot, irrespective of the heel height, primarily through increased plantarflexion of the leading swing ankle. However, the shoe heel-clearance was significantly reduced when compared with barefoot, presumably related to the difficulty in precisely sensing the position of the shoe-heel tip. With an increasing obstacle height, the toe-clearance, heel-clearance and shoe heel-clearance were reduced linearly, indicating an increasing risk of tripping over the obstacle. The results will be helpful for the design and development of strategies to reduce the risk of falling when wearing narrow-heeled shoes. **Practitioner Summary:** Knowledge of the influence of narrow-heeled shoes and obstacles on lower limb joint and end-point kinematics helps in shoe design to address fall risks. Compared to barefoot, narrow-heeled shoes reduced shoe heel-clearances, which were further reduced linearly with increasing obstacle height, indicating an increasing risk of tripping over the obstacle.

- **Keywords:** Obstructed gait, joint kinematics, lower limb, locomotion, high heels

Taekyoung Kim & Shuping Xiong. *Comparison of seven fall risk assessment tools in community-dwelling Korean older women*. Pages: 421-429.

This study aimed to compare seven widely used fall risk assessment tools in terms of validity and practicality, and to provide a guideline for choosing appropriate fall risk assessment tools for elderly Koreans. Sixty community-dwelling Korean older women (30 fallers and 30 matched non-fallers) were evaluated. Performance measures of all tools were compared between the faller and non-faller groups through two sample *t*-tests. Receiver Operating Characteristic curves were generated with odds ratios for discriminant analysis. Results showed that four tools had significant discriminative power, and the shortened version of Falls Efficacy Scale (SFES) showed excellent discriminant validity, followed by Berg Balance Scale (BBS) with acceptable discriminant validity. The Mini Balance Evaluation System Test and Timed Up and Go, however, had limited discriminant validities. In terms of practicality, SFES was also excellent. These findings suggest that SFES is the most suitable tool for assessing the fall risks of community-dwelling Korean older women, followed by BBS. **Practitioner Summary**: There is no general guideline on which fall risk assessment tools are suitable for community-dwelling Korean older women. This study compared seven widely used assessment tools in terms of validity and practicality. Results suggested that the short Falls Efficacy Scale is the most suitable tool, followed by Berg Balance Scale.

- **Keywords:** Fall risk assessment tool, ageing, validity, practicality, Receiver Operating Characteristic (ROC), discriminant analysis

Aaron J. E. Bach, Joseph T. Costello, David N. Borg & Ian B. Stewart. The *Pandolf load carriage equation is a poor predictor of metabolic rate while wearing explosive ordnance disposal protective clothing*. Pages: 430-438.

This investigation aimed to quantify metabolic rate when wearing an explosive ordnance disposal (EOD) ensemble (~33kg) during standing and locomotion; and determine whether the Pandolf load carriage equation accurately predicts metabolic rate when wearing an EOD ensemble during standing and locomotion. Ten males completed 8 trials with metabolic rate measured through indirect calorimetry. Walking in EOD at 2.5, 4.0 and 5.5km·h^{-1} was significantly ($p < 0.05$) greater than matched trials without the EOD ensemble by 49% (127W), 65% (213W) and 78% (345W), respectively. Mean bias (95% limits of agreement) between predicted and measured metabolism during standing, 2.5, 4 and 5.5km·h^{-1} were 47W (19 to 75W); −111W (−172 to −49W); −122W (−189 to −54W) and −158W (−245 to −72W), respectively. The Pandolf equation significantly underestimated measured metabolic rate during locomotion. These findings have practical implications for EOD technicians during training and operation and should be considered when developing maximum workload duration models and work-rest schedules. **Practitioner Summary:** Using a rigorous methodological design we quantified metabolic rate of wearing EOD clothing during locomotion. For the first time we demonstrated that metabolic rate when wearing this ensemble is greater than that predicted by the Pandolf equation. These original findings have significant implications for EOD training and operation.

- **Keywords:** Metabolism, military ergonomics, occupational, personal protective equipment, predictive equation

Celeste E. Coltman, Deirdre E. McGhee & Julie R. Steele. *Three-dimensional scanning in women with large, ptotic breasts: implications for bra cup sizing and design*. Pages: 439-445.

Background*:* This study aimed to compare breast volume calculated from scanning large, ptotic breasts of women while they were standing upright relative to when lying prone in order to identify the error associated with breast volume calculations. **Methods***:* Breast volume and visualisation were compared in 50 women with large breasts (D^+ bra cup size) while they were scanned in three different positions. **Results***:* Full visualisation of both breasts occurred in 100% of participants in the prone position and only 5% of participants in either standing position. Breast volume was significantly greater ($p < 0.01$) in the prone position, with the percentage of underestimation in the standing position increasing as breast volume increased. **Conclusion***:* Breast volume measured by three-dimensional scanning in the standing position will be underestimated by 7–10% in large, ptotic breasts. Consideration of these inaccuracies in breast volume relative to breast size can assist bra manufacturers when designing bras. **Practitioner Summary**: Errors have been reported when measuring the breast volume of women with large, ptotic breasts using three-dimensional scanning. This original research provides evidence for bra designers and manufacturers on the degree of error associated with this measurement. These errors should be accounted for in future bra designs.

- **Keywords:** Breast volume, three-dimensional scanning, scanning position, bra design