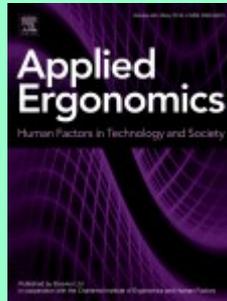


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Roland Peter Gräbe, Cor-Jacques Kat, Paul Jacobus van Staden, Pieter Schalk Els. *Difference thresholds for a vehicle on a 4-poster test rig.*

Improving vibration-induced discomfort often requires a reduction in the vibration experienced by vehicle occupants. Simulation software and test equipment are able to measure changes in vibration that are too small for humans to perceive. It is therefore important to know how large the change in vibration should be, i.e. the difference threshold, for occupants to perceive an improvement in comfort. This study estimates difference thresholds for ten automotive engineers seated in a vehicle on a 4-poster test rig. Participants were exposed to multi-axis vibration. Component ride values were calculated by applying BS 6841 frequency weightings and multiplication factors to seat accelerations in the six directions. Difference thresholds were estimated for two road profiles using the vertical component ride value and combined point ride value (i.e. the root-sums-of-squares of the six component ride values). The two road profiles had different magnitudes, but the same spectral shape, resulting in median vertical component ride values of 0.58 and 1.01 m.s.⁻², root-mean-square. An up-down transformed response rule was used with a three-down-one-up response grouping to estimate difference thresholds at a 79.4% probability level. The median relative difference threshold for the two roads was 10.13% and 8.58% considering the vertical component ride value, and 10.99% and 9.24% considering the combined point ride value. No statistically significant difference was found between the medians of the relative difference threshold over the two roads considering either of the two ride values (p-value = 0.995 in both instances), suggesting that Weber's law holds.

- **Keywords:** Difference threshold; Whole-body vibration; Multi-axis vibration; Vibration-induced discomfort; Ride comfort

Natasha C. Francksen, Thijs M.A. Ackermans, Denis Holzer, Sophia A. Ebner, Constantinos N. Maganaris, Mark A. Hollands, Kiros Karamanidis, Mike Roys, Thomas D. O'Brien. *Negotiating stairs with an inconsistent riser: Implications for stepping safety.*

Stairs are associated with falls, especially when step dimensions are inconsistent. However, the mechanisms by which inconsistencies cause this higher risk are mostly theoretical. In this experimental study we quantified the effect of inconsistent rise heights on biomechanical measurements of stepping safety from younger ($n = 26$) and older adults ($n = 33$). In ascent, both groups decreased foot clearance (~ 9 mm) over the inconsistently higher step ($F(1,56) = 48.4$, $p < 0.001$). In descent, they reduced foot contact length on the higher step by 3% ($F(1,56) = 9.1$, $p < 0.01$). Reduced clearance

may result in a toe-catch potentially leading to a trip, while reduced foot contact lengths increase the risk of overstepping which may also lead to a fall. These effects occurred because participants did not alter their foot trajectories, indicating they either did not detect or were not able to adjust to the inconsistent rise, increasing the likelihood of a fall. Consistent stair construction is vital, and existing inconsistencies should be identified and safety interventions developed.

- **Keywords:** Variable dimensions; Step geometry; Fall risk

Richard J. Holden, Carly N. Daley, Robin S. Mickelson, Davide Bolchini, Tammy Toscos, Victor P. Cornet, Amy Miller, Michael J. Mirro. *Patient decision-making personas: An application of a patient-centered cognitive task analysis (P-CTA).*

Personas can be used to understand patterns of variation in patients' performance of cognitive work, particularly self-care decision making. In this study, we used a patient-centered cognitive task analysis (P-CTA) to develop self-care decision-making personas. We collected data from 24 older adults with chronic heart failure and 14 support persons, using critical incident and fictitious scenario interviews. Qualitative analyses produced three personas but revealed that individuals exemplify different personas across situations. The Rule-Following persona seeks clear rules, exercises caution under uncertainty, and grounds actions in confidence in clinician experts. The Researching persona seeks information to gain better understanding, invents strategies, and conducts experiments independently or with clinicians. The Disengaging persona does not actively seek rules or information and does not attempt to reduce uncertainty or conduct experiments. We discuss the situational nature of personas, their use in design, and the benefits of P-CTA for studying patient decision making.

- **Keywords:** Naturalistic decision making; Patient ergonomics and human factors; Cognitive task analysis; Chronic heart failure (CHF); User-centered design; Critical incident technique; Personas

Louis Galey, Sabyne Audignon, Olivier Witschger, Sébastien Bau, Nathalie Judon, Aude Lacourt, Alain Garrigou. *What does ergonomics have to do with nanotechnologies? A case study.*

Despite recent concerns for workers' health, exposure situations to nanoparticles can occur in numerous workplaces. Understanding how exposures occur considering human work in these transformations remains a crucial issue of nanotechnologies. The objective of this article is to understand exposure situations to nanoparticles, their determinants and the resources to act on them. This understanding was achieved by specific measurement of nanoparticles aerosols, combined with an analysis of work activity (actions performed and physical strain) in a rubber industry. The presentation of real time measurements, associated with the video of work situations, during confrontation interviews becomes a means of making exposing work activities visible, to analyze and transform them from the points of view formulated by the company's stakeholders. In this way, characterized "typical exposure situations" serve to trigger discussions and open up new spaces for debate highlighting how innovation affects work and gives rise to enhanced prevention projects.

- **Keywords:** Design project; Participatory ergonomics; Measurement; Nanotechnologies

Chih-Kun Hsiao, Yuan-Kun Tu, Yi-Jung Tsai, Chun-Yuh Yang, Chih-Wei Lu. *Forearm muscular strength and performance fatigability in orthopaedic surgeons when performing bone screw fixations.*

This study investigated the muscle strength and performance fatigability of the forearms in eight male orthopaedic surgeons when performing bone screw fixations. Each surgeon performed an eight-bone screws operations in a porcine femur model to simulate fractural fixation using plating technique. The pre- and post-fatigue maximum isometric forces and corresponding electromyography responses were measured to assess the forearm muscle strength loss and fatigue due to screwing. Results showed that after eight bone screws were inserted, the maximal grip force, maximal driving torque and maximal push force losses were approximately 29%, 20% and 23%, respectively. While the grip force and/or driving torque acting, both the brachioradialis and extensor carpi ulnaris had a higher percentage change of EMG than the biceps brachii. The driving forces decreased with the number of screw insertions; however, the insertion time increased parabolically with the number of screws and significantly decreased the insertion rate of the screws, indicating that forearm muscle fatigue may occur in surgeons who treat fracture fixation using more than eight bone screws.

- **Keywords:** Performance fatigability; Maximum isometric forces; driving torque; Handgrip

Brian Thoroman, Paul Salmon, Natassia Goode. *Applying AcciMap to test the common cause hypothesis using aviation near misses.*

The common cause hypothesis, as applied here, proposes that similar networks of influencing factors may contribute to both adverse outcomes and near misses. This hypothesis has not been evaluated using a systems-thinking perspective. The aims of this study are to evaluate whether networks of contributory and protective factors exist within aviation serious near miss reports and to determine if the common cause hypothesis is applicable in this context. Sixteen incident reports from French civil aviation crash investigation bureau were analysed using the AcciMap method. Contributory and protective factors, and relationships between both were identified via coding of the reports. The results indicate that considering protective factors support a richer picture of incidents and provide support for the common cause hypothesis as measured by similar mean factor volume and sociotechnical levels for both contributory and protective factors. However, the findings also show the direction of relationships among protective and contributory factors may be indicative of a difference among adverse outcomes, near misses, and normal work. Future research should consider how a network of relationships may impact on the common contributory and protective factors found in near misses.

- **Keywords:** Near miss; AcciMap analysis; Aviation; Common cause hypothesis

David P. Azari, Brady L. Miller, Brian V. Le, Caprice C. Greenberg, Robert G. Radwin. *Quantifying surgeon maneuvers across experience levels through marker-less hand motion kinematics of simulated surgical tasks.*

This paper compares clinician hand motion for common suturing tasks across a range of experience levels and tissue types. Medical students (32), residents (41), attending surgeons (10), and retirees (2) were recorded on digital video while suturing on one of: foam, pig feet, or porcine bowel. Depending on time in position, each medical student, resident, and attending participant was classified as junior or senior, yielding six experience categories. This work focuses on trends associated with increasing tenure observed from those medical students (10), residents (15), and attendings (10) who sutured on foam, and draws comparison across tissue types where pertinent. Utilizing custom software, the two-dimensional location of each of the participant's hands were automatically recorded in every video frame, producing a rich spatiotemporal feature set. While suturing on foam, increasing clinician experience was associated with conserved path length per cycle of the non-dominant hand, significantly reducing from junior medical students (mean = 73.63 cm, sd = 33.21 cm) to senior residents (mean = 46.16 cm, sd = 14.03 cm, $p = 0.015$), and again between senior residents and

senior attendings (mean = 30.84 cm, sd = 14.51 cm, p = 0.045). Despite similar maneuver rates, attendings also accelerated less with their non-dominant hand (mean = 16.27 cm/s², sd = 81.12 cm/s², p = 0.002) than senior residents (mean = 24.84 cm/s², sd = 68.29 cm/s², p = 0.002). While tying, medical students moved their dominant hands slower (mean = 4.39 cm/s, sd = 1.73 cm/s, p = 0.033) than senior residents (mean = 6.53 cm/s, sd = 2.52 cm/s). These results suggest that increased psychomotor performance during early training manifest through faster dominant hand function, while later increases are characterized by conserving energy and efficiently distributing work between hands. Incorporating this scalable video-based motion analysis into regular formative assessment routines may enable greater quality and consistency of feedback throughout a surgical career.

- **Keywords:** Marker-less; Assessment; Surgery

Steven J. Wurzelbacher, Michael P. Lampl, Stephen J. Bertke, Chih-Yu Tseng. *The effectiveness of ergonomic interventions in material handling operations.*

This study evaluated the effectiveness of ergonomic interventions in material handling operations involving 33 employers and 535 employees from 2012 to 2017. Outcomes included employee-reported low back/upper extremity pain and safety incidents at baseline, every three months, and annually for up to two years. A total of 32.5% of employees completed at least one survey, while 13.6% completed all nine surveys over two years. Among highly exposed employees (who reported handling ≥ 50 lbs. $> 33\%$ of the time), upper extremity pain frequency and severity were lower among those who reported using the intervention routinely versus those that reported using their body strength alone to handle objects ≥ 50 lbs. After excluding from analyses one employer that used anti-fatigue mats, low back pain frequency was also significantly lower among highly exposed intervention users. In conclusion, there was some evidence that the interventions were effective in reducing employee-reported pain for highly exposed employees.

Ephrem Abebe, Matthew C. Scanlon, K. Jane Lee, Michelle A. Chui. *What do family caregivers do when managing medications for their children with medical complexity?*

Using a work domain analysis and complementary thematic analysis, this paper aims to describe medication management work, its constraints, and complexities from the perspectives of family caregivers of children with medical complexity—a medically fragile segment of the pediatric population often dependent on multiple and complex medication regimens for survival and optimal functioning. Analyses were informed by data generated through observations of 12 care coordination clinic visits within a pediatric complex care program, semi-structured interviews of 11 family caregivers, and reviews of program documents. Our results show that family caregivers: (1) formulate medication management goals, identify values and criteria to judge goals but these may not necessarily be acknowledged and explicitly supported by system resources and healthcare professionals (2) are engaged in a range of complex medication management tasks that are both physically and emotionally demanding without the support of well-designed tools and resources to enhance their work.

- **Keywords:** Children with medical complexity; Disabled children; Ergonomics; Medication therapy Management

Changwon Son, Farzan Sasangohar, Timothy Neville, S. Camille Peres, Jukrin Moon. *Investigating resilience in emergency management: An integrative review of literature.*

There is a growing need for resilience in dealing with unexpected events during disasters. The purpose of this review was to summarize and synthesize the literature that examined resilience in the context of emergency management (EM). Four groups of findings were synthesized: definitions, key dimensions, technical tools, and research settings employed in the research. First, definitions of resilience, improvisation, and adaptation were summarized and critically evaluated. Second, four key dimensions of EM resilience were identified: collective sensemaking, team decision making, harmonizing work-as-imagined and work-as-done, and interaction and coordination. Third, this review identified five prevalent technical tools used to enhance resilience in EM: mapmaking, event history logging, mobile communication applications, integrated information management system, and decision support tools. Fourth, two major design features of emergency simulations, incident scenarios and participant roles, are evaluated. For each finding, directions for future research efforts to improve resilience in EM are proposed.

- **Keywords:** Resilience engineering; Emergency response; Systematic review; System safety

Mathieu Lecocq, Pascaline Lantoine, Clément Bougard, Jean-Marc Allègre, Laurent Bauvineau, Christophe Bourdin, Tanguy Marqueste, Erick Dousset. *Neuromuscular fatigue profiles depends on seat feature during long duration driving on a static simulator.*

Prolonged driving could induce neuromuscular fatigue and discomfort since drivers have little opportunity to adjust their position. However, better car seat design could play a major role in limiting these effects. This study compared the effect of two different seats (S - soft and F - firm) on neuromuscular fatigue and driver's perceived discomfort during prolonged driving, also assessing the effect of different road types on neuromuscular activity. Twenty participants performed two 3-h driving sessions, one for each seat, on a static simulator. Every 20 min, participants self-evaluated their level of whole-body and individual body-area discomfort. Surface electromyography (sEMG) was recorded for eight muscles including Trapezius descendens (TD), Erector spinae longissimus (ESL), Multifidus (MF), Vastus lateralis (VL) and Tibialis anterior (TA) throughout the driving sessions. Moreover, an endurance static test (EST) was performed prior to and after each driving session. Whole-body discomfort increased with time with both seats, but no difference in discomfort scores was observed between seats throughout the driving sessions. The highest discomfort scores were for neck and lower back areas with both seats. Neuromuscular fatigue was revealed by a shorter endurance time in post-driving EST for both seats. EMG recordings showed different neuromuscular fatigue profiles for the two seats, with earlier onset of fatigue for S. Despite the lack of difference in perceived discomfort level, the two seats have different impacts: the softness of S induces greater activity of the lower back muscles, while F offers greater support for the lower back.

- **Keywords:** Seat design; Prolonged driving; Neuromuscular fatigue; Discomfort

Jaejin Hwang, Hemateja Ari, Megha Matoo, Jie Chen, Jeong Ho Kim. *Air-assisted devices reduce biomechanical loading in the low back and upper extremities during patient turning tasks.*

This laboratory study evaluated different assistive devices for reducing biomechanical loading during patient turning tasks. Twenty caregivers (18 females and 2 males) performed standardized patient turning tasks with two simulated patients (body mass: 74 kg and 102 kg). The turning tasks were performed in two turning directions (toward vs. away relative to caregivers) using five device conditions: draw sheet, friction-reducing turning sheet, air-assisted transfer device, air-assisted turning device, and no assistive device. Low back and upper extremity muscle activity, trunk and shoulder

postures, low back moment, and self-reported usability ratings were evaluated. While all assistive devices reduced trunk flexion, both air-assisted transfer and turning devices reduced the trunk flexion (p 's < 0.001) and muscle activity (p 's < 0.001) in the erector spinae and triceps compared to no assistive device condition. These results suggest that the air-assisted devices have potential as an effective intervention to considerably reduce physical risk factors associated with caregivers' musculoskeletal disorders in low back and upper extremities.

- **Keywords:** Low back moment; Shoulder posture; Musculoskeletal disorders; Patient handling; Electromyography

Sofía Iranzo, Alicia Piedrabuena, Daniel Iordanov, Ursula Martinez-Iranzo, Juan-Manuel Belda-Lois. *Ergonomics assessment of passive upper-limb exoskeletons in an automotive assembly plant.*

Over the years, the industry's interest in using external support devices, such as exoskeletons, is increasing. They are introduced as a new technique for improving the conditions of workers and for reducing the risk of musculoskeletal injuries. An investigation of muscle activity, Jonsson's (Jonsson, 1982) ergonomic acceptance ranges, and shoulder range of motion was conducted with a sample of 12 workers using an upper extremity exoskeleton in an automotive assembly line. The operators performed continuous cycles of dynamic overhead work consisting of the assembly of the car body at the underside of the car making use of pneumatic screwdrivers. The EMGs (anterior part of deltoid, trapezius, latissimus dorsi and erector spinae) were measured for the muscle activity analysis on the one hand, and for the ergonomics study on the other hand. The latter consisted of an approach based on Jonsson's work, that establishes acceptance thresholds of cumulative percentage of maximum voluntary contraction of muscle activity (%MVC) in a work cycle. The joint angles motion capture was carried out by measuring the angles of the neck, back, and arms joints. All measurements were performed during experimental sessions with and without an exoskeleton. The key findings show reductions of 34% and 18% of the deltoid and the trapezius muscular activities, respectively, which in turn could lead to a reduction of discomfort and fatigue. The erector spinae and latissimus dorsi muscles were not significantly affected by exoskeleton. The values of muscular activity were also represented over Jonsson's acceptance areas. Referring to the posture, some differences were found in the range of movement of back, neck, and arms owing to the use of the exoskeleton; however, the differences were smaller than 5% in all cases.

- **Keywords:** Exoskeleton; Upper-limb; EMG; Motion-tracking; Industry conditions; Automotive

J.E. Anderson, A.J. Ross, C. Macrae, S. Wiig. *Defining adaptive capacity in healthcare: A new framework for researching resilient performance.*

Resilience principles show promise for improving the quality of healthcare, but there is a need for further theoretical development to include all levels and scales of activity across the whole healthcare system. Many existing models based on engineering concepts do not adequately address the prominence of social, cultural and organisational factors in healthcare work. Promising theoretical developments include the four resilience potentials, the CARE model and the Moments of Resilience Model, but they are all under specified and in need of further elaboration. This paper presents the Integrated Resilience Attributes Framework in which these three theoretical perspectives are integrated to provide examples of anticipating, responding, monitoring and learning at different scales of time and space. The framework is intended to guide researchers in researching resilience, especially the linkages between resilience at different scales of time and space across the whole healthcare system.

- **Keywords:** Resilience potentials; Resilience framework; Multi-level resilience; Resilient healthcare

Li Li, Tara Martin, Xu Xu. *A novel vision-based real-time method for evaluating postural risk factors associated with musculoskeletal disorders.*

Real-time risk assessment for work-related musculoskeletal disorders (MSD) has been a challenging research problem. Previous methods such as using depth cameras suffered from limited visual range and wearable sensors could cause intrusiveness to the workers, both of which are less feasible for long-run on-site applications. This document examines a novel end-to-end implementation of a deep learning-based algorithm for rapid upper limb assessment (RULA). The algorithm takes normal RGB images as input and outputs the RULA action level, which is a further division of RULA grand score. Lifting postures collected in laboratory and posture data from Human 3.6 (a public human pose dataset) were used for training and evaluating the algorithm. Overall, the algorithm achieved 93% accuracy and 29 frames per second efficiency for detecting the RULA action level. The results also indicate that using data augmentation (a strategy to diversify the training data) can significantly improve the robustness of the model. The proposed method demonstrates its high potential for real-time on-site risk assessment for the prevention of work-related MSD. A demo video can be found at https://github.com/LLDavid/RULA_2DImage.

- **Keywords:** RULA; Deep learning; MSD risk assessment

Jennifer Jackson, Jo Iacovides, Myanna Duncan, Matthew Alders, Jill Maben, Janet Anderson. *Operationalizing resilient healthcare concepts through a serious video game for clinicians.*

Resilient healthcare emphasises the importance of adaptive capacity in quality healthcare. This theory has had extensive theoretical development, but comparatively limited translation for clinicians in practice. This study is the first to present resilient healthcare principles in a serious video game. Serious games are an effective tool for engaging users, sharing ideas and eliciting reflections. The aim of this study was to communicate principles from resilient healthcare to clinicians through a serious video game, and to evaluate the game's feasibility as a prompt to reflect on practice. The game, Resilience Challenge, is scenario-based and requires players to resolve dilemmas in clinical practice. It was disseminated online, and was played 1949 times during the four-month study. The game was evaluated using an immediate cross-sectional survey, which included both Likert-style and free text responses. Participants reported that the game was engaging (93%) and that they would recommend it to others (89%). Fewer participants reported learning about resilient healthcare concepts (64%). Resilience Challenge is a promising way to prompt reflections about clinical work, and demonstrates mixed outcomes in communicating resilient healthcare principles to clinicians.

- **Keywords:** Resilience; Safety II; Serious video game; Healthcare; Resilience engineering; Gamification; Resilient healthcare; Serious games; Feasibility; Reflection; Survey

Saif K. Al-Qaisi, Adnan El Tannir, Lina A. Younan, Roland N. Kaddoum. *An ergonomic assessment of using laterally-tilting operating room tables and friction reducing devices for patient lateral transfers.*

Patient lateral transfers between two adjacent surfaces pose high musculoskeletal disorder risks for nurses and patient handlers. The purpose of this research was to examine the ergonomic benefits of utilizing the laterally-tilting function of operating room

(OR) tables during such transfers – along with different friction-reducing devices (FRD). This method allows the patient to slide down to the adjacent surface as one nurse guides the transfer and another controls the OR table angle with a remote control. Sixteen nursing students and sixteen college students were recruited to act as nurses and patients, respectively. Two OR table angles were examined: flat and tilted. Three FRD conditions were considered: a standard blanket sheet, a plastic bag, and a slide board. Electromyography (EMG) activities were measured bilaterally from the posterior deltoids, upper trapezii, latissimus dorsi, and lumbar erector spinae muscles. The Borg-CR10 scale was used for participants to rate their perceived physical exertions. The efficiency of each method was measured using a stopwatch. Results showed that the tilted table technique completely replaced the physical efforts that would have been exerted by the pushing-nurse, in that muscle activation did not increase in the pulling-nurse. On the contrary, EMG activities of the pulling-nurse for most of the muscles significantly decreased ($p < 0.05$). The subjective Borg-ratings also favored the tilted table with significantly lower ratings. However, the tilted table required on average 7.22 s more than the flat table to complete the transfer ($p < 0.05$). The slide board and plastic bag were associated with significantly lower Borg-ratings and EMG activities for most muscles than blanket sheet, but they both were not significantly different from each other. However, they each required approximately 5 s more than the blanket sheet method to complete the patient transfer ($p < 0.05$). By switching from flat + blanket sheet to tilted + slide board, EMG activities in all muscles decreased in the range of 18.4–72.3%, and Borg-ratings decreased from about 4 (somewhat difficult) to 1 (very light). The findings of this study propose simple, readily available ergonomic interventions for performing patient lateral transfers that can have significant implications for nurses' wellbeing and efficiency.

- **Keywords:** Patient lateral transfer; Operating room table angle; Friction-reducing device; Ergonomics; Electromyography