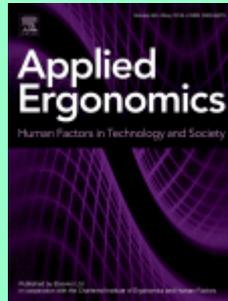


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Aneurin Canham, Gyuchan Thomas Jun, Patrick Waterson, Suzanne Khalid. *Integrating systemic accident analysis into patient safety incident investigation practices.* Pages 1-9.

There is growing awareness of the limitations of current practice regarding the investigation of patient safety incidents, including a reliance on Root Cause Analysis (RCA) and a lack of safety expertise. Human Factors and Ergonomics (HFE) can offer safety expertise and systemic approaches to incident analysis. However, HFE is underutilised in healthcare. This study aims to explore the integration of HFE systemic accident analysis into current practice. The study compares the processes and outputs of a current practice RCA-based incident analysis and a Systems Theoretic Accident Modelling and Processes (STAMP) analysis on the same medication error incident. The STAMP analysis was undertaken by two HFE researchers with the participation of twenty-one healthcare stakeholders. The STAMP-based approach guided healthcare stakeholders towards consideration of system design issues and remedial actions, going beyond the individual-based remedial actions proposed by the RCA. The study offers insights into how HFE can be integrated into current practice.

- **Keywords:** Patient safety; Incident analysis; Systemic accident analysis

Kirsten Huysamen, Valerie Power, Leonard O'Sullivan. *Elongation of the surface of the spine during lifting and lowering, and implications for design of an upper body industrial exoskeleton.* Pages 10-16.

The aim of this study was to assess the elongation of the skin surface of the spine for simulated industrial lifting and lowering tasks to aid the design of industrial exoskeletons worn on the back. Eighteen male participants lifted and lowered a box of varying loads (5 kg, 10 kg, 15 kg) using three techniques (squat, semi-squat, stooped) from the ground to a table. Motion capture sensors attached to the spine from C7 to S1 measured movement. Stoop lifting involved significantly more elongation (mean 71.1 mm; margin of error ± 6.9) than squat lifting (mean 36.8 mm; margin of error ± 6.9). Load and Task (lift vs. lower) did not have a significant effect on elongation. Elongation of the skin surface of the lumbar spine was greater than for the thoracic spine. These data detail example levels of elongation of the skin surface of the spine, which should be considered in upper body wearable industrial exoskeleton design. Further, exoskeleton design should take into account that the skin surface of the lumbar spine involves greater elongation than the skin surface of the thoracic spine during deep lifting.

Xueke Wang, Steven Bigelow, Kelly E. Seagren, Alaina K. Preddie, Zimei Wang, Ardiyanto Ardiyanto, W. Gary Allread, Steven A. Lavender. *Rethinking floor mat design from an ergonomics perspective: Can a two-part mat system reduce biomechanical loads during normal mat handling tasks?* Pages 17-24.

Floor mats are commonplace in commercial buildings, particularly in entry ways. These mats are routinely handled by delivery personnel as the mats are picked up for cleaning and clean mats are deployed. A new two-part mat design, which eliminates the need to move the rubber base during mat change operations, was hypothesized to reduce the physical demands on delivery personnel. Electromyographic data from back and shoulder muscles and spinal kinematics were obtained as 12 volunteers simulated mat selection, mat deployment, and mat pick-up tasks. Other factors considered in this study included mat size, pick-up method, and mat textile orientation during deployment. Results indicated that the two-part design reduced muscle activation levels across all tasks. Biomechanical benefits were also found when the mats were picked-up using a kick-fold as opposed to hand-fold method and when mats were deployed with the textile component rolled towards the inside of the roll.

- **Keywords:** Musculoskeletal disorders; Low back; Shoulder; Delivery driver; Floor mat

Felix Schwarz, Wolfgang Fastenmeier. *Visual advisory warnings about hidden dangers: Effects of specific symbols and spatial referencing on necessary and unnecessary warnings.* Pages 25-36.

Augmented reality has the potential to improve the effectiveness of collision warnings in vehicles because they inherently convey spatial information about the hazard and can guide the attention of the driver towards it. For future warning systems, which can detect sight obstructed dangers, related work already revealed some advantages. In a driving simulator study with 80 participants, we investigated the effects of three corresponding design parameters which are commonly integrated at augmented reality warnings. This study analyzes the individual contribution of specific warning symbols, warning animation, and spatial referencing. Part one of the study concentrates on the effectiveness of necessary warnings and part two on the drivers' compliance despite false alarms. Compared to the control condition with static unspecific warning symbols, static specific warning symbols depicting the type and motion direction of the hazard led to several but inconsistent advantages. The scaling animation only improved subjective evaluation. However, spatial referencing of an (unspecific) warning symbol consistently improved drivers' reactions to as well as evaluations of necessary and unnecessary warnings. The results emphasize the potential of spatial referencing, particularly for in-vehicle warnings of future collision avoidance systems.

- **Keywords:** Collision avoidance; Sight obstruction; Reliability; Warning design; Specific warnings; Augmented reality; Spatial referencing; Specificity

Rui Lin, Liang Ma, Wei Zhang. *An interview study exploring Tesla drivers' behavioural adaptation.* Pages 37-47.

Partially automated vehicles (PAVs) have been used in real-world environments for several years since the emergence of autonomous driving. It is important to understand the effects of partial automation systems (PAS) on the understanding of drivers and their behaviour during the first months of use. In order to adapt to new vehicle technology, drivers usually exhibit specific behaviours in this stage that are not intended by the developers, namely behavioural adaptation. The present study investigated the behavioural adaptations by early PAV adopters after short-term usage. A semi-structured

interview was conducted among 20 Tesla drivers who had relatively high experience (one to five months) with Autopilot, and the interviews were synthesized to understand their behavioural adaptation, mental models, and trust during the period of use. The results showed that PAV drivers had a very positive attitude towards the PAS and drivers universally engaged in secondary tasks during automated driving. They also learned from their experiences to identify relatively safe usage conditions and they employed a safety margin to avoid exposure to excessively risky situations.

- **Keywords:** Automated driving; Partial automation system; Secondary task

Bert Boute, Liv Veldeman, Bruno Speleers, Annick Van Greveling, Tom Van Hoof, Joris Van de Velde, Tom Vercauteren, Wilfried De Neve, Jan Detand. *The relation between patient discomfort and uncompensated forces of a patient support device for breast and regional lymph node radiotherapy. Pages 48-57.*

Although many authors stated that a user-centred design approach in medical device development has added values, the most common research approach within healthcare is evidence-based medicine, which tend to focus on functional data rather than patient wellbeing and comfort. End user comfort is well addressed in literature for commercial products such as seats and hand tools but no data was found for medical devices. A commercial patient support device for breast radiotherapy was analysed and a relation was found between discomfort and uncompensated internal body forces. Derived from CT-images, simplified patient free-body diagrams were analysed and pain and comfort evaluated. Subsequently, a new patient position was established and prototypes were developed. Patient comfort- and prototype optimization was done through iterative prototyping. With this approach, we were able to compensate all internal body forces and establish a force neutral patient free-body diagram. This resulted in comfortable patient positioning and favourable medical results.

- **Keywords:** Comfort evaluation; Free-body diagram; Prone breast radiotherapy

Nicole Hättenschwiler, Yanik Sterchi, Marcia Mendes, Adrian Schwaninger. *Automation in airport security X-ray screening of cabin baggage: Examining benefits and possible implementations of automated explosives detection. Pages 58-68.*

Bomb attacks on civil aviation make detecting improvised explosive devices and explosive material in passenger baggage a major concern. In the last few years, explosive detection systems for cabin baggage screening (EDSCB) have become available. Although used by a number of airports, most countries have not yet implemented these systems on a wide scale. We investigated the benefits of EDSCB with two different levels of automation currently being discussed by regulators and airport operators: automation as a diagnostic aid with an on-screen alarm resolution by the airport security officer (screener) or EDSCB with an automated decision by the machine. The two experiments reported here tested and compared both scenarios and a condition without automation as baseline. Participants were screeners at two international airports who differed in both years of work experience and familiarity with automation aids. Results showed that experienced screeners were good at detecting improvised explosive devices even without EDSCB. EDSCB increased only their detection of bare explosives. In contrast, screeners with less experience (tenure < 1 year) benefitted substantially from EDSCB in detecting both improvised explosive devices and bare explosives. A comparison of all three conditions showed that automated decision provided better human-machine detection performance than on-screen alarm resolution and no automation. This came at the cost of slightly higher false alarm rates on the human-machine system level, which would still be acceptable from an operational point of view. Results indicate that a wide-

scale implementation of EDSCB would increase the detection of explosives in passenger bags and automated decision instead of automation as diagnostic aid with on screen alarm resolution should be considered.

- **Keywords:** Airport security X-ray screening; Explosives detection; Automation

Firdaous Sekkay, Daniel Imbeau, Yuvin Chinniah, Philippe-Antoine Dubé, Nathalie de Marcellis-Warin, Nancy Beauregard, Martin Trépanier. *Risk factors associated with self-reported musculoskeletal pain among short and long distance industrial gas delivery truck drivers. Pages 69-87.*

Aim: This study investigated and compared the associations between self-reported exposures to individual as well as work-related physical and psychosocial risk factors for musculoskeletal (MS) disorders and the prevalence of MS symptoms in different body areas among short- (P&D) and long-distance (Bulk delivery) truck drivers working for the same large gas delivery company in Canada. **Methods:** 123 truck drivers nationwide participated in this questionnaire-based cross-sectional study. Univariate and multivariate logistic regression analyses were performed. **Results:** 43.1% of drivers reported MS pain in at least one body area over the past 12 months and 26.8% over the past 7 days. Bulk drivers had a significantly higher prevalence of MS pain than P&D drivers for both periods. When P&D and Bulk drivers were pooled together, belonging to the Bulk subgroup emerged as the strongest factor for low back pain (OR = 8.45, $p = 0.002$), for shoulder pain (OR = 3.70, $p = 0.027$) and for MS pain in any body area (OR = 4.05, $p = 0.006$). In Bulk drivers "High effort-reward imbalance" was strongly associated with MS pain in any body area (OR = 6.47, $p = 0.01$), with shoulder pain (OR = 4.95, $p = 0.016$), and with low back pain (OR = 4.51, $p = 0.02$). In P&D drivers MS pain in any body area was strongly associated with "Working with hands above shoulders" (OR = 6.58, $p = 0.009$) and "Whole-body vibration" (OR = 5.48, $p = 0.018$), while shoulder pain was strongly associated with "Hand-arm vibration" (OR = 7.27, $p = 0.041$). **Conclusions:** Prevalence of MS pain was higher among industrial gas delivery truck drivers than in the general Quebec male worker population, and higher for Bulk drivers compared to P&D drivers. MS pain in Bulk drivers was mainly associated with psychosocial risk factors and lifestyle; MS pain in P&D drivers was mainly associated with physical risk factors.

- **Keywords:** Musculoskeletal pain; Musculoskeletal risk factors; Self-reports; Professional truck drivers

Judy Edworthy, Scott Reid, Katie Peel, Samantha Lock, Jessica Williams, Chloe Newbury, Joseph Foster, Martin Farrington. *The impact of workload on the ability to localize audible alarms. Pages 88-93.*

Very little is known about people's ability to localize sound under varying workload conditions, though it would be expected that increasing workload should degrade performance. A set of eight auditory clinical alarms already known to have relatively high localizability (the ease with which their location is identified) when tested alone were tested in six conditions where workload was varied. Participants were required to indicate the location of a series of alarms emanating at random from one of eight speaker locations. Additionally, they were asked to read, carry out mental arithmetic tasks, be exposed to typical ICU noise, or carry out either the reading task or the mental arithmetic task in ICU noise. Performance in the localizability task was best in the control condition (no secondary task) and worst in those tasks which involved both a secondary task and noise. The data does therefore demonstrate the typical pattern of increasing workload affecting a primary task in an area where there is little data. In addition, the data demonstrates that performance in the control condition results in a missed alarm on one in ten occurrences, whereas performance in the heaviest workload conditions results

in a missed alarm on every fourth occurrence. This finding has implications for the understanding of both 'inattentional deafness' and 'alarm fatigue' in clinical environments.

- **Keywords:** Auditory alarms; Clinical alarms; Clinical safety; Patient safety; Auditory processes; Alarm fatigue

S.J. Baltrusch, J.H. van Dieën, C.A.M. van Bennekom, H. Houdijk. *The effect of a passive trunk exoskeleton on functional performance in healthy individuals.* Pages 94-106.

The objective of this study was to assess the effect of a passive trunk exoskeleton on functional performance for various work related tasks in healthy individuals. 18 healthy men performed 12 tasks. Functional performance in each task was assessed based on objective outcome measures and subjectively in terms of perceived task difficulty, local and general discomfort. Wearing the exoskeleton tended to increase objective performance in static forward bending, but decreased performance in tasks, such as walking, carrying and ladder climbing. A significant decrease was found in perceived task difficulty and local discomfort in the back in static forward bending, but a significant increase of perceived difficulty in several other tasks, like walking, squatting and wide standing. Especially tasks that involved hip flexion were perceived more difficult with the exoskeleton. Design improvements should include provisions to allow full range of motion of hips and trunk to increase versatility and user acceptance.

- **Keywords:** Assistive device; Low back pain; User acceptance

C.M. Bauer, F.M. Rast, C. Böck, R.P. Kuster, D. Baumgartner. *Determination of a sagittal plane axis of rotation for a dynamic office chair.* Pages 107-112.

Objective: This study investigated the location of the axis of rotation in sagittal plane movement of the spine in a free sitting condition to adjust the kinematics of a mobile seat for a dynamic chair. **Background:** Dynamic office chairs are designed to avoid continuous isometric muscle activity, and to facilitate increased mobility of the back during sitting. However, these chairs incorporate increased upper body movement which could distract office workers from the performance of their tasks. A chair with an axis of rotation above the seat would facilitate a stable upper back during movements of the lower back. The selection of a natural kinematic pattern is of high importance in order to match the properties of the spine. **Method:** Twenty-one participants performed four cycles of flexion and extension of the spine during an upper arm hang on parallel bars. The location of the axis of rotation relative to the seat was estimated using infrared cameras and reflective skin markers. **Results:** The median axis of rotation across all participants was located 36 cm above the seat for the complete movement and 39 cm for both the flexion and extension phases, each with an interquartile range of 20 cm. **Conclusion:** There was no significant effect of the movement direction on the location of the axis of rotation and only a weak, non-significant correlation between body height and the location of the axis of rotation. Individual movement patterns explained the majority of the variance. **Application:** The axis of rotation for a spinal flexion/extension movement is located above the seat. The recommended radius for a guide rail of a mobile seat is between 36 cm and 39 cm.

- **Keywords:** Office workers; Dynamic sitting; Product design; Kinematics; Spine; Low back pain

Kasper Edwards, Jörgen Winkel. *A method for effect modifier assessment (EMA) in ergonomic intervention research.* Pages 113-120.

The numerous opportunities for effect modifications pose a major challenge in ergonomic intervention research. Even studies in systematic reviews that are assessed as being of high quality generally lack any proper consideration of the potential effect modifiers. We have developed a method for effect modifier assessment (EMA) in intervention research. The EMA method uses a participatory workshop consisting of representatives from all occupational groups in the investigated organization. The workshop identifies both intervention and modifier events. These are categorized into themes, then analyzed and evaluated for their potential effects on the investigated outcomes. The overall impact of the pooled modifier themes is finally estimated in relation to the estimated impact of the intervention events. In the present study, the EMA method was tested in two cases. The findings suggest that it provides information that strengthens inferences about the impact of the investigated ergonomic interventions. Further evaluation of the method is recommended.

- **Keywords:** Ergonomic intervention; Effect modification; Research method

Larissa M. Fedorowich, Julie N. Côté. *Effects of standing on typing task performance and upper limb discomfort, vascular and muscular indicators.* Pages 121-127.

Standing is a popular alternative to traditionally seated computer work. However, no studies have described how standing impacts both upper body muscular and vascular outcomes during a computer typing task. Twenty healthy adults completed two 90-min simulated work sessions, seated or standing. Upper limb discomfort, electromyography (EMG) from eight upper body muscles, typing performance and neck/shoulder and forearm blood flow were collected. Results showed significantly less upper body discomfort and higher typing speed during standing. Lower Trapezius EMG amplitude was higher during standing, but this postural difference decreased with time (interaction effect), and its variability was 68% higher during standing compared to sitting. There were no effects on blood flow. Results suggest that standing computer work may engage shoulder girdle stabilizers while reducing discomfort and improving performance. Studies are needed to identify how standing affects more complex computer tasks over longer work bouts in symptomatic workers.

- **Keywords:** Computer work; Standing; Neck/shoulder