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Elin Pöllänen, Gemma J. M. Read, Ben R. Lane, Jason Thompson & Paul M. Salmon. *Who is to blame for crashes involving autonomous vehicles? Exploring blame attribution across the road transport system*. Pages: 525-537.

The introduction of fully autonomous vehicles is approaching. This warrants a re-consideration of road crash liability, given drivers will have diminished control. This study, underpinned by attribution theory, investigated blame attribution to different road transport system actors following crashes involving manually driven, semi-autonomous and fully autonomous vehicles. It also examined whether outcome severity alters blame ratings. 396 participants attributed blame to five actors (vehicle driver/user, pedestrian, vehicle, manufacturer, government) in vehicle–pedestrian crash scenarios. Different and unique patterns of blame were found across actors, according to the three vehicle types. In crashes involving fully autonomous vehicles, vehicle users received low blame, while vehicle manufacturers and government were highly blamed. There was no difference in the level of blame attributed between high and low severity crashes regarding vehicle type. However, the government received more blame in high severity crashes. The findings have implications for policy and legislation surrounding crash liability. **Practitioner summary:** Public views relating to blame and liability in transport accidents is a vital consideration for the introduction of new technologies such as autonomous vehicles. This study demonstrates how a systems ergonomics framework can assist to identify the implications of changing public opinion on blame for future road transport systems.

- **Keywords:** Road crashes, autonomous vehicles, blame attribution, liability, self-driving cars

Jacob D. Achtemeier, Curtis M. Craig, Nichole L. Morris & Brian Davis. *Superior side sound localisation performance in a full-chassis driving simulator*. Pages: 538-547.

Alerts presented through the auditory modality improve drivers' crash avoidance performance in driving simulations, but drivers' ability to accurately localise the source of the auditory alerts is understudied. Because the results of driving simulation studies may

hinge on assumptions that sound locations are accurately perceived by drivers, this study used a sound localisation task in a full-chassis driving simulator. Twenty-nine participants engaged in a sound localisation task while seated in the driving simulator. Performance was assessed by sound localisation accuracy, relative directional error, and participant confidence across seven sound sources surrounding the simulator. Performance was best when sounds were presented in left and right cardinal regions, and poorest when presented from the front and rear. Participants were less confident in their localisation judgments when sounds were presented from the rear. **Practitioner summary:** Drivers' ability to accurately localise auditory alerts is understudied. Participants performed an auditory localisation task with external sounds while seated in a full-chassis driving simulator. Participants were better detecting sounds from the sides instead of the front and rear. This has implications for external auditory alarms during driving.

- **Keywords:** Perception, ergonomics tools and methods, driving, hearing, transport, ergonomics

Adam J. Reiner, Justin G. Hollands, Greg A. Jamieson & Sabah Boustila. *A mirror in the sky: assessment of an augmented reality method for depicting navigational information*. Pages: 548-562.

We investigated the efficacy of a novel augmented reality (AR) navigation display called Mirror in the Sky (MitS). AR displays can reduce the distance between virtual imagery content and the user's view of the environment but may have limited benefit for depicting map-based survey information. MitS presents a simulated mirror in the upper visual field, which reflects the topographic layout of the terrain in front of the user. In our experiment, 28 participants used MitS and a track-up Map in virtual reality to perform a *route confirmation* task, which required participants to decide whether a route could be successfully navigated. A post-trial *threat location* recall task examined spatial awareness. On that task, accuracy, duration, and subjective workload measures favoured the Map. However, participants with virtual reality experience made more accurate route confirmation decisions with MitS than the Map. **Practitioner summary:** We compared an augmented reality display called Mirror in the Sky (MitS) to a conventional electronic map for route confirmation and threat location tasks. Although the electronic map showed advantages over MitS on some measures, users with some VR experience performed route confirmation more accurately with MitS than a map.

- **Keywords:** Navigation, wayfinding, display, head-up display, augmented reality, virtual reality

Mingcai Hu, Fu Guo, Vincent G. Duffy, Zenggen Ren & Peng Yue. *Constructing and measuring domain-specific emotions for affective design: a descriptive approach to deal with individual differences*. Pages: 563-578.

Assessing design solutions via domain-specific emotions has been widely concerned and explored in the field of affective design. However, the examination and accommodation of individual differences have not been settled sufficiently in the literature. To address this research gap, this paper proposes a descriptive approach to draw calibrated collective emotion patterns in survey-based affective design assessment. A 'Repertory Grid Interview linked with Rate-All-That-Apply' (RGI/RATA) procedure is firstly conducted to elicit and code the individual's personal emotional descriptions into mid-level Emotion Words (EWs) and to gather emotion data grids with each grid quantified by an individual's own EWs. The obtained individualised emotion data grids are then subjected to Multiple Factor Analysis (MFA) to extract collective emotional space, thus to enable conceptualising collective emotional dimensions and measuring calibrated collective responses. A case study demonstrating the implementation process for a simple project

of appearance design assessment is also presented. **Practitioner Summary:** The proposed methodology may help a design team to investigate the shared patterns of domain-specific emotions through a single assessment survey. With the provided *post hoc* analysis tools, designers may also evaluate multi-level individual differences (e.g. regarding user groups or even intra-individual) quantitatively and at a low cost.

- **Keywords:** Domain-specific emotions, affective design, individual differences, repertory grid interview, multiple factor analysis

Rudolf Wall, Gabriela Garcia, Thomas Läubli, Robert Seibt, Monika A. Rieger, Bernard Martin & Benjamin Steinhilber. *Physiological changes during prolonged standing and walking considering age, gender and standing work experience*. Pages: 579-592.

Occupational standing is associated with musculoskeletal and venous disorders. The aim was to investigate whether lower leg oedema and muscle fatigue development differ between standing and walking and whether age, gender and standing work habituation are factors to consider. Sixty participants (15 young females, 15 young males, 15 older males, and 15 young males habituated to standing work) were included and required to stand/walk for 4.5 hours in three periods with two seated breaks. Waterplethysmography/bioelectrical impedance, muscle twitch force and surface electromyography were used to assess lower leg swelling (LLS) and muscle fatigue as well as gastrocnemius muscle activity, respectively. While standing led to LLS and muscle fatigue, walking did not. Low-level medial gastrocnemius activity was not continuous during standing. No significant influence of age, gender and standing habituation was observed. Walking can be an effective prevention measure to counteract the detrimental effects of quasi-static standing. **Practitioner summary:** Prolonged standing leads to lower leg oedema and muscle fatigue while walking does not. The primary cause of fatigue may be in other muscles than the medial gastrocnemius. Walking may be an effective prevention measure for health risks of occupational standing when included intermittently.

- **Keywords:** Standing work, lower leg, surface electromyography, oedema, muscle twitch force, bioelectrical impedance

Tobias Hellig, Laura Johnen, Alexander Mertens, Verena Nitsch & Christopher Brandl. *Prediction model of the effect of postural interactions on muscular activity and perceived exertion*. Pages: 593-606.

Musculoskeletal disorders are a prevalent disease in many Western countries. While a large number of ergonomic analyses and assessment methods are nowadays available, most current methods that assess exposure calculate overall risk scores of individual body segments without considering interaction effects of exposure variables. Therefore, a study was conducted that aimed at investigating and quantifying interaction effects of trunk inclination and arm lifting on ratings of perceived exertion (RPE) and muscle activity. A multiple regression model to predict musculoskeletal load under consideration of interaction effects was derived. The study revealed that there is a significant interaction effect of trunk inclination and arm lifting. Furthermore, final regression models explained variance in exposure variables in a range of $R^2 = 0.68$ to $R^2 = 0.147$ with a subset of two to three inputs. The predicative equations support the computer-based post-processing of sensor data. **Practitioner summary:** This article elaborates on the importance of interaction effects of working postures on assessment results of load. In practise, easy to-use-methods for an assessment of working postures are needed. Therefore, a regression model is derived, which facilitates the quantification of work load

under consideration of interaction effects. The use of this regression model for the assessment of posture data gathered by range sensors is recommended.

- **Keywords:** Postural load, working postures, workplace design, multiple regression

Peter Fjeldstad Hendriksen, Mette Korshøj, Jørgen Skotte & Andreas Holtermann. *Detection of kneeling and squatting during work using wireless triaxial accelerometers*. Pages: 607-617.

Occupational kneeling and squatting are well-documented risk factors for knee disorders. A method using 3 wireless accelerometers to detect and discriminate kneeling and squatting during work were developed based on data from a semi-standardised laboratory protocol. The method was tested for validity under free-living working conditions. The developed method showed high sensitivity (88–99%) and specificity (98–99%) for detection of kneeling and squatting during the semi-standardised laboratory conditions. During free-living working conditions, kneeling showed very high sensitivity (94%) and specificity (99%), while squatting results were non-conclusive due to limited duration of squatting during the free-living working conditions. This method shows great promise for long-term technical measurement of kneeling and squatting during normal working conditions using wireless accelerometers. The method opens up possibilities for using technical measurements to provide valid exposure assessments and intervention evaluations of kneeling and squatting, as well as increased feasibility for technical measurements in large cohort studies. **Practitioner summary:** Quantification of kneeling and squatting during work is important for prevention, but limited by either imprecise or costly methods. This study developed and validated an inexpensive wireless accelerometer-based measurement method that can be used by practitioners and researchers for long-term measurements of kneeling and squatting during free-living working conditions.

- **Keywords:** Knee-straining, occupational, accelerometry, validation, posture

Tjaša Kermavnar, Kevin J. O'Sullivan, Adam de Eyto & Leonard W. O'Sullivan. *The effect of simulated circumferential soft exoskeleton compression at the knee on discomfort and pain*. Pages: 618-628.

There is a lack of data and guidance on soft exoskeleton pressure contact with the body. The purpose of this research was to study the relationship between circumferential loading at the knee and discomfort/pain, to inform the design of soft exoskeletons/exosuits. The development of discomfort and pain was studied during standing and walking with circumferential compression using a pneumatic cuff. Our results show higher tolerance for intermittent than continuous compression during standing. Discomfort was triggered at pressures ranging from 13.7 kPa (continuous compression) to 30.4 kPa (intermittent compression), and pain at 52.9 kPa (continuous compression) to 60.6 kPa (intermittent compression). During walking, cyclic compression caused an increase in discomfort with time. Higher cuff inflation pressures caused an earlier onset and higher end intensities of discomfort than lower pressures. Cyclic cuff inflation of 10 kPa and 20 kPa was reasonably well tolerated. **Practitioner summary** Soft exoskeleton compression of the knee was simulated during static and dynamic compression cycles. The results can be used to understand how users tolerate pressure at the knee, and also to understand the levels at which discomfort and pain are experienced.

- **Keywords:** Soft exoskeleton, circumferential compression, exosuit, discomfort, pain

Jennifer E. Earl-Boehm, Daniel N. Poel, Kathryn Zalewski & Kyle T. Ebersole. *The effects of military style ruck marching on lower extremity loading and muscular, physiological and perceived exertion in ROTC cadets*. Pages: 629-638.

Military ruck marching with load carriage increases ground reaction forces, which are related to bone stress injuries (BSI). This study's purpose was to examine whether a ruck march increases impact loading and to describe muscular, physiological and perceived exertion in Army Reserve Officer Training Corps (ROTC) cadets. Secondary purposes examined relationships among loading changes after the ruck march and baseline characteristics. Fifteen Army ROTC cadets performed a 4-mile march. Lower extremity loading and muscular, physiological and perceived exertion were measured pre- and post-march. Results indicated significant increases in peak impact force and loading rate and decreases in ankle dorsiflexion and plantarflexion strength. Factors that might have been related to changes seen in lower extremity loading did not yield any compelling relationships to explain those changes. In conclusion, the ruck march led to increased peak impact force and loading rate, which have been shown to be related to the risk of BSI. **Practitioner summary:** This study examined ROTC cadets ankle strength and lower extremity loading before and after a ruck march. We found that lower extremity loading increased after the march, and ankle dorsiflexion (DF) strength decreased, despite the cadets not feeling fatigued. These changes are consistent with risk factors for bone stress injuries.

- **Keywords:** Overuse injury, peak impact force, bone stress injury, ROTC, load carriage, ankle