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BIOMECHANICS, ANTHROPOMETRY, WORK PHYSIOLOGY

Tessy Luger, Mona Bär, Robert Seibt, Monika A. Rieger, Benjamin Steinhilber. [Using a Back Exoskeleton During Industrial and Functional Tasks: Effects on Muscle Activity, Posture, Performance, Usability, and Wearer Discomfort in a Laboratory Trial.](#) S. 5–21

Objective: To investigate the effect of using a passive back-support exoskeleton (Laevo V2.56) on muscle activity, posture, heart rate, performance, usability, and wearer comfort during a course of three industrial tasks (COU; exoskeleton worn, turned-on), stair climbing test (SCT; exoskeleton worn, turned-off), timed-up-and-go test (TUG; exoskeleton worn, turned-off) compared to no exoskeleton. **Background:** Back-support exoskeletons have the potential to reduce work-related physical demands. **Methods:** Thirty-six men participated. Activity of erector spinae (ES), biceps femoris (BF), rectus abdominis (RA), vastus lateralis (VL), gastrocnemius medialis (GM), trapezius descendens (TD) was recorded by electromyography; posture by trunk, hip, knee flexion angles; heart rate by electrocardiography; performance by time-to-task accomplishment (s) and perceived task difficulty (100-mm visual analogue scale; VAS); usability by the System Usability Scale (SUS) and all items belonging to domains skepticism and user-friendliness of the Technology Usage Inventory; wearer comfort by the 100-mm VAS. **Results:** During parts of COU, using the exoskeleton decreased ES and BF activity and trunk flexion, and increased RA, GM, and TD activity, knee and hip flexion. Wearing the exoskeleton increased time-to-task accomplishment of SCT, TUG, and COU and perceived difficulty of SCT and TUG. Average SUS was 75.4, skepticism 11.5/28.0, user-friendliness 18.0/21.0, wearer comfort 31.1 mm. **Conclusion:** Using the exoskeleton modified muscle activity and posture depending on the task applied, slightly impaired performance, and was evaluated mildly uncomfortable. **Application:** These outcomes require investigating the effects of this passive back-supporting exoskeleton in longitudinal studies with longer operating times, providing better insights for guiding their application in real work settings.

- **Keywords:** ergonomics, passive exoskeleton, electromyography, kinematics, assistive device

COGNITION

Sarah A. Powers, Mark W. Scerbo. *Examining the Effect of Interruptions at Different Breakpoints and Frequencies Within a Task.* S. 22–36.

Objective: The purpose was to explore how event segmentation theory (EST) can be used to determine optimal moments for an interruption relying on hierarchical task analysis (HTA) to identify coarse and fine event boundaries. **Background:** Research on the effects of interruptions shows that they can be either disruptive or beneficial, depending on which aspects of an interruption are manipulated. Two important aspects that contribute to these conflicting results concern when and how often interruptions occur. **Method:** Undergraduates completed a trip planning task divided into three subtasks. The within-subjects factor was interruption timing with three levels: none, coarse breakpoints, and fine breakpoints. The between-subjects factor was interruption frequency with two levels: one and three. The dependent measures included resumption lag, number of errors, mental workload, and frustration. **Results:** Participants took longer to resume the primary task and reported higher mental workload when interruptions occurred at fine breakpoints. The effect of interruptions at coarse breakpoints was similar to completing the task without interruption. Interruption frequency had no effect on performance; however, participants spent significantly longer attending to interruptions in the initial task, and within a task, the first and second interruptions were attended to significantly longer than the third interruption. **Conclusion:** The disruptiveness of an interruption is tied to the point within the task hierarchy where it occurs. **Application:** The performance cost associated with interruptions must be considered within the task structure. Interruptions occurring at coarse breakpoints may not be disruptive or have a negative effect on mental workload.

DISPLAYS AND CONTROLS

Frederik Schewe, Mark Vollrath. *Ecological Interface Design and Head-Up Displays: The Contact-Analog Visualization Tradeoff.* S. 37–49.

Objective: This study investigated how the visualization of an ecological interface affects its subjective and objective usefulness. Therefore, we compared a simple 2D visualization against a contact-analog 3D visualization. **Background:** Recently, head-up displays (HUDs) have become contact-analog and visualizations have been enabled to be merged with the real environment. In this regard, ecological interface design visualizing boundaries of acceptable performance might be a perfect match. Because the real-world environment already provides such boundaries (e.g., lane markings), the interface might directly use them. However, visual illusions and undesired interference with the environment might influence the overall usability. **Method:** To allow for a comparison, 49 participants tested the same ecological interface in two configurations, contact-analog (3D) and two dimensional (2D). Both visualizations were shown in the car's head-up display (HUD). **Results:** The driving simulator experiment reveals that 3D was rated as more demanding and more disturbing, but also more innovative and appealing. However, regarding driving performance, the 3D representation decreased the accuracy of speed control by 6% while significantly increasing lane stability by 20%. **Conclusion:** We conclude that, if we want environmental boundaries guiding our behavior, the indicator for the behavior should be visualized contact-analog. If we desire artificial boundaries (e.g., speed limits) to guide behavior, the behavioral indicator should be visualized in 2D.

This is less prone to optical illusions and allows for a more precise control of behavior. **Application:** These findings provide guidance to human factors engineers, how contact-analog visualizations might be used optimally.

HEALTH CARE/HEALTH SYSTEMS

Xiaomei Wang, Carl Markert, Farzan Sasangohar. [*Investigating Popular Mental Health Mobile Application Downloads and Activity During the COVID-19 Pandemic.*](#) S. 50–61.

Objective: This article analyzes the changes in downloads and activity of users of select popular mental health mobile applications (mHealth apps) during coronavirus disease 2019 (COVID-19). **Background:** The outbreak of the COVID-19 crisis has shown a negative impact on public mental health. Mobile health has the potential to help address the psychological needs of existing and new patients during the pandemic and beyond. **Method:** Downloads data of 16 widely used apps were analyzed. The quality of apps was reviewed using the Mobile Application Rating Scale (MARS) framework. Correlation analysis was conducted to investigate the relationship between app quality and app popularity. **Results:** Among the 16 apps, 10 were meditative in nature, 13 showed increased downloads, with 11 apps showing above 10% increase in the downloads after the pandemic started. The popular apps were satisfactory in terms of functionality and aesthetics but lacked clinical grounding and evidence base. There exists a gap between app quality and app popularity. **Conclusion:** This study provided evidence for increased downloads of mental mHealth apps (primarily meditation apps) during the COVID-19 pandemic but revealed several gaps and opportunities to address deficiencies in evidence-based design, usability and effective assessment, and integration into current workflows. **Application:** The COVID-19 pandemic is a potential turning point for mHealth applications for mental health care. Whereas the evidence suggests a need for alternative delivery of care, human factors and ergonomics methods should be utilized to ensure these tools are user-centered, easy to use, evidence-based, well-integrated with professional care, and used sustainably.

- mobile health (mHealth), mental health, mobile apps, COVID-19, Mobile Health Rating Scale (MARS)

Leonard Joseph, Lenny Vasanthan, Miles Standen, Raija Kuisma, Aatit Paungmali [...]. [*Causal Relationship Between the Risk Factors and Work-Related Musculoskeletal Disorders Among Professional Drivers: A Systematic Review.*](#) S. 62–85.

Objective: This review evaluates the evidence on the strength of causal relationship between categories of risk factors (RFs) and work-related musculoskeletal disorders (WRMSDs) among professional drivers. **Background:** A compilation of evidence on the causal relationship between RFs and WRMSDs among professional drivers is lacking. **Methods:** A systematic search of the literature was conducted in major electronic data bases that include Medline (1946 + via OvidSP), Embase (1974 + OvidSP), CINAHL (1982+), AMED, and Web of Science. The methodological quality of the studies was assessed and scored. A descriptive analysis on the categories of RFs associated with WRMSDs was conducted. The Bradford–Hill causation criteria and evidence interpretation tool were used to evaluate the causal relationship between RFs and WRMSDs in professional drivers. **Results:** Among the 54 studies reviewed, a strong evidence suggests a causal relationship between RFs such as whole-body vibration, awkward postures, lifting tasks, manual material handling, job stress, job demand, and previous pain episodes with WRMSDs. Moderate evidence was observed on RFs such as

uncomfortable seat and low job satisfaction. The evidence on causal relationship between RFs such as years of professional driving, driving duration, and individual characteristics such as age and body mass index was inconclusive. **Conclusion:** There is strong to moderate evidence on the causal relationship between the physical and psychosocial RFs and WRMSDs among professional drivers. **Application:** Potential application of this review highlights evidence to occupational health practitioners, policy makers, and stakeholders on the strength of causal relationship between RFs and WRMSDs among professional drivers.

- mobile EEG, neuroergonomics, mental states, information processing

NEUROERGONOMICS

Edmund Wascher, Julian Reiser, Gerhard Rinkenauer, Mauro Larrá, Felix A. Dreger [...]. [Neuroergonomics on the Go: An Evaluation of the Potential of Mobile EEG for Workplace Assessment and Design](#). S. 86–106.

Objective: We demonstrate and discuss the use of mobile electroencephalogram (EEG) for neuroergonomics. Both technical state of the art as well as measures and cognitive concepts are systematically addressed. **Background:** Modern work is increasingly characterized by information processing. Therefore, the examination of mental states, mental load, or cognitive processing during work is becoming increasingly important for ergonomics. **Results:** Mobile EEG allows to measure mental states and processes under real live conditions. It can be used for various research questions in cognitive neuroergonomics. Besides measures in the frequency domain that have a long tradition in the investigation of mental fatigue, task load, and task engagement, new approaches—like blink-evoked potentials—render event-related analyses of the EEG possible also during unrestricted behavior. **Conclusion:** Mobile EEG has become a valuable tool for evaluating mental states and mental processes on a highly objective level during work. The main advantage of this technique is that working environments don't have to be changed while systematically measuring brain functions at work. Moreover, the workflow is unaffected by such neuroergonomic approaches.

- mobile EEG, neuroergonomics, mental states, information processing

PHYSIOLOGICAL AND PSYCHOLOGICAL CONDITIONS (“INTERNAL ENVIRONMENT”)

Behrang Keshavarz, Brandy Murovec, Niroshica Mohanathas, John F. Golding. [The Visually Induced Motion Sickness Susceptibility Questionnaire \(VIMSSQ\): Estimating Individual Susceptibility to Motion Sickness-Like Symptoms When Using Visual Devices](#). S. 107–124.

Objective: Two studies were conducted to develop and validate a questionnaire to estimate individual susceptibility to visually induced motion sickness (VIMS). **Background:** VIMS is a common side-effect when watching dynamic visual content from various sources, such as virtual reality, movie theaters, or smartphones. A reliable questionnaire predicting individual susceptibility to VIMS is currently missing. The aim was to fill this gap by introducing the Visually Induced Motion Sickness Susceptibility Questionnaire (VIMSSQ). **Methods:** A survey and an experimental study were conducted. Survey: The VIMSSQ investigated the frequency of nausea, headache,

dizziness, fatigue, and eyestrain when using different visual devices. Data were collected from a survey of 322 participants for the VIMSSQ and other related phenomena such as migraine. Experimental study: 23 participants were exposed to a VIMS-inducing visual stimulus. Participants filled out the VIMSSQ together with other questionnaires and rated their level of VIMS using the Simulator Sickness Questionnaire (SSQ). **Results:** Survey: The most prominent symptom when using visual devices was eyestrain, and females reported more VIMS than males. A one-factor solution with good scale reliability was found for the VIMSSQ. Experimental study: Regression analyses suggested that the VIMSSQ can be useful in predicting VIMS ($R^2 = .34$) as measured by the SSQ, particularly when combined with questions pertaining to the tendency to avoid visual displays and experience syncope ($R^2 = .59$).

Conclusion: We generated normative data for the VIMSSQ and demonstrated its validity. **Application:** The VIMSSQ can become a valuable tool to estimate one's susceptibility to VIMS based on self-reports.

- simulator sickness, cybersickness, virtual reality, sex, migraine

SIMULATION AND VIRTUAL REALITY

Ken Chen, Karen B. Chen. *Task-Oriented and Imitation-Oriented Movements in Virtual Reality Exercise Performance and Design*. S. 125–136.

Objective: This study investigated the influence of game features and practice type on human kinematic and muscular performance in a virtual reality exercise (VRE). Participants demonstrated changes in shoulder flexion angle and muscle activation under different virtual scenarios. **Background:** Conventional VRE studies often compared the outcomes between an experimental group that underwent exercise in VR and a real-world exercise control group, whereas comparisons between VRE programs are lacking. Besides, the attributes of VREs received little attention. **Method:** Thirteen able-bodied participants performed upper extremity exercise movements in immersive VR using a head-mounted display. Participants performed task-oriented and imitation-oriented movements with different game features. Shoulder muscle activity (the deltoid, supraspinatus, and infraspinatus) and shoulder motion were collected. **Results:** Practice type (task-oriented, imitation-oriented) significantly influenced the flexion angle of the shoulder complex ($F(1,11) = 9.53, p = .01$), and the muscle activity of the supraspinatus ($F(1,9) = 12.61, p = .006$) and the infraspinatus ($F(1,9) = 12.71, p = .006$). Game features did not have a statistically significant effect on shoulder flexion angle or shoulder muscles' activations. **Conclusions:** Compared to imitation-oriented practice, task-oriented practice elicited more intensive shoulder movements and muscular efforts but also induced greater movement variations. Substantial differences across game features levels should be further investigated to have significant effects. **Applications:** This research may help guide the design of future VREs. For strength training or rehabilitation where intensive practice is required, task-oriented practice should be considered; for movement learning where movement consistency is required, imitation oriented practice should be adopted.

SOCIAL PROCESSES

Erin K. Chiou, John D. Lee. *Trusting Automation: Designing for Responsivity and Resilience*. s. 137–165.

Objective: This paper reviews recent articles related to human trust in automation to guide research and design for increasingly capable automation in complex work environments. **Background:** Two recent trends—the development of increasingly capable automation and the flattening of organizational hierarchies—suggest a reframing of trust in automation is needed. **Method:** Many publications related to human trust and human–automation interaction were integrated in this narrative literature review. **Results:** Much research has focused on calibrating human trust to promote appropriate reliance on automation. This approach neglects relational aspects of increasingly capable automation and system-level outcomes, such as cooperation and resilience. To address these limitations, we adopt a relational framing of trust based on the decision situation, semiotics, interaction sequence, and strategy. This relational framework stresses that the goal is not to maximize trust, or to even calibrate trust, but to support a process of trusting through automation responsivity. **Conclusion:** This framing clarifies why future work on trust in automation should consider not just individual characteristics and how automation influences people, but also how people can influence automation and how interdependent interactions affect trusting automation. In these new technological and organizational contexts that shift human operators to co-operators of automation, automation responsivity and the ability to resolve conflicting goals may be more relevant than reliability and reliance for advancing system design. **Application:** A conceptual model comprising four concepts—situation, semiotics, strategy, and sequence—can guide future trust research and design for automation responsivity and more resilient human–automation systems.

SURFACE TRANSPORTATION

Bradley W. Weaver, Patricia R. DeLucia, Jason Jupe. *Factors That Affect Drivers' Perception of Closing and an Immediate Hazard*. S. 166–181.

Objective: To measure the looming threshold for when drivers perceive closing and an immediate hazard and determine what factors affect these thresholds. **Background:** Rear-end collisions are a common type of crash. One key issue is determining when drivers first perceive they need to react. The looming threshold for closing and an immediate hazard are critical perceptual thresholds that reflect when drivers perceive they need to react. **Method:** Two driving simulator experiments examined whether engaging in a cell phone conversation and whether the complexity of the roadway environment affect these thresholds for the perception of closing and immediate hazard. Half of the participants engaged in a cognitive task, the last letter task, to emulate a cell phone conversation, and all participants experienced both simple and complex roadway environments. **Results:** Drivers perceived an immediate hazard later when engaged in a cell phone conversation than when not engaged in a conversation but only when the driving task was relatively less demanding (e.g., simple roadway, slow closing velocity). Compared to simple scenes, drivers perceived closing and an immediate hazard later for complex scenes but only when closing velocity was 30 mph (48.28 km/h) or greater. **Conclusion:** Cell phone conversation can affect when drivers perceive an immediate hazard when the roadway is less demanding. Roadway complexity can affect when drivers perceive closing and an immediate hazard when closing velocity is high. **Application:** Results can aid accident analysis cases and the design of driving automation systems by suggesting when a typical driver would respond.