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AUTOMATION, EXPERT SYSTEMS

Rebecca Wiczorek andDietrich Manzey. *Supporting Attention Allocation in Multitask Environments : Effects of Likelihood Alarm Systems on Trust, Behavior, and Performance*. S. 1209-1221.

Objective: The aim of the current study was to investigate potential benefits of likelihood alarm systems (LASs) over binary alarm systems (BASs) in a multitask environment. **Background:** Several problems are associated with the use of BASs, because most of them generate high numbers of false alarms. Operators lose trust in the systems and ignore alarms or cross-check all of them when other information is available. The first behavior harms safety, whereas the latter one reduces productivity. LASs represent an alternative, which is supposed to improve operators' attention allocation. **Method:** We investigated LASs and BASs in a dual-task paradigm with and without the possibility to cross-check alerts with raw data information. Participants' trust in the system, their behavior, and their performance in the alert and the concurrent task were assessed. **Results:** Reported trust, compliance with alarms, and performance in the alert and the concurrent task were higher for the LAS than for the BAS. The cross-check option led to an increase in alert task performance for both systems and a decrease in concurrent task performance for the BAS, which did not occur in the LAS condition. **Conclusion:** LASs improve participants' attention allocation between two different tasks and therefore lead to an increase in alert task and concurrent task performance. The performance maximum is achieved when LAS is combined with a cross-check option for validating alerts with additional information. **Application:** The use of LASs instead of BASs in safety-related multitask environments has the potential to increase safety and productivity likewise.

- **Keywords:** automation, graded warnings, decision support systems, compliance, trust, safety, signal detection theory

BIOMECHANICS, ANTHROPOMETRY, WORK PHYSIOLOGY

Todd Ramsey, Kermit G. Davis, Susan E. Kotowski, Vern P. Anderson, and Thomas Waters. *Reduction of Spinal Loads Through Adjustable Interventions at the Origin and Destination of Palletizing Tasks*. S. 1222-1234.

Objective: This article evaluates the effectiveness of two interventions: a self-leveling pallet carousel designed to position the loads vertically and horizontally at origin, and an adjustable cart designed to raise loads vertically at destination to reduce spine loads.

Background: Low back disorders among workers in manual material handling industries are very prevalent and have been linked to manual palletizing operations. Evidence into the effectiveness of ergonomic interventions is limited, with no research that investigates interventions with adjustable load location. **Method:** Thirteen males experienced in manual material handling participated in simulated order selecting tasks where spine loads were quantified for each intervention condition: carousel to traditional cart, pallet to traditional cart, pallet to adjustable cart, and carousel to adjustable cart. **Results:** The results showed that combining both devices results in reduction in spine compression (61%), anterior-posterior shear (72%), and lateral shear (63%) compared to traditional palletizing conditions. Individually, the carousel was responsible for the greatest reductions, but the lowest values were typically achieved by combining the adjustable cart and carousel. **Conclusion:** The combination of the interventions (self-leveling carousel and adjustable cart) was most effective in reducing the spine loads when compared to the traditional pallet-cart condition. The individual interventions also reduced the loads compared to the traditional condition. **Application:** With de-palletizing/palletizing tasks being a major source of low back injuries, the combination of self-leveling carousel and adjustable cart has been found to be effective in reducing the peak spine loading as compared to traditional pallet on floor and nonadjustable flat cart conditions

- **Keywords:** intervention, manual material handling, item selectors, low back injuries, compression spine load

Jeong Ho Kim, Lovenoor Aulck, Ornwipa Thamsuwan, Michael C. Bartha, and Peter W. Johnson. *The Effect of Key Size of Touch Screen Virtual Keyboards on Productivity, Usability, and Typing Biomechanics*. S. 1235-1248.

Objective: We investigated whether different virtual keyboard key sizes affected typing force exposures, muscle activity, wrist posture, comfort, and typing productivity. **Background:** Virtual keyboard use is increasing and the physical exposures associated with virtual keyboard key sizes are not well documented. **Method:** Typing forces, forearm/shoulder muscle activity, wrist posture, subjective comfort, and typing productivity were measured from 21 subjects while they were typing on four different virtual keyboards with square key sizes, which were 13, 16, 19, and 22 mm on each side with 2-mm between-key spacing. **Results:** The results showed that virtual keyboard key size had little effect on typing force, forearm muscle activity, and ulnar/radial deviation. However, the virtual keyboard with the 13-mm keys had a 15% slower typing speed ($p < .0001$), slightly higher static (10th percentile) shoulder muscle activity (2% maximum voluntary contractions, $p = .01$), slightly greater wrist extension in both hands (2° to 3°, $p < .01$), and the lowest subjective comfort and preference ratings ($p < .1$). **Conclusions:** The study findings indicate that virtual keyboards with a key size less than 16 mm may be too small for touch typing given the slower typing speed, higher static shoulder muscle activity, greater wrist extension, and lowest subjective preferences. **Applications:** We evaluated the effects of virtual keyboard key sizes on typing force exposures, muscle activity, comfort, and typing productivity.

- **Keywords:** typing biomechanics, human–computer interface, electromyography, electrogoniometer

Kermit G. Davis andSusan E. Kotowski. *Postural Variability : An Effective Way to Reduce Musculoskeletal Discomfort in Office Work*. S. 1249-1261.

Objective: This article investigates whether different interventions aimed at promoting postural change could increase body movement throughout the shift and reduce musculoskeletal discomfort. **Background:** Many researchers have reported high levels of discomfort for workers that have relatively low-level demands but whose jobs are

sedentary in nature. To date, few interventions have been found to be effective in reducing worker discomfort. **Methods:** Thirty-seven call center operators were evaluated in four different workstation conditions: conventional workstation, sit-stand workstation, conventional workstation with reminder software, and sit-stand workstation with break reminder software–prompt to remind workers to take break. The primary outcome variables consisted of productivity, measured by custom software; posture changes, measured by continuous video recording; and discomfort, measured by simple survey. Each condition was evaluated over a 2-week period. **Results:** Significant reductions in short-term discomfort were reported in the shoulders, upper back, and lower back when utilizing reminder software, independent of workstation type. Although not significant, many productivity indices were found to increase by about 10%. **Conclusions:** Posture-altering workstation interventions, specifically sit-stand tables or reminder software with traditional tables, were effective in introducing posture variability. Further, postural variability appears to be linked to decreased short-term discomfort at the end of the day without a negative impact on productivity. **Applications:** An intervention that can simply induce the worker to move throughout the day, such as a sit-stand table or simple software reminder about making a large posture change, can be effective in reducing discomfort in the worker, while not adversely impacting productivity.

- **Keywords:** sedentary, static postures, musculoskeletal discomfort, productivity, posture

COGNITION

Cyrus K. Foroughi, Nicole E. Werner, Erik T. Nelson, and Deborah A. Boehm-Davis. *Do Interruptions Affect Quality of Work?* S. 1262-1271.

Objective: The aim of this study was to determine if interruptions affect the quality of work. **Background:** Interruptions are commonplace at home and in the office. Previous research in this area has traditionally involved time and errors as the primary measures of disruption. Little is known about the effect interruptions have on quality of work. **Method:** Fifty-four students outlined and wrote three essays using a within-subjects design. During Condition 1, interruptions occurred while participants were outlining. During Condition 2, interruptions occurred while they were writing. No interruptions occurred in Condition 3. **Results:** Quality of work was significantly reduced in both interruption conditions when compared to the non-interruption condition. The number of words produced was significantly reduced when participants were interrupted while writing the essay but not when outlining the essay. **Conclusion:** This research represents a crucial first step in understanding the effect interruptions have on quality of work. Our research suggests that interruptions negatively impact quality of work during a complex, creative writing task. Since interruptions are such a prevalent part of daily life, more research needs to be conducted to determine what other tasks are negatively impacted. Moreover, the underlying mechanism(s) causing these decrements needs to be identified. Finally, strategies and systems need to be designed and put in place to help counteract the decline in quality of work caused by interruptions.

- **Keywords:** performance, creative tasks, essays, memory for goals

COGNITIVE PROCESSES

Eva-Maria Skottke, Günter Debus, Lei Wang, and Lynn Huestegge. *Carryover Effects of Highly Automated Convoy Driving on Subsequent Manual Driving Performance*. S. 1272-1283.

Objective: In the present study, we tested to what extent highly automated convoy driving involving small spacing ("platooning") may affect time headway (THW) and standard deviation of lateral position (SDLP) during subsequent manual driving.

Background: Although many previous studies have reported beneficial effects of automated driving, some research has also highlighted potential drawbacks, such as increased speed and reduced THW during the activation of semiautomated driving systems. Here, we rather focused on the question of whether switching from automated to manual driving may produce unwanted carryover effects on safety-relevant driving performance. **Method:** We utilized a pre–post simulator design to measure THW and SDLP after highly automated driving and compared the data with those for a control group (manual driving throughout). **Results:** Our data revealed that THW was reduced and SDLP increased after leaving the automation mode. A closer inspection of the data suggested that specifically the effect on THW is likely due to sensory and/or cognitive adaptation processes. **Conclusion:** Behavioral adaptation effects need to be taken into account in future implementations of automated convoy systems. **Application:** Potential application areas of this research comprise automated freight traffic (truck convoys) and the design of driver assistance systems in general. Potential countermeasures against following at short distance as behavioral adaptation should be considered.

- **Keywords:** highly automated driving, platooning, traffic safety, driver assistance systems, carryover effects, adaptive cruise control, behavioral adaptation, time headway, SDLP

HUMAN-SYSTEMS INTEGRATION

James J. Potter andWilliam E. Singhose. *Effects of Input Shaping on Manual Control of Flexible and Time-Delayed Systems*. S. 1284-1295.

Objective: The objective was to study the performance of a manual tracking task with system flexibility and time delays in the input channel and to examine the effects of input shaping the human operator's commands. **Background:** It has long been known that low-frequency, lightly damped vibration hinders performance of a manually controlled system. Recently, input shaping has been shown to improve the performance of such systems in a compensatory-display tracking task. It is unknown if similar improvements are seen with pursuit-display tasks, or how the improvement changes when time delays are added to the system. **Method:** A total of 18 novice participants performed a pursuit-view tracking experiment with a spring-centered joystick. Controlled elements included an integrator, an integrator with a lightly damped flexible mode, and an input-shaped integrator with a flexible mode. The input to these controlled elements was delayed between 0 and 1 s. Tracking performance was quantified by root mean square tracking error, and subjective difficulty was quantified by ratings on a Cooper–Harper scale. **Results:** Performance was best with the undelayed integrator. Both time delay and flexibility degraded performance. Input shaping improved control of the flexible element, with a diminishing benefit as the time delay increased. Tracking error and subjective rating were significantly related. Some operators used a pulsive control strategy. **Conclusion:** Input shaping can improve the performance of a manually controlled system with flexibility, even when time delays are present. **Application:** This study is useful to designers of human-controlled systems, especially those with problematic flexibility and/or time delays.

- **Keywords:** manual tracking, input shaping, human operator, Cooper–Harper rating

MOTOR BEHAVIOUR

Patricia Hölzle, Christian Tatarau, and Joachim Hermsdörfer. *Visually Guided Tracking on a Handheld Device: Can It Be Used to Measure Visuomotor Skill in Shift Workers?* S. 1296-1306.

Objective: We introduced a new visually controlled tracking task that can be assessed on a handheld device in shift workers to evaluate time-of-day dependent modulations in visuomotor performance. **Background:** Tracking tasks have been used to predict performance fluctuations depending on time of day mainly under laboratory conditions. One challenge to an extended use at the actual working site is the complex and fixed test setup consisting of a test unit, a monitor, and a manipulation object, such as a joystick. **Method:** Participants followed an unpredictably moving target on the screen of a handheld device with an attachable stylus. A total of 11 shift workers (age range: 20–59, mean: 33.64, standard deviation: 10.56) were tested in the morning, the evening, and the night shift in 2-hr intervals with the tracking task and indicated their fatigue levels on visual analogue scales. We evaluated tracking precision by calculating the mean spatial deviation from the target for each session. **Results:** Tracking precision was significantly influenced by the interaction between shift and session, suggesting a clear time-of-day effect of visuomotor performance under real-life conditions. Tracking performance declined during early-morning hours whereas fatigue ratings increased. **Conclusion:** These findings suggest that our setup is suitable to detect time-of-day dependent performance changes in visually guided tracking. **Application:** Our task could be used to evaluate fluctuations in visuomotor coordination, a skill that is decisive in various production steps at the actual working place to assess productivity.

- **Keywords:** field study, shift work, hand function, tracking task, visuomotor coordination, sleeptime of day

SURFACE TRANSPORTATION SYSTEMS

Ben D. Sawyer, Victor S. Finomore, Andres A. Calvo, and P. A. Hancock. *Google Glass : A Driver Distraction Cause or Cure?* S. 1307-1321.

Objective: We assess the driving distraction potential of texting with Google Glass (Glass), a mobile wearable platform capable of receiving and sending short-message-service and other messaging formats. **Background:** A known roadway danger, texting while driving has been targeted by legislation and widely banned. Supporters of Glass claim the head-mounted wearable computer is designed to deliver information without concurrent distraction. Existing literature supports the supposition that design decisions incorporated in Glass might facilitate messaging for drivers. **Method:** We asked drivers in a simulator to drive and use either Glass or a smartphone-based messaging interface, then interrupted them with an emergency brake event. Both the response event and subsequent recovery were analyzed. **Results:** Glass-delivered messages served to moderate but did not eliminate distracting cognitive demands. A potential passive cost to drivers merely wearing Glass was also observed. Messaging using either device impaired driving as compared to driving without multitasking. **Conclusion:** Glass in not a panacea as some supporters claim, but it does point the way to design interventions that effect reduced load in multitasking. **Application:** Discussions of these identified benefits are framed within the potential of new in-vehicle systems that bring both novel forms of distraction and tools for mitigation into the driver's seat.

- **Keywords:** attention, mobile, wearable, SMS, texting