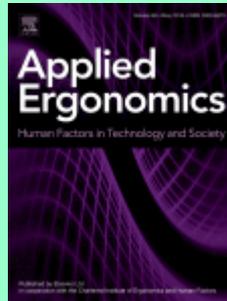


Applied Ergonomics - rok 2018, Volume 70

July 2018



Seobin Choi, Gwanseob Shin. *Effects of the center of mass of a stick vacuum cleaner on the muscle activities of the upper extremity during floor vacuuming.* Pages 1-5.

Cordless stick vacuum cleaners on the market have two distinctive styles. One with the center of mass (CoM) near user's hand and the other with the CoM near the brush. The main objective of this study was to determine whether the CoM would affect the muscle activities of upper extremity during floor vacuuming. Twenty-four participants conducted floor vacuuming strokes on carpeted floor and tiled floor at two different speeds with a 2.57 kg stick cleaner model with the CoM near its handle and near its brush. The 50th %-ile muscle activities ranged from 5.4% to 16.3% of the maximum activity level (mild to moderate intensity), with significantly greater activities ($p < 0.05$) when vacuuming with the high CoM model. Study results suggest that conventional low CoM stick cleaners are preferable to high CoM stick cleaners to lower physical loads to user's upper extremity muscles for floor vacuuming.

- **Keywords:** Vacuum cleaning; EMG; Center of mass

Sandra D. Starke, Chris Baber. *The effect of four user interface concepts on visual scan pattern similarity and information foraging in a complex decision making task.* Pages 6-17.

User interface (UI) design can affect the quality of decision making, where decisions based on digitally presented content are commonly informed by visually sampling information through eye movements. Analysis of the resulting scan patterns – the order in which people visually attend to different regions of interest (ROIs) – gives an insight into information foraging strategies. In this study, we quantified scan pattern characteristics for participants engaging with conceptually different user interface designs. Four interfaces were modified along two dimensions relating to effort in accessing information: data presentation (either alpha-numerical data or colour blocks), and information access time (all information sources readily available or sequential revealing of information required). The aim of the study was to investigate whether a) people develop repeatable scan patterns and b) different UI concepts affect information foraging and task performance. Thirty-two participants (eight for each UI concept) were given the task to correctly classify 100 credit card transactions as normal or fraudulent based on nine transaction attributes. Attributes varied in their usefulness of predicting the correct outcome. Conventional and more recent (network analysis- and bioinformatics-based) eye tracking metrics were used to quantify visual search. Empirical findings were evaluated in context of random data and possible accuracy for theoretical

decision making strategies. Results showed short repeating sequence fragments within longer scan patterns across participants and conditions, comprising a systematic and a random search component. The UI design concept showing alpha-numerical data in full view resulted in most complete data foraging, while the design concept showing colour blocks in full view resulted in the fastest task completion time. Decision accuracy was not significantly affected by UI design. Theoretical calculations showed that the difference in achievable accuracy between very complex and simple decision making strategies was small. We conclude that goal-directed search of familiar information results in repeatable scan pattern fragments (often corresponding to information sources considered particularly important), but no repeatable complete scan pattern. The underlying concept of the UI affects how visual search is performed, and a decision making strategy develops. This should be taken in consideration when designing for applied domains.

Annie W.Y. Ng, Alan H.S. Chan. *Color associations among designers and non-designers for common warning and operation concepts. Pages 18-25.*

Abstract: This study examined color-concept associations among designers and non-designers with commonly used warning and operation concepts. This study required 199 designers and 175 non-designers to indicate their choice among nine colors to associate with each of the 38 concepts in a color-concept table. The results showed that the designers and non-designers had the same color associations and similar strengths of stereotypes for 17 concepts. The strongest color-concept stereotypes for both groups were red-danger, red-fire, and red-hot. However, the designers and non-designers had different color associations for the concepts of escape (green, red), increase (green, red), potential hazard (red, orange), fatal (black, red), and normal (white, green), while the strengths of the 16 remaining associations for both groups were not at equivalent levels. These findings provide ergonomists and design practitioners with a better understanding of population stereotypes for color coding, and consequently to effectively use colors in their user-centered designs.

- **Keywords:** Stereotype; Color-concept association; Design

Emily R. Watkins, Mark Hayes, Peter Watt, Alan J. Richardson. *Practical pre-cooling methods for occupational heat exposure. Pages 26-33.*

This study aimed to identify a pre-cooling method to reduce the physiological and perceptual strain, and the inflammatory response, experienced by individuals who wear personal protective equipment. Eleven males (age 20 ± 2 years, weight 75.8 ± 9.3 kg, height 177.1 ± 5.0 cm) completed 15min pre-cooling (phase change vest [PCV], forearm cooling [ARM], ice slurry consumption [ICE], or a no cooling control [CON]) and 45min intermittent walk (4 km h^{-1} , 1% gradient) in 49.5 ± 0.6 °C and $15.4 \pm 1.0\%$ RH, whilst wearing firefighter ensemble. ICE reduced rectal temperature (T_{re}) before heat exposure compared to CON (ΔT_{re} : 0.24 ± 0.09 °C, $p < 0.001$, $d = 0.38$) and during exercise compared to CON, ARM, and PCV ($p = 0.026$, $\eta^2 = 0.145$). Thermal sensation was reduced in ICE and ARM vs. CON ($p = 0.018$, $\eta^2 = 0.150$). Interleukin-6 was not affected by pre-cooling ($p = 0.648$, $\eta^2 = 0.032$). It is recommended that those wearing protective equipment consume 500 ml of ice slurry 15min prior to work to reduce physiological and perceptual strain.

- **Keywords:** Pre-cooling; Heat exposure; Occupational health; Interleukin-6

Martine A. Gilles, Pascal Wild. *Grasping an object at floor-level: Is movement strategy a matter of age? Pages 34-43.*

Bending down to pick things up off the floor is something that we do every day. This multisegment task can be done in a considerable number of postural configurations

because of the large number of degrees of freedom to be controlled when executing it. In this study where volunteers performed a repetitive bending task, multisegment kinematic analysis allowed us to identify seven different bending strategies. Most operators used more than one bending strategy, but no particular strategy-type was found to be specific for a specific age group. However, the number of strategies used by an operator decreased with increasing age. It therefore appears that this factor influences the variability of the strategies used when repeatedly executing a movement involving the lower limbs to collect small objects from floor-level. This decrease in movement variability in senior operators may contribute to their increased risk of developing musculoskeletal disorders.

- **Keywords:** Bending strategy; Age; Work pace; Squat and stoop

Kiwon Park, Julian F. Sy, Gavin P. Horn, Richard M. Kesler, Matthew N. Petrucci, Karl S. Rosengren, Elizabeth T. Hsiao-Wecksler. *Assessing gait changes in firefighters after firefighting activities and while carrying asymmetric loads.* Pages 44-50.

One of the most common causes of injuries among firefighters is slips, trips, and falls on the fireground. Acute fatigue from firefighting activities and/or carrying asymmetric loads might impact gait characteristics increasing slip, trip, and fall risk. The purpose of this study was to examine the effects of fatigue from simulated firefighting activities and carrying asymmetric loads (fire hose over one shoulder) on firefighters' gait behavior. Both firefighting activities and asymmetric hoseload carriage led to shorter step lengths, stride lengths, single leg support time, and longer double leg support time, suggesting firefighters adopted cautious gait strategies. Simulated firefighting activities performed in either a live-fire training tower or laboratory-based environmental chamber using a firefighting activity simulator resulted in nearly identical effects on gait kinematics. This result suggests that gait assessment in a laboratory-based environmental chamber can be used as effective simulations in place of specialized burn facilities.

- **Keywords:** Gait parameters; Firefighting activities; Load carriage; Firefighters

Sungbin Kim, Michael E. Miller, Christina F. Rusnock, John J. Elshaw. *Spatialized audio improves call sign recognition during multi-aircraft control.* Pages 51-58.

We investigated the impact of a spatialized audio display on response time, workload, and accuracy while monitoring auditory information for relevance. The human ability to differentiate sound direction implies that spatial audio may be used to encode information. Therefore, it is hypothesized that spatial audio cues can be applied to aid differentiation of critical versus noncritical verbal auditory information. We used a human performance model and a laboratory study involving 24 participants to examine the effect of applying a notional, automated parser to present audio in a particular ear depending on information relevance. Operator workload and performance were assessed while subjects listened for and responded to relevant audio cues associated with critical information among additional noncritical information. Encoding relevance through spatial location in a spatial audio display system--as opposed to monophonic, binaural presentation--significantly reduced response time and workload, particularly for noncritical information. Future auditory displays employing spatial cues to indicate relevance have the potential to reduce workload and improve operator performance in similar task domains. Furthermore, these displays have the potential to reduce the dependence of workload and performance on the number of audio cues.

- **Keywords:** Spatial auditory displays; Automation; Call signs

Michael J. Angelini, Richard M. Kesler, Matthew N. Petrucci, Karl S. Rosengren, Gavin P. Horn, Elizabeth T. Hsiao-Wecksler. *Effects of simulated firefighting and asymmetric load carriage on firefighter obstacle crossing performance.* Pages 59-67.

Slips, trips, and falls (STF) of firefighters may occur while traversing stationary obstacles. STF risk may be amplified by fatigue from firefighting and carrying an asymmetric load. Vertical and horizontal clearances of the lead (VCL, HCL) and trailing (VCT, HCT) foot and contact with a 30 cm obstacle were examined in 24 firefighters. We examined the impact on obstacle crossing performance due to three exercise protocols (treadmill walking or simulated firefighting in an environmental chamber, and simulated firefighting in a live-fire burn building) and carrying a hose load on the right shoulder. Post-activity fatigue resulted in significant decreases in HCL and VCT. Adding a hose load did not affect choice of lead/trailing foot, but did significantly decrease HCL and increase VCL. The hose load amplified acute fatigue effects by causing a sharper decrease in both VCL and VCT. Clearances were significantly impacted by interaction effects of exercise protocol type and acute fatigue. HCL decreased and VCL remained consistent following both simulated firefighting tasks, but HCL remained unchanged and VCL increased following the treadmill protocol. Contact errors increased with fatigue and load, and more errors occurred following simulated firefighting task protocols compared to treadmill walking. Our findings suggest that both acute fatigue and carrying an additional load can cause decrements in firefighter movement, which may place a firefighter at greater STF risk. Simulated firefighting testing protocols may have greater impact on movement performance than treadmill walking. Knowledge of these results may assist in the development of a reliable, laboratory based, and standardizable simulated firefighting exercise protocol.

- **Keywords:** Foot clearance; Obstacle crossing; Firefighters

Aditya Tammana, Cody McKay, Stephen M. Cain, Steven P. Davidson, Rachel V. Vitali, Lauro Ojeda, Leia Stirling, Noel C. Perkins. *Load-embedded inertial measurement unit reveals lifting performance.* Pages 68-76.

Manual lifting of loads arises in many occupations as well as in activities of daily living. Prior studies explore lifting biomechanics and conditions implicated in lifting-induced injuries through laboratory-based experimental methods. This study introduces a new measurement method using load-embedded inertial measurement units (IMUs) to evaluate lifting tasks in varied environments outside of the laboratory. An example vertical load lifting task is considered that is included in an outdoor obstacle course. The IMU data, in the form of the load acceleration and angular velocity, is used to estimate load vertical velocity and three lifting performance metrics: the lifting time (speed), power, and motion smoothness. Large qualitative differences in these parameters distinguish exemplar high and low performance trials. These differences are further supported by subsequent statistical analyses of twenty three trials (including a total of 115 total lift/lower cycles) from fourteen healthy participants. Results reveal that lifting time is strongly correlated with lifting power (as expected) but also correlated with motion smoothness. Thus, participants who lift rapidly do so with significantly greater power using motions that minimize motion jerk.

- **Keywords:** Manual load lifting; Performance; Inertial sensors; Biomechanics

Michael A. Rupp, Jessica R. Michaelis, Daniel S. McConnell, Janan A. Smither. *The role of individual differences on perceptions of wearable fitness device trust, usability, and motivational impact.* Pages 77-87.

Lack of physical activity is a severe health concern in the United States with fewer than half of all Americans meeting the recommended weekly physical activity guidelines. Although wearable fitness devices can be effective in motivating people to be active, consumers are abandoning this technology soon after purchase. We examined the impact of several user (i.e. personality, age, computer self-efficacy, physical activity level) and device characteristics (trust, usability, and motivational affordances) on the behavioral intentions to use a wearable fitness device. Novice users completed a brief interaction with a fitness device similar to a first purchase experience before completing questionnaires about their interaction. We found computer self-efficacy, physical activity level, as well as personality traits indirectly increased the desire to use a fitness device and influenced the saliency of perceived motivational affordances. Additionally, trust, usability, and perceived motivational affordances were associated with increased intentions to use fitness devices.

- **Keywords:** Wearable fitness device; Technological trust; Usability; Motivation; Individual differences

Natalie Watson-Brown, Bridie Scott-Parker, Teresa Senserrick. *Development of a higher-order instruction coding taxonomy for observational data: Initial application to professional driving instruction. Pages 88-97.*

Development of a higher-order instruction taxonomy, informed by best practice in driver education (Goals for Driver Education) and self-determination theory (guiding teaching strategies), was tested. Inter-coder reliability was assessed by coding 93 data elements from 5-min clips from three driving instructors. Seventy-three instruction and 32 teaching approach codes were selected. Reliability between two independent coders was high (IOC = 94.6%). Application to data from 17 randomly-selected, 1-h lessons (n = 3 driving instructors) in a pilot study of professional learner driver lessons assessed taxonomy validity. Missed, taken, and untaken opportunities for higher-order instruction via 9 instruction and 19 teaching-approach categories were identified. Reliability assessment and taxonomy application demonstrates evidence to facilitate a comprehensive understanding of driving instruction content and quality, with implications for assessing and evaluating the impact of higher-order instruction in relation to driving and other safety-critical sectors requiring higher-order skills.

- **Keywords:** Higher order skills; Driving instruction; Coding reliability

Yinsheng Tian, Haibo Zhang, Li Wang, Li Ding, Deyu Li. *Effects of EVA glove on hand dexterity at low temperature and low pressure. Pages 98-103.*

Hand dexterity is an important index to assess whether extravehicular activity (EVA) gloves are appropriately designed. Pressurized gloves and low temperature environments can both cause a decrease in hand dexterity. However, due to the difficulty in performing tests under extreme conditions, there has been no report on dexterity tests with gloves under pressure and low temperature. To fill this gap, we performed a dexterity test of EVA gloves with twelve male volunteers involved under the extreme conditions, which were created in the low-pressure simulation cabin with vaporized liquid nitrogen used to cool it down. A total of nine conditions were designed. Purdue pegboard test and nut fastening test were improved before being applied in a hand dexterity test. Completion times for both tests, finger temperatures and cold feeling of the hand were recorded and analyzed. Results showed that the completion times for both tests increased either as the temperature decreased or as the pressure increased. Furthermore, a combined effect of low temperature and pressure was observed. The study provides evidence in support of astronaut training and optimization of EVA glove productivity.

- **Keywords:** EVA glove; Dexterity; Low temperature; Pressure; Finger temperature

Ethan C. Douglas, Kaitlin M. Gallagher. *A radiographic investigation of cervical spine kinematics when reading a tablet in a reclined trunk position.* Pages 104-109.

The purpose of this study was to use radiographic measurements to compare cervical spine kinematics in various tablet computer reading postures. Radiographs were taken of twenty-two participants reading a tablet computer in five different postures. The lower cervical spine was more flexed in the semi-reclined ($-8.2 \pm 3.8^\circ$) and the reclined ($-14.9 \pm 4.0^\circ$) tablet positions compared to an upright ($-4.43 \pm 4.8^\circ$) tablet posture. Of the tablet reading positions, the reclined position had the lowest gravitational moment arm (5.2 ± 2.3 cm) and a skull angle closest to neutral ($-9.4 \pm 11.4^\circ$), while exhibiting the largest extension in the C1-C2 joint ($34.4 \pm 9.1^\circ$). Altering trunk position when reading a tablet could reduce the load required to support the head, but could put the head in a more forward head posture, stretch the cervical extensor muscles, and potentially result in pain.

- **Keywords:** Biomechanics; Neck; Tablet; Mobile computing; Sitting

Simon Y.W. Li, Anna L. Cox, Calvin Or, Ann Blandford. *Effects of monetary reward and punishment on information checking behaviour: An eye-tracking study.* Pages 110-117.

The aim of the present study was to investigate the effect of error consequence, as reward or punishment, on individuals' checking behaviour following data entry. This study comprised two eye-tracking experiments that replicate and extend the investigation of Li et al. (2016) into the effect of monetary reward and punishment on data-entry performance. The first experiment adopted the same experimental setup as Li et al. (2016) but additionally used an eye tracker. The experiment validated Li et al. (2016) finding that, when compared to no error consequence, both reward and punishment led to improved data-entry performance in terms of reducing errors, and that no performance difference was found between reward and punishment. The second experiment extended the earlier study by associating error consequence to each individual trial by providing immediate performance feedback to participants. It was found that gradual increment (i.e. reward feedback) also led to significantly more accurate performance than no error consequence. It is unclear whether gradual increment is more effective than gradual decrement because of the small sample size tested. However, this study reasserts the effectiveness of reward on data-entry performance.

- **Keywords:** Error; Reward; Punishment; Data-entry; Eye-tracking

Arian Iraqi, Rakié Cham, Mark S. Redfern, Kurt E. Beschorner. *Coefficient of friction testing parameters influence the prediction of human slips.* Pages 118-126.

Measuring the available coefficient of friction (ACOF) of a shoe-floor interface is influenced by the choice of normal force, shoe-floor angle and sliding speed. The purpose of this study was to quantify the quality of slip prediction models based on ACOF values measured across different testing conditions. A dynamic ACOF measurement device that tests entire footwear specimens (Portable Slip Simulator) was used. The ACOF was measured for nine different footwear-contaminant combinations with two levels of normal force, sliding speed and shoe-floor angle. These footwear-contaminant combinations were also used in human gait studies to quantify the required coefficient of friction

(RCOF) and slip outcomes. The results showed that test conditions significantly influenced ACOF. The condition that best predicted slip risk during the gait studies was 250 N normal force, 17° shoe-floor angle, 0.5 m/s sliding speed. These findings can inform footwear slip-resistance measurement methods to improve design and prevent slips.

- **Keywords:** Slip and fall accidents; Coefficient of friction; Footwear

Markus Due Jakobsen, Emil Sundstrup, Mikkel Brandt, Roger Persson, Lars L. Andersen. *Estimation of physical workload of the low-back based on exposure variation analysis during a full working day among male blue-collar workers. Cross-sectional workplace study. Pages 127-133.*

This study aims to quantify physical workload of the low-back using exposure variation analysis (EVA) during a full working day among blue-collar workers with manual lifting tasks. One hundred and ten male employees (39 warehouse workers, 27 operators, 24 postal workers and 20 slaughterhouse workers) with manual lifting tasks from 12 workplaces participated. The workers performed standardized box lifts using 5, 10, 20 and 30 kg before and after a working day. Muscular activity of the low-back was measured throughout the working day using surface electromyography (sEMG). Corresponding sEMG-values for 0–30 kg lifts were identified using linear regression. EVA at exposure levels corresponding to “lifting periods” of [1-5, 5-10, 10-20, 20-30 and >30] kg in time intervals [0–0.5, 0.5–1, 1–2, 2–5, 5–10, >10] sec was computed. Back inclination was measured using tri-axial accelerometers. Compared to the other job groups, the operators’ low-back muscles were exposed to more short duration “lifting periods” with varying loads and more frequent medium duration high load “lifting periods”, respectively. The operators also worked more with their back inclined (>30°, >60°, and >90°) than the remaining job groups. Nonetheless, more than 41% of the workers performed heavy “lifting periods” that exceeded Danish lifting guidelines. This EVA demonstrates that almost half of the blue-collar workers were exposed to heavy low-back loading which puts them at risk of developing musculoskeletal disorders and low-back injury. Operators are, in particular, exposed to more short duration and medium duration “lifting periods” with varying load compared to warehouse-, postal- and slaughterhouse workers.

- **Keywords:** Borg; EMG; Manual handling; Occupational lifting; Physical exertion; Self-report; Low-back pain; Musculoskeletal disorders

Alan C. Cudlip, Clark R. Dickerson. *Female maximal push/pull strength capabilities by humeral abduction angle in bilateral exertions. Pages 136-141.*

Pushing or pulling an object constitutes the majority of manual materials handling tasks. Anthropometric differences between workers alter pushing and pulling strategies at fixed heights, potentially modifying exposures and causing overexertion. Capability normalized to arm posture rather than work height remains unknown, and the purpose of this research was to quantify maximal pushing and pulling strength and upper extremity joint moments using fixed humeral abduction angles and a flexed arm position. Twenty university-aged females completed maximal pushes and pulls at 0°, 30°, 60°, 90°, and 120° of humeral abduction with an elbow to 90°. Abduction angle was the largest modifier of both push and pull force generating capability ($p < 0.01$), with increasing abduction reducing force capability by up to 30%. While push exertions on average exceeded pulls by 17 N ($p < 0.01$), the difference is much smaller than previous reports. Ergonomists should consider humeral angle of the worker rather than work heights, as individuals working in increased abduction decreases capability and increases potential overexertion injury risk.

- **Keywords:** Shoulder biomechanics; Maximal strength; Ergonomics; Work design

Jason R. Anderson, Payton L. Hagerdorn, John Gunstad, Mary Beth Spitznagel. *Using coffee to compensate for poor sleep: Impact on vigilance and implications for workplace performance.* Pages 142-147.

Poor sleep negatively impacts vigilance and is associated with reduced well-being and work productivity. While many individuals depend on caffeine to counteract the cognitive consequences of poor sleep and restore optimal work performance, few studies have naturalistically evaluated this strategy. This study examined the effects of coffee on vigilance, comparing individuals based on recent sleep quality. Sixty-nine participants completed two randomized, counterbalanced trials consisting of 237 ml water or coffee (100 mg caffeine), followed by a continuous performance test assessing vigilance at 30, 90, and 120 min. While coffee improved and stabilized reaction time at all three assessments regardless of recent sleep history, its effects on omission and commission errors were seen only at 90 min; coffee increased commission errors and only partially reduced omission errors in individuals reporting poor sleep quality. The use of coffee to combat poor sleep may therefore be detrimental in situations requiring inhibitory control.

- **Keywords:** Performance; Inhibitory control; Coffee; Sleep; Vigilance

Jibo He, Jason S. McCarley, Kirsten Crager, Murtuza Jadliwala, Lesheng Hua, Sheng Huang. *Does wearable device bring distraction closer to drivers? Comparing smartphones and Google Glass.* Pages 156-166.

Background: Head-up and wearable displays, such as Google Glass™, are sometimes marketed as safe in-vehicle alternatives to phone-based displays, as they allow drivers to receive messages without eye-off-the-road glances. However, head-up displays can still compromise driver performance (e.g., He et al., 2015b), as the distracting effect of interacting with any device will depend on the user's multitasking strategies. The present experiment examined drivers' interaction with a head-down smartphone display and a wearable head-up display. **Method:** Participants performed a simulated driving task while receiving and responding to text messages via smartphone or the head-mounted display (HMD) on the Google Glass™. Incoming messages were signaled by an auditory alert, and responses were made vocally. **Results:** When using Google Glass, participants' responses were quicker than that of smartphone, and the time to engage in a task did not vary according to lane-keeping difficulty. Results suggest that a willingness to engage more readily in distracting tasks may offset the potential safety benefits of wearable devices.

- **Keywords:** Texting while driving; Driver distraction; Multitasking strategy; Wearable devices; Head-mounted display; Google Glass

Uma Lad, Nathalie M.C.W. Oomen, Jack P. Callaghan, Steven L. Fischer. *Comparing the biomechanical and psychophysical demands imposed on paramedics when using manual and powered stretchers.* Pages 167-174.

The aim of this investigation was to compare the effect of three different stretchers (two powered and one manual) on the biomechanical and psychophysical demands experienced by paramedics when performing routine stretcher handling activities. Eight experienced paramedics performed stretcher raising, lowering, unloading and loading tasks. Video data of task performance and static force requirements were recorded and input into a posture matching program with a quasi-static linked segment model (3DMatch) to compute peak and cumulative L4/L5 compression and shear forces and shoulder moments during each activity. Ratings of perceived exertion (RPE) were recorded from paramedics upon the completion of each task. Use of powered stretchers

with load assist functionality reduced the demands on paramedics. Peak L4/L5 forces were reduced by 13–62% and 58–93% for compression and shear respectively when using powered stretchers to perform routine stretcher handling activities. Shoulder flexor moments and RPE scores were reduced by 16–95% and 29–60% respectively when using the powered stretchers compared to the manual stretcher. However, cumulative forces showed mixed results. Although powered stretcher use decreased peak forces, loading and unloading a powered stretcher took 1.5 to 3.4 times longer than when using the manual stretcher, which may explain the mixed results regarding cumulative forces. Based on the RPE scores, paramedics preferred power stretchers relative to the manual stretcher. This study demonstrates that powered stretchers can reduce peak biomechanical and psychophysical exposures associated with the development of musculoskeletal disorder (MSD) during routine stretcher handling activities with minimal increases in cumulative exposures.

- **Keywords:** Physical ergonomics; Occupational biomechanics; Paramedics; Lifting; Equipment

Anna Sofie Larsen, Frederik G. Larsen, Frederik F. Sørensen, Mathias Hedegaard, Nicolai Støttrup, Ernst A. Hansen, Pascal Madeleine. *The effect of saddle nose width and cutout on saddle pressure distribution and perceived discomfort in women during ergometer cycling.* Pages 175-181.

The objectives were 1) to design and produce two novel unpadded bicycle saddles with a wide/medium width and partial nose cutout; 2) to investigate the responses on pressure distribution and perceived discomfort in female cyclists. For comparison, a standard saddle was also tested. Nineteen female cyclists pedaled on an ergometer cycle for 20 min with each saddle in a counterbalanced order. A pressure mat measured saddle interface pressure. Discomfort ratings were collected using a visual analogue scale. Total mean saddle pressure remained similar across saddles. The wide saddle increased anterior and decreased posterior mean saddle pressure as compared with the standard ($p < .002$) and the medium saddle ($p < .001$). Significantly increased ischial tuberosity discomfort was found for the novel saddles ($p < .001$), while crotch discomfort was not significantly different between saddles. The medium width saddle appeared to be the best compromise since increased crotch discomfort was avoided and saddle pressures were redistributed. Such design may be suggested as an alternative to traditional saddles for women reporting discomfort in the perineal region.

- **Keywords:** Bicycling; Discomfort; Gender; Saddle design; Variability

Gene M. Alarcon, Rose F. Gamble, Tyler J. Ryan, Charles Walter, Sarah A. Jessup, David W. Wood, August Capiola. *The influence of commenting validity, placement, and style on perceptions of computer code trustworthiness: A heuristic-systematic processing approach.* Pages 182-193.

Computer programs are a ubiquitous part of modern society, yet little is known about the psychological processes that underlie reviewing code. We applied the heuristic-systematic model (HSM) to investigate the influence of computer code comments on perceptions of code trustworthiness. The study explored the influence of validity, placement, and style of comments in code on trustworthiness perceptions and time spent on code. Results indicated valid comments led to higher trust assessments and more time spent on the code. Properly placed comments led to lower trust assessments and had a marginal effect on time spent on code; however, the effect was no longer significant after controlling for effects of the source code. Low style comments led to marginally higher trustworthiness assessments, but high style comments led to longer time spent on the

code. Several interactions were also found. Our findings suggest the relationship between code comments and perceptions of code trustworthiness is not as straightforward as previously thought. Additionally, the current paper extends the HSM to the programming literature.

Nicole D. Karpinsky, Eric T. Chancey, Dakota B. Palmer, Yusuke Yamani. *Automation trust and attention allocation in multitasking workspace.* Pages 194-201.

Previous research suggests that operators with high workload can distrust and then poorly monitor automation, which has been generally inferred from automation dependence behaviors. To test automation monitoring more directly, the current study measured operators' visual attention allocation, workload, and trust toward imperfect automation in a dynamic multitasking environment. Participants concurrently performed a manual tracking task with two levels of difficulty and a system monitoring task assisted by an unreliable signaling system. Eye movement data indicate that operators allocate less visual attention to monitor automation when the tracking task is more difficult. Participants reported reduced levels of trust toward the signaling system when the tracking task demanded more focused visual attention. Analyses revealed that trust mediated the relationship between the load of the tracking task and attention allocation in Experiment 1, an effect that was not replicated in Experiment 2. Results imply a complex process underlying task load, visual attention allocation, and automation trust during multitasking. Automation designers should consider operators' task load in multitasking workspaces to avoid reduced automation monitoring and distrust toward imperfect signaling systems.

- **Keywords:** Human-machine systems; Trust; Attention allocation; Human-automation interaction

Anjum Naweed, Ganesh Balakrishnan, Jillian Dorrian. *Going solo: Hierarchical task analysis of the second driver in "two-up" (multi-person) freight rail operations.* Pages 202-231.

While many countries have dual-driver ("two-up") modes in freight rail, driver shortage creates increasing pressure to move to single-driver operations. While this change has implications for workload and safety, the roles of the primary and second drivers have not been systematically mapped. This mapping is the focus of this paper, which presents a hierarchical task analysis (HTA) from a multi-methods study (n = 40). Results indicated that transitioning from two-up to single driver operations will result in substantial changes in physical and cognitive workload for the remaining driver. These changes go much further than the simple loss of a crew-mate to double-check or verify actions and cues. This HTA can form the basis of an evidence-based safety case for the change from two-up to single-driver operations, as well as a platform for considering mechanisms to maintain safety and productivity for the now solo train driver.

- **Keywords:** Freight rail; Multi-person train crew; Hierarchical task analysis; Rail safety

Ewa Gustafsson, Pieter Coenen, Amity Campbell, Leon Straker. *Texting with touchscreen and keypad phones - A comparison of thumb kinematics, upper limb muscle activity, exertion, discomfort, and performance.* Pages 232-239.

This study aimed to compare thumb kinematics and upper limb muscle activity, and the influence of hand size, when texting on a keypad smartphone and a touchscreen smartphone. Furthermore, the study compared exertion, discomfort, and performance

when texting on the two phones. The thumb kinematics were tracked using a 3D motion analysis system and muscle activity was registered in six upper limb muscles using surface electromyography in 19 participants. When texting on the touchscreen phone compared to the keypad phone thumb flexion ($p = 0.008$) and flexion/extension range of motion were smaller ($p = 0.02$), the thumb was on average less internally rotated ($p = 0.02$), and activity (50th and 90th percentile) of the thumb and forearm muscles was lower ($p \leq 0.05$). The differences in thumb flexion were found only in the group with shorter hands and the differences in muscle activity was found only in the group with longer hands. These findings suggest there are differences in risks for developing musculoskeletal disorders during smartphone use with different key activation mechanisms and different hand sizes.

- **Keywords:** Smartphones; Hand size; EMG

Jonathan Dobres, Benjamin Wolfe, Nadine Chahine, Bryan Reimer. *The effects of visual crowding, text size, and positional uncertainty on text legibility at a glance.* Pages 240-246.

Reading at a glance, once a relatively infrequent mode of reading, is becoming common. Mobile interaction paradigms increasingly dominate the way in which users obtain information about the world, which often requires reading at a glance, whether from a smartphone, wearable device, or in-vehicle interface. Recent research in these areas has shown that a number of factors can affect text legibility when words are briefly presented in isolation. Here we expand upon this work by examining how legibility is affected by more crowded presentations. Word arrays were combined with a lexical decision task, in which the size of the text elements and the inter-line spacing (leading) between individual items were manipulated to gauge their relative impacts on text legibility. In addition, a single-word presentation condition that randomized the location of presentation was compared with previous work that held position constant. Results show that larger text was more legible than smaller text. Wider leading significantly enhanced legibility as well, but contrary to expectations, wider leading did not fully counteract decrements in legibility at smaller text sizes. Single-word stimuli presented with random positioning were more difficult to read than stationary counterparts from earlier studies. Finally, crowded displays required much greater processing time compared to single-word displays. These results have implications for modern interface design, which often present interactions in the form of scrollable and/or selectable lists. The present findings are of practical interest to the wide community of graphic designers and interface engineers responsible for developing our interfaces of daily use.

- **Keywords:** Typography; Legibility; Visual crowding

Ming-Lun Lu, Jonathan S. Dufour, Eric B. Weston, William S. Marras. *Effectiveness of a vacuum lifting system in reducing spinal load during airline baggage handling.* Pages 247-252.

Information on spinal loading for using lift assist systems for airport baggage handling is lacking. We conducted a laboratory study to evaluate a vacuum lift system for reducing lumbar spinal loads during baggage loading/unloading tasks. Ten subjects performed the tasks using the industry average baggage weight of 14.5 kg on a typical two-shelved baggage cart with or without using the lift system (i.e. lifting technique). Repeated measures analysis of variance (2 tasks \times 2 shelf heights \times 2 techniques) was used. Spinal loads were estimated by an electromyography-driven biomechanical model. On average, the vacuum lift system reduced spinal compressive forces on the lumbar spine by 39% and below the 3400 N damage threshold. The system also resulted in a 25% reduction in the anterior-posterior shear force at the L5/S1 inferior endplate level. This study provides evidence for the potential to reduce spinal loads when using a vacuum lift system.

- **Keywords:** Airport baggage lifting; Biomechanical model; Vacuum lift

Nadine Matton, Camille Vrignaud, Yves Rouillard, Julie Lemarié. *Learning flight procedures by enacting and receiving feedback. Pages 253-259.*

Learning flight procedures is part of any pilot training. The conventional learning method consists in learning and practicing the procedure written on a sheet of paper along with printed images of the cockpit. The purpose of the present paper was to test the efficiency of a tactile interactive multimedia training tool designed to foster the self-regulated learning of flight procedures, especially through enacting relevant gestures and providing feedback. Results showed that learning with this tool did not lead to significant shorter learning times than with the conventional learning. However, on a delayed retention test in a real A320 cockpit simulator, learners of the experimental group performed the procedure more rapidly than those of the control group. Results suggested that a training tool that incites learners to perform similar gestures than those in the real environment and that provides feedback, helped learners to transform declarative into procedural knowledge.

- **Keywords:** Procedural learning; Multimedia learning; Embodied cognition

Meredith McQuerry, Roger Barker, Emiel DenHartog. *Relationship between novel design modifications and heat stress relief in structural firefighters' protective clothing. Pages 260-268.*

The purpose of this study was to investigate design modifications in structural firefighter turnout suits for their ability to reduce heat stress during firefighting activities. A secondary aim of this research established a benchmark for the manikin heat loss value necessary to achieve significant improvements in physiological comfort. Eight professional firefighters participated in five simulated exercise sessions wearing a control turnout suit and one of four turnout prototypes: Single Layer, Vented, Stretch, and Revolutionary. Physiological responses (internal core body temperature, skin temperature, physiological strain, heart rate, and sweat loss) were measured when wearing each turnout suit prototype. Results demonstrated a significant increase in work time and significant reductions in heat stress (core temperature, skin temperature, and physiological strain) when participants wore the Single Layer, Vented, and Revolutionary prototypes. An estimated garment heat loss value of 150 W/m² was determined in order to achieve a significant reduction in heat stress.

- **Keywords:** Firefighter; Heat stress; Physiological comfort

Kapil Chalil Madathil, Joel S. Greenstein. *An investigation of the effect of anecdotal information on the choice of a healthcare facility. Pages 269-278.*

This article includes two studies investigating the impact of anecdotal healthcare information from the Internet on healthcare decisions. The availability of anecdotal information on the Internet through social media and peer support groups has increased the risk of the dissemination of misleading information. The first study investigated the effect of demographics, quality of life, health status and public reports usage on the use of anecdotal healthcare information from the Internet. The second employed a 2 (anecdotal information presented as videos supporting and contradicting public report information) * 2 (phase of introduction of anecdotal information: early, late) between-subjects experimental design to investigate the consumer's choice between two health facilities, the level of confidence in the decision, the knowledge acquired and the workload experienced. The results from the first study found that age, gender, educational level, health status and public report usage were significant predictors of

consumer use of anecdotal information on the Internet. The results from the second suggest that the probability of making the optimal choice was reduced by more than half when contradicting rather than supporting anecdotal information was presented first. The data from anecdotal information became the anchor points for developing an understanding of the healthcare situation, meaning initial perceptions did not change after the presentation of the more reliable public reports. Because of comprehension issues related to public reports, consumers may give more weight to anecdotal information found online. Thus, new approaches are needed to ensure the former is engaging for a wide range of healthcare consumers.

- **Keywords:** Healthcare consumer decision making; Anecdotal information; Public reports

Lena Nord Nilsson, Annika Vänje. *Occupational safety and health professionals' skills – A call for system understanding? Experiences from a co-operative inquiry within the manufacturing sector.* Pages 279-287.

Sector specific skills in occupational safety and health (OS&H) are crucial for being able to contribute to good work environment and decrease today's high levels of sick absences. Large manufacturing companies are due to tradition good at OS&H and can serve as an interesting context for investigating the knowledge level in the area today, and needs for the future. For this purpose a case study was performed in this sector as a co-operative inquiry, including 10 OS&H professionals (engineers and ergonomists) employed at in-house and external occupational health services (OHS). Professional experiences, good examples from practice and current research were shared jointly within the inquiry. The results show needs to work more preventively than today comprehending aspects as system understanding, integrated work teams, participation, a clear role in change projects plus skills in risk assessments. Skills in how to conduct well-functioning dialogues with stakeholders were also on the agenda.

- **Keywords:** Participation; Learning; Integrated occupational safety and health

Sara Bayramzadeh, Anjali Joseph, David Allison, Jonas Shultz, James Abernathy. *Using an integrative mock-up simulation approach for evidence-based evaluation of operating room design prototypes.* Pages 288-299.

This paper describes the process and tools developed as part of a multidisciplinary collaborative simulation-based approach for iterative design and evaluation of operating room (OR) prototypes. Full-scale physical mock-ups of healthcare spaces offer an opportunity to actively communicate with and to engage multidisciplinary stakeholders in the design process. While mock-ups are increasingly being used in healthcare facility design projects, they are rarely evaluated in a manner to support active user feedback and engagement. Researchers and architecture students worked closely with clinicians and architects to develop OR design prototypes and engaged clinical end-users in simulated scenarios. An evaluation toolkit was developed to compare design prototypes. The mock-up evaluation helped the team make key decisions about room size, location of OR table, intra-room zoning, and doors location. Structured simulation based mock-up evaluations conducted in the design process can help stakeholders visualize their future workspace and provide active feedback.

- **Keywords:** Operating room; Mock-up; Mock-up evaluation; Multidisciplinary design evaluation; Design communication; Simulation

Gosia Speed, Kate Harris, Tessa Keegel. *The effect of cushioning materials on musculoskeletal discomfort and fatigue during prolonged standing at work: A systematic review. Pages 300-314.*

This systematic review updates the current state of evidence on the effectiveness of softer flooring and cushioned shoe insoles on reducing musculoskeletal discomfort amongst workers who are required to stand for prolonged periods to work and the impact of factors such as age and gender on the outcomes. A systematic search identified 10 unique studies that met the eligibility criteria. The heterogeneity of study designs impacted on the strength of evidence. A moderate level of evidence was found in support of using cushioned materials in reducing discomfort/fatigue among standing workers. A limited level of evidence exists in favour of using insoles over anti-fatigue mats. Insufficient information exists for the impact of gender or age. Larger, good quality prospective intervention trials based in real workplaces that consider the impact of psychosocial and organisational factors on musculoskeletal discomfort whilst standing at work are required to inform industry recommendations.

- **Keywords:** Standing; Discomfort; Mat

Sunwook Kim, Maury A. Nussbaum, Mohammad Iman Mokhlespour Esfahani, Mohammad Mehdi Alemi, Saad Alabdulkarim, Ehsan Rashedi. *Assessing the influence of a passive, upper extremity exoskeletal vest for tasks requiring arm elevation: Part I – “Expected” effects on discomfort, shoulder muscle activity, and work task performance. Pages 315-322.*

Use of exoskeletal vests (designed to support overhead work) can be an effective intervention approach for tasks involving arm elevation, yet little is known on the potential beneficial impacts of their use on physical demands and task performance. This laboratory study (n = 12) evaluated the effects of a prototype exoskeletal vest during simulated repetitive overhead drilling and light assembly tasks. Anticipated or expected benefits were assessed, in terms of perceived discomfort, shoulder muscle activity, and task performance. Using the exoskeletal vest did not substantially influence perceived discomfort, but did decrease normalized shoulder muscle activity levels (e.g., $\leq 45\%$ reduction in peak activity). Drilling task completion time decreased by nearly 20% with the vest, but the number of errors increased. Overall, exoskeletal vest use has the potential to be a new intervention for work requiring arm elevation; however, additional investigations are needed regarding potential unexpected or adverse influences (see Part II).

- **Keywords:** Overhead work; Exoskeleton; Intervention

Sunwook Kim, Maury A. Nussbaum, Mohammad Iman Mokhlespour Esfahani, Mohammad Mehdi Alemi, Bochen Jia, Ehsan Rashedi. *Assessing the influence of a passive, upper extremity exoskeletal vest for tasks requiring arm elevation: Part II – “Unexpected” effects on shoulder motion, balance, and spine loading. Pages 323-330.*

Adopting a new technology (exoskeletal vest designed to support overhead work) in the workplace can be challenging since the technology may pose unexpected safety and health consequences. A prototype exoskeletal vest was evaluated for potential unexpected consequences with a set of evaluation tests for: usability (especially, donning & doffing), shoulder range of motion (ROM), postural control, slip & trip risks, and spine loading during overhead work simulations. Donning/doffing the vest was easily done by a wearer alone. The vest reduced the max. shoulder abduction ROM by $\sim 10\%$, and increased the mean center of pressure velocity in the anteroposterior direction by $\sim 12\%$.

However, vest use had minimal influences on trip-/slip-related fall risks during level walking, and significantly reduced spine loadings (up to ~30%) especially during the drilling task. Use of an exoskeletal vest can be beneficial, yet the current evaluation tests should be expanded for more comprehensiveness, to enable the safe adoption of the technology.

- **Keywords:** Overhead work; Exoskeleton; Intervention