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Gemma J. M. Read, Steven Shorrock, Guy H. Walker & Paul M. Salmon.
[State of science: evolving perspectives on 'human error'](#). Pages: 1091-1114.

This paper reviews the key perspectives on human error and analyses the core theories and methods developed and applied over the last 60 years. These theories and methods have sought to improve our understanding of what human error is, and how and why it occurs, to facilitate the prediction of errors and use these insights to support safer work and societal systems. Yet, while this area of Ergonomics and Human Factors (EHF) has been influential and long-standing, the benefits of the 'human error approach' to understanding accidents and optimising system performance have been questioned. This state of science review analyses the construct of human error within EHF. It then discusses the key conceptual difficulties the construct faces in an era of systems EHF. Finally, a way forward is proposed to prompt further discussion within the EHF community. **Practitioner statement:** This state-of-science review discusses the evolution of perspectives on human error as well as trends in the theories and methods applied to understand, prevent and mitigate error. It concludes that, although a useful contribution has been made, we must move beyond a focus on an individual error to systems failure to understand and optimise whole systems.

- **Keywords:** Human error, accident analysis, systems thinking, complex systems, future of ergonomics

J. C. F. de Winter & P. A. Hancock. [Why human factors science is demonstrably necessary: historical and evolutionary foundations](#). Pages: 1115-1131.

We review the theoretical foundation for the need for human factors science. Over the past 2.8 million years, humans and tools have co-evolved. However, in the last century, technology is introduced at a rate that exceeds human evolution. The proliferation of computers and, more recently, robots, introduces new cognitive demands, as the human is required to be a monitor rather than a direct controller. The usage of robots and artificial intelligence is only expected to increase, and the present COVID-19 pandemic may prove to be catalytic in this regard. One way to improve overall system performance

is to 'adapt the human to the machine' via task procedures, operator training, operator selection, a Procrustean mandate. Using classic research examples, we demonstrate that Procrustean methods can improve performance only to a limited extent. For a viable future, therefore, technology must adapt to the human, which underwrites the necessity of human factors science. **Practitioner Summary:** Various research articles have reported that the science of Human Factors is of vital importance in improving human-machine systems. However, what is lacking is a fundamental historical outline of why Human Factors is important. This article provides such a foundation, using arguments ranging from pre-history to post-COVID.

- **Keywords:** General ergonomics, individual differences, learning and skill acquisition, allocation of functions, robotics and cybernetics

Jieun Lee, Yusuke Yamani, Shelby K. Long, James Unverricht & Makoto Itoh. Revisiting human-machine trust: a replication study of Muir and Moray (1996) using a simulated pasteurizer plant task. Pages: 1132-1145.

This study aimed to replicate Muir and Moray that demonstrated operators' trust in automated machines developing from faith, then dependability, and lastly predictability. Following the procedure of Muir and Moray, we asked undergraduate participants to complete a training program in a simulated pasteuriser plant and an experimental program including various errors in the pasteuriser. Results showed that the best predictor of overall trust was not faith but dependability, and that dependability consistently governed trust throughout the interaction with the pasteuriser. Thus, the obtained data patterns were inconsistent with those reported in Muir and Moray. We observed that operators in the current study used automatic control more frequently than manual control to successfully produce performance scores contrary to the operators in Muir and Moray. The results imply that dependability is a critical predictor of human-machine trust, which automation designer may focus on. More extensive future research using more modern automated technologies is necessary for understanding what factors control human-autonomy trust in modern ages. **Practitioner Summary:** The results suggest that dependability is a key factor that shapes human-machine trust across the time course of the trust development. This replication study suggests a new perspective for designing effective human-machine systems for untrained users who do not go through extensive training programs on automated systems.

- **Keywords:** Trust, automation, human-machine trust, supervisory control, human-machine interaction

Arturo Peralta, Antonio Fernández-Caballero & José Miguel Latorre. Determining the ambient influences and configuration of optimised environments for emotional wellbeing of older adults. Pages: 1146-1159.

It is now widely recognised that aspects such as tiredness or mood state can have an impact on an individual's wellbeing. However, there also exist other less studied factors that might be influential, and whose analysis is important to maximise personal wellbeing. The aim of this study was to determine the influence of a set of 12 selected factors. Using the analysis of a 20-experiment case study by soft computing techniques the intention was to establish the most appropriate configuration for each factor to compose an optimal living environment to foster wellbeing. The analysis revealed that ambient lighting and stress level are the factors that most impact emotional wellbeing. To a lesser extent, being able to take a break, ambient temperature and ambient noise play a relatively determining role. The findings of this work can be used to establish a living environment for older persons that favours their emotional wellbeing. **Practitioner**

summary: This study analyses the level of influence of a set of ambient factors on the emotional wellbeing of older people, conducting, to this end, a series of controlled experiments, and concluding that ambient lighting and stress level are the factors most relevant to promote a better living environment.

- **Keywords:** Built environment design, ageing, environmental ergonomic, user pleasure and emotion

Hamed Asadi, Sara Monfared, Dimitrios I. Athanasiadis, Dimitrios Stefanidis & Denny Yu. Continuous, integrated sensors for predicting fatigue during non-repetitive work: demonstration of technique in the operating room. Pages: 1160-1173.

Surface electromyography (sEMG) can monitor muscle activity and potentially predict fatigue in the workplace. However, objectively measuring fatigue is challenging in complex work with unpredictable work cycles where sEMG may be influenced by the dynamically changing posture demands. This study proposes a multi-modal approach integrating sEMG with motion sensors and demonstrates the approach in the live surgical work environment. Seventy-two exposures from twelve participants were collected, including self-reported musculoskeletal discomfort, sEMG, and postures. Posture sensors were used to identify time windows where the surgeon was static and in non-demanding positions, and mean power frequencies (MPF) were then calculated during those time windows. In 57 out of 72 exposures (80%), participants experienced an increase in musculoskeletal discomfort. Integrated (multi-modality) measurements showed better performance than single-modality (sEMG) measurements in detecting decreases in MPF, a predictor of fatigue. Based on self-reported musculoskeletal discomfort, sensor-based thresholds for identifying fatigue are proposed for the trapezius and deltoid muscle groups. **Practitioner summary** Work-related fatigue is one of the intermediate risk factors to musculoskeletal disorders. This article presents an objective integrated approach to identify musculoskeletal fatigue using wearable sensors. The presented approach could be implemented by ergonomists to identify musculoskeletal fatigue more accurately and in a variety of workplaces.

- **Keywords:** Musculoskeletal fatigue, surface electromyography, mean power frequency, integrated measurement, fatigue threshold

Yi-Lang Chen, Ting-Kuang Ho & Kuan-Liang Chen. Maximum strength levels for pulling and pushing handleless cartons in warehousing tasks. Pages: 1174-1182.

This study examined the variation in individuals' static maximum forward pushing and backward pulling (FPBP) strength for handleless cartons under different task conditions. Thirty young Taiwanese men were recruited as participants and were requested to perform maximum FPBP exertion tests under four exertion heights (50, 80, 110, and 140 cm), two types of hand contact (bare hands and gloves), and two carton widths (40 and 60 cm). The results of this study indicated that the pushing strength for handleless cartons was almost twice the pulling strength for all exertion heights. This finding is different from those of previous relevant studies. The pulling force generated when gloves were worn was 38% higher than that generated under barehanded pulling. Moreover, the pulling force generated with a 40-cm-wide carton was 13% higher than that generated with a 60-cm-wide carton. Pushing strength was affected by only the exertion height. **Practitioner Summary:** We examined the effects of exertion height, carton width, and type of contact on the maximum FPBP strengths. Pulling strength should be considered first for the related task design because it is lower than pushing strength. However, pulling strength can be maximised by wearing gloves to pull a 60-cm-wide carton.

- **Keywords:** Musculoskeletal disorders, gloves, bare hands, exertion height, rack operations

Kent Delbridge, Joanne Caldwell, Kane Middleton, Jace R. Drain, Adam Hayes, Catriona A. Burdon & Herbert Groeller. Is muscular strength a critical physical attribute for the apprehension of a simulated non-compliant suspect? Pages: 1183-1190.

This investigation determined the influence of technique and experience on arm retraction force required to apprehend a non-compliant suspect. Phase-One: Nine experienced RAAF military-police completed four apprehension simulations, peak arm retraction force was measured; i) Control(CON), ii) Pressure-Point(PP), iii) Targeted-Striking(TS) and iv) 2-Person(2Per) techniques. Phase-Two: Experienced (EXP, $n = 8$) or Inexperienced (INEXP, $n = 22$) military-police completed CON, PP and Pressure-Point + Coaching(PP + C). Strength was assessed in INEXP. EXP produced more force ($178.7 \text{ N} \pm 25.9$) than INEXP during CON, but no participant successfully apprehended the suspect. All EXP were successful with PP, arm retraction force 357 N (CI: 233.7,480.2) was lower compared to CON, but no difference was observed between PP and CON for INEXP. PP + C, 82% of INEXP were successful, force declined 138.2 N (CI: 67.8,208.5) compared to CON. All EXP required PP for successful apprehension. INEXP required PP + C for apprehension success. Muscular strength had a limited relationship with arm retraction force. **Practitioner summary:** For law enforcement personnel, apprehension of a suspect is a critical and physically demanding task, where success is associated with muscular strength and technique. We observed success in the apprehension of a simulated suspect by military law enforcement personnel was primarily determined by participant skill and experience and not muscular strength.

- **Keywords:** Physical employment standard, incumbents, fitness, performance, selection

Sean Hudson, Benedicte Vanwanseele, Martin Barwood, Chris Low, Carlton Cooke & Ray Lloyd. The energetic, kinematic and kinetic responses to load carried on the back, on the head and in a doublepack. Pages: 1191-1204.

The determinants of energy saving phenomena reported for load carried on the head, back and in a doublepack remain unclear. This study compared the energetic, kinematic and kinetic responses to head (H), back (B) and doublepack (DP) loading. Fifteen volunteers walked on an instrumented treadmill at $3 \text{ km}\cdot\text{h}^{-1}$ with 0, 3, 12 and 20 kg in each loading method. Whole body motion, ground reaction forces (GRF) and metabolic cost were measured. H was less economical than B ($p = 0.014$) and DP ($p = 0.010$). H was also associated with increased step length ($p = 0.045$), decreased cadence ($p = 0.001$), greater trunk ($p < 0.001$) and hip ($p < 0.001$) extension and greater minimum vertical GRF ($p = 0.001$) than B and DP. In conclusion, no energy saving was found for head- or back-loading but economy may be improved with methods that cause smaller perturbations from unloaded walking. **Practitioner summary:** Energy saving phenomena have been reported for load carried on the head, back and in a doublepack, yet the determinants are unclear. This study shows that smaller perturbations from unloaded to loaded walking are associated with improved economy for certain load carriage conditions, such as the doublepack.

- **Keywords:** Load carriage, economy, kinetics, kinematics

Daniel Preece, Thian Hong Ng, Heam Kit Tong, Roger Lewis & Matt J. Carré. [The effects of chlorination, thickness, and moisture on glove donning efficiency](#). Pages: 1205-1216.

Changing gloves more frequently is encouraged, more now than ever given the COVID-19 pandemic. When the donning process has moisture introduced, however, complications can arise, which consumes vital time. Most commonly, gloves undergo a chlorination treatment to reduce glove tack, allowing easier donning. To assess the effects of different chlorination strengths and glove thicknesses on donning, acrylonitrile butadiene gloves were manufactured at two different thicknesses (0.05 and 0.10 mm) with 4 different chlorination treatments: 0, 500, 1000 and 2000 ppm. Six participants were used to assess the time taken to don each of the glove sets with dry and wet hands (16 tests in total). Overall, the thicker gloves took longer to don, due to differences in the material stiffness hindering the donning process. The quickest performance from the chlorinated gloves was noted in the 1000 and 2000 ppm concentrations. Wet conditions also showed significant increases in the donning time. **Practitioners Summary:** The study was conducted based on the gaps identified in previous literature reviews which revealed the requirement for a greater understanding of glove donning process. It was found a stronger chlorination was detrimental when the hands were wet, but better when dry. Thicker gloves were also found to be detrimental.

- **Keywords:** Donning, Chlorination, Medical Examination Gloves, Nitrile, Personal Protective Equipment

Christopher Mitropoulos-Rundus, Chris Schwarz & Daniel McGehee. [Benefits estimation of regenerative braking versus service braking](#). Pages: 1217-1227.

A central question not yet examined in the literature is whether regenerative braking provides a kinematic deceleration safety advantage in time and distance over traditional service braking. This research explores three conditions of braking (traditional service braking, low level of regenerative braking, and high level of regenerative braking) to determine any safety advantages regenerative braking offers. Thirty participants took part in a simulator study with a between-subjects study design, allocating 10 participants per condition. The study drive took place in a simulator and involved three braking events. The results showed a significant difference between the means of the three conditions for average deceleration of the vehicle in the time interval between the driver releasing the accelerator and pressing the brake for all three events showing RB did provide the drivers with a braking advantage. When events 1 and 2 were combined, there was also significance with maximum brake force. **Practitioner summary:** This research looked to determine whether regenerative braking provides a deceleration safety advantage over traditional service braking. The results showed RB did provide the drivers with a braking advantage. The results also showed driver foot behaviour differed with the RB High condition.

- **Keywords:** Regenerative braking, service braking: time to collision, deceleration, driver response