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**Tiago F.A.C. Sigahi, Laerte Idal Szelwar, Izabela Simon Rampasso, Gustavo Hermínio Salati Marcondes de Moraes, Gildo Giroto Júnior, Arnaldo Pinto Júnior & Rosley Anholon. *Proposal of guidelines to assist managers to face pressing challenges confronting Latin American universities: a complexity theory perspective.* Pages: 1203-1218.**

The Covid-19 pandemic exacerbated pre-existing problems in Latin America and posed unprecedented challenges for Latin American universities (LAU). These challenges can be characterised as complex problems that cannot be understood through reductionist approaches. This paper aims (i) to provide a complex system perspective of the challenges confronting LAUs and (ii) to propose guidelines for managers of LAUs to address them in practice. A multidisciplinary group was formed and conducted an iterative process of research, brainstorming and debate of potential solutions to the following problems considered particularly important by their universities: mental health issues in the university environment, student learning gaps, brain drain, and anti-science movements. Complexity theory and E/HF concepts are integrated to demonstrate that understanding what LAUs are experiencing in a fragmented manner is impossible, and that the interactions between the challenges should be at the centre of the managers' actions plans. **Practitioner summary:** Managers of LAUs can benefit from the guidelines proposed to understand the pressing challenges confronting universities and develop systemic approaches to address them.

- **Keywords:** Complexity theory, complex systems, Latin American universities, current challenges, wicked problems, guidelines

**Chayston B. Brown, Tyson S. Barrett, Christopher Long, Samantha Corbridge, Alex Braeger, Brevin J. Zollinger, Kenneth Harrison, Shandon L. Poulsen, Travis Boman, Christopher J. Dakin & Sara A. Harper. *Step edge highlighters and illuminance changes influence stair descent in a real-world setting.* Pages: 1219-1228.**

Studies investigating the effect of tread edge highlighters on descent speed differ, but collectively report the potential benefit of reduced fall risk. Here we examine the impact

of adding high-contrast black vinyl striping to the front edge of each step's tread and its impact on descending gait speed (intervention), while controlling for illumination. Descending gait speed was estimated from 5,824 video observations using the stairway length and entry and exit times. A second stairway was unaltered (control) to compare to the intervention. Stair users were primarily 18–30 years old with a small percentage being middle-aged and older adults. Descending gait speed was significantly slower on the intervention stairway (Linear mixed effects model: standardised coefficient =  $-0.07$ , 95% CI =  $[-0.12, -0.02]$ ,  $p = .010$ ) compared to the control and may be impacted by illuminance. We propose that the slowed gait speed could be due to changes in gait kinematics (e.g. foot clearance) and may reduce fall-risk. **Practitioner summary:** Tread-edge contrast enhancement could be a low-cost means to reduce fall-risk on stairways, but its impact on gait kinematics is not well understood. We found that contrast enhancement reduced descending gait speed, but descending gait speed's impact on fall risk reduction ultimately requires further investigation.

- **Keywords:** Visual contrast, walk speed, stairs, vision and lighting, edge highlighter

**Jonathan Valencia, Lynn Eaton, Marty Smets, Julie Brazier, Patricia Racco, Allison Stephens, Gwen Malone, Ryan Porto & Joel Cort. *Physical capability limits for right-angle power tool operation*. Pages: 1229-1245.**

Automotive assembly operations require power tools to secure fasteners and these operations have been linked to increased risk of musculoskeletal disorders. This work was designed to develop physical capability limits for direct current right-angle power tool (RAPT) operations using psychophysics. Forty females fastened joints of different hardness's using three fastening strategies, at three fastening frequencies. Participants chose to fasten, independent of orientation, joints up to 89 (10.6) Nm using Atlas Copco's TurboTight®, compared to 51.8 (8.1) Nm using Atlas Copco's Quickstep and 48.6 (10.2) Nm using Stanley's Automatic Tightening Control. The differences between fastening strategies were not as large when fastening soft joints; 59.2 (16.2), 52.3 (14.6), and 53.5 (11.3) Nm, respectively. As fastening frequency increased, participants chose lower target torque magnitudes to fasten. Based on this work, RAPT manufactures can adjust fastening strategies to improve their tool's ergonomics performance. **Practitioner summary:** Fastening tasks was identified as posing an injury risk to workers performing automotive assembly, yet presently there are no published physical capability limits for direct current right-angle power tool operation. Using a psychophysical methodology, physical capability limits for RAPT fastenings were established for different joint hardness, fastening frequencies and RAPT position/orientation.

- **Keywords:** Industrial ergonomics, physical ergonomics, direct current, right-angle power tool, physical capability limits

**L. Eduardo Cofré Lizama, Jonathan Wheat, Patrick Slattery & Kane Middleton. *Can handling a weapon make soldiers more unstable?* Pages: 1246-1254.**

Gait stability in soldiers can be affected by task constraints that may lead to injuries. This study determined the effects of weapon handling and speed on gait stability in seventeen soldiers walking on a treadmill with and without a replica weapon at self-selected (SS),  $3.5 \text{ km}\cdot\text{h}^{-1}$ ,  $5.5 \text{ km}\cdot\text{h}^{-1}$ , and  $6.5 \text{ km}\cdot\text{h}^{-1}$  while carrying a 23-kg load. Local dynamic stability was measured using accelerometry at the sacrum (LDE<sub>SAC</sub>) and sternum (LDE<sub>STR</sub>). No significant weapon and speed interaction were found. A significant effect of speed for the LDE<sub>SAC</sub>, and a significant effect of speed and weapon for the LDE<sub>STR</sub> were found. Per plane analyses showed that the weapon effect was consistent across all directions for the LDE<sub>STR</sub> but not for LDE<sub>SAC</sub>. Weapon handling increased trunk but did not

affect pelvis stability. Speed decreased stability when walking slower than SS and increased when faster. These findings can inform injury prevention strategies in the military. **Practitioner summary:** We determined the effects of two constraints in soldier's walking stability, weapon handling and speed, measured at the trunk and sacrum. No constraints interactions were found, however, lower stability when walking slow and greater stability with the weapon at the trunk can inform preventive strategies in military training.

- **Keywords:** Load carriage, weapon handling, Lyapunov, stability

**Matthias G. Arend, Tobias M. Benz, Alexander Mertens, Christopher Brandl & Verena Nitsch. [Do multimodal search cues help or hinder teleoperated search and rescue missions?](#) Pages: 1255-1269.**

In search and rescue missions, teleoperated rovers equipped with sensor technology are deployed into harsh environments to search for targets. To support the search task, unimodal/multimodal cues can be presented via visual, acoustic and/or haptic channels. However, human operators often perform the search task in parallel with the driving task, which can cause interference of attentional resources based on multiple resource theory. Navigating corners can be a particularly challenging aspect of remote driving, as described with the Cornering Law. Therefore, search cues should not interfere with cornering. The present research explores how unimodal/multimodal search cues affect cornering performance, with typical communication delays of 50 ms and 500 ms. One-hundred thirty-one participants, distributed into two delay groups, performed a target search task with unimodal/multimodal search cues. Search cues did not interfere with cornering performance with 50 ms delays. For 500 ms delays, search cues presented via the haptic channel significantly interfered with the driving task. **Practitioner summary:** Teleoperated rovers can support search and rescue missions. Search cues may assist the human operator, but they may also interfere with the task of driving. The study examined interference of unimodal and multimodal search cues. Haptic cues should not be implemented for systems with a delay of 500 ms or more.

- **Keywords:** Teleoperation, remote control, Cornering Law, dual-task interference, search and rescue

**Stefano Marelli, Cristina Ferrario, Giuseppe Lorenzini, Yuvan Sathya Ravi, Andrea Mazzoleni, Enrico Marchetti & Marco Tarabini. *Effects of the whole-body vibration direction on the cognitive response of standing subjects.* Pages: 1270-1279.**

This study aims to investigate the effect of whole-body vibration along different axes on the response time (RT) of standing subjects during a customised psychomotor vigilance task (PVT). Twenty-five subjects were exposed to harmonic vibration with amplitude of 0.7 m/s<sup>2</sup> RMS and frequencies between 1.5 Hz and 12.5 Hz. ANOVA was used to assess if the difference of RT with and without vibration had a statistical relevance. Results showed that the RT was statistically affected by the vibration only at frequencies below 2 Hz. The vibration at higher frequencies had a minor effect on the RT. The RTs during the vibration exposure was, on average, 15% higher than the RT post exposure. **Practitioner summary:** This study investigates the effects of whole-body vibration (WBV) along different axes on the response time (RT). We measured the RTs to a psychomotor vigilance task of 25 standing subject exposed to WBV. The cognitive response was statistically affected by the WBV and, on average RT have increased of 15%.

- **Keywords:** Whole-body vibration, cognitive performance, PVT, standing posture

**Guilherme De Moura Araujo, Farzaneh Khorsandi Kouhanestani & Fadi Fathallah. *Forces required to operate controls on agricultural all-terrain vehicles: implications for youth*. Pages: 1280-1294.**

All-terrain vehicle (ATV) crashes are among the leading causes of injury and death among youth in the agriculture industry. It is hypothesised that youth are involved in ATV-related incidents because they cannot effectively activate the vehicle's controls. This study evaluated potential discrepancies between the required activation forces of the controls of fifty-four utility ATVs and the strength of male-and-female youth of varying ages (6–20 years old) and strength percentiles (5th, 50th, and 95th). The activation forces of the ATVs' controls were measured experimentally, while the youth's corresponding strength was retrieved from the literature. The results of this study demonstrated a physical mismatch between the forces required to operate ATV controls and youth's strength. Turning the handlebar, pressing the footbrake, and pushing the ATV off are the most difficult tasks for ATV operation. These discrepancies compromise the youth's ability to ride ATVs, increasing their risk of crashes. **Practitioner summary:** Previous studies indicate that some youth engage in ATV incidents because they cannot activate the vehicle's controls. We measured the forces required to operate eight ATV controls and compared them with the youth's corresponding strength. Our results demonstrated physical mismatches between the forces required to operate ATV controls and the youth's strength.

- **Keywords:** ATV, children, farm, strength, quadbike

**Hamid Jahangiri, Zahra Zamanian, Hadi Daneshmandi, Mozghan Seif & Hamid Jamshidi. *Investigating the short-term effects of using full-body hospital personal protective equipment and changes in physical workload intensity on human physiological and cognitive performance*. Pages: 1295-1309.**

The present study investigated the short-term effects of using Personal Protective Equipment (PPE) and physical workload intensity on human physiological and cognitive performance among 21 males and 19 females. PPE1 consisted of a medical coverall and surgical mask, while PPE2 consisted of impermeable full-body coverall, shoe covers, latex gloves, N95 mask, and face shield. Objective assessments were heart rate, energy expenditure, core body temperature, clothing microclimate temperature and humidity, and cognitive performance were the continuous performance test and N-Back test. Subjective assessments included thermal sensation, perceived fatigue/skin wetness/clothing moisture. Using PPE2 and increased workload intensity significantly increased the values of all physiological parameters and the subjective ratings of fatigue, thermal sensation, skin wetness, and clothing moisture. Moreover, the participants' cognitive performance was not affected by the type of PPE. **Practitioner summary:** Healthcare workers are at the highest risk in the fight against pandemics. Therefore, these people are required to use personal protective equipment. Using this equipment may have difficulties. The results show physiological strain and higher subjective ratings associated with using full-body hospital PPE and increased physical workload.

- **Keywords:** Healthcare workers, personal protective equipment, physical workload, physiological performance, cognitive performance

**Jiawei Fu & Liang Ma. *Individualisation method of biomathematical model of fatigue for predicting individual performance in mild and irregular sleep deprivation*. Pages: 1310-1324.**

Individual biomathematical models of fatigue (BMMF) are promising tools for detecting fatigue and possible incidents. Existing individual BMMFs have been validated in laboratory experiments in which subjects experience total sleep deprivation (TSD) and regular chronic sleep deprivation (CSD). However, some shift populations experience mild sleep deprivation (MSD) or irregular sleep deprivation (ISD) in real life. We employed the adaptive momentum estimation algorithm to adjust the classical SAFTE model for an individual. Model individualisation can be performed in real-time when new performance data are collected. The individual SAFTE model was compared with existing BMMFs in TSD, CSD, MSD, and ISD. The validation results show that the individual SAFTE model has advantages in MSD and ISD datasets collected from officers and truck drivers in real life. This study expands previous research results on the real-time individualisation of BMMFs and exposes individual BMMFs to various sleep-deprivation conditions in the field. **Practitioner summary:** This study proposes an individual biomathematical models of fatigue to predict human performance in mild and irregular sleep deprivation. The validation results in both laboratory and field show the proposed model has advantages over existing models when predicting officers' and truck drivers' performance in real life.

- **Keywords:** Biomathematical model of fatigue, individual model, mild sleep deprivation, irregular sleep deprivation, validation in the field

**Yujia Du, Kexiang Liu, Yuxin Ju & Haining Wang. *A comfort analysis of AR glasses on physical load during long-term wearing*. Pages: 1325-1339.**

The present study investigated the effect of the physical load of augmented reality (AR) glasses on subjective assessments for an extended duration of a video viewing task. Ninety-six subjects were recruited for this test and were divided by spectacle use, sex, age, and body mass index (BMI). Four glasses frame weights were assessed. To investigate their effectiveness, a novel prototype adopting three design interventions, (1) adjustable frame width, (2) ergonomic temples, and (3) fixed centre of gravity, was designed with regard to subjective discomfort ratings (nose, ear, and overall). Subjective discomfort in all regions was significantly increased with increasing physical load on the nose. In addition, non-spectacle users, women, older users, and participants in the middle BMI category reported higher discomfort than other groups. This finding could have important implications for the ergonomic design of AR glasses and could help to identify design considerations relevant to the emerging wearable display industry. **Practitioner summary:** This research aims to explore the influence of the physical load of augmented reality (AR) glasses. It found that discomfort was increased with added nose load. Non-spectacle users, women, older users, and participants in the middle BMI category were more sensitive to discomfort. The results have important implications for glasses-type wearables' design.

- **Keywords:** AR glasses, prolonged wearing, physical load, wearing comfort

**Sharon M.H. Tsang, Gladys L.Y. Cheing & Jess W.K. Chan. *Severity of slouched posture during smartphone use is associated with the musculoskeletal discomfort, daily usage, and school year among adolescents*. Pages: 1340-1353.**

Real-time measurement of the craniovertebral, thoracic kyphosis, and lumbar lordosis angles during natural and smartphone usage postures in sitting were analysed in a cohort

of 560 adolescents using independent *t*-tests and Spearman's correlations between their reported musculoskeletal symptoms, daily device use and school year. Students with musculoskeletal symptoms (mean difference: 4.1–9.4°,  $p < .001$ ) and in secondary schools (mean difference: 13.6–29.4°,  $p < .001$ ) had a greater forward-head posture quantified by craniovertebral angle in both postures. Loss of lumbar lordosis was found in students spending  $\geq 2$  h/day on electronic devices (mean difference: 3.2°,  $p = .029$ ) and those with musculoskeletal symptoms (mean difference: 5.4°,  $p = .001$ ). Secondary school students exhibited a greater thoracic kyphosis when using smartphones (mean difference: 3.3°,  $p = .003$ ). Findings suggest the urgent need for early and proactive intervention targeted to minimise the risk of developing musculoskeletal disorders related to intense device use for young adolescents. **Practitioner Summary:** Adolescents: (1) in higher school year had increased forward-head posture (FHP) and thoracic kyphosis; (2) with musculoskeletal symptoms had increased FHP and loss of lumbar lordosis, and; (3) with extended device use had a loss of lumbar lordosis. Early intervention targeting young adolescents promoting optimal posture and habit of device use is warranted.

- **Keywords:** Adolescents, smartphone, spine posture, musculoskeletal disorders

**Yan Yan, Yonghong Liu, Jiang Rui, Kexiang Liu, Yujia Du & Haining Wang. *In-ear earphone design-oriented pressure sensitivity evaluation on the external ear.* Pages: 1354-1368.**

This study aimed to explore the pressure sensitivity of the external ear that can be the basis for adapting the pressure distribution on the concha for in-ear earphone design. Overall, 30 participants were included in this study, where an electronic mechanical algometer with a stepping motor was used to apply constant pressure. Before the experiment, the customised concha shell models of the participants were positioned in the ear perpendicular to the concha surface. Furthermore, the pressure discomfort threshold (PDT), moderate pressure discomfort (MPD), and maximum pressure threshold (MPT) in eight regions of the ear were recorded. This study's results indicate that the four regions of the external ear are less sensitive to pressure than those of the other regions. Additionally, women had higher pressure sensitivity values in the external ear. Therefore, this study's findings could have important implications for earphone designs and evaluating discomfort conditions in the external ear. **Practitioner summary:** This study explores the pressure sensitivity threshold (PDT, MPD, and MPT) on the external ear and the relevant implications for in-ear earphone design. Interestingly, regions closer to the bone structure were less sensitive to pressure, and men could tolerate greater pressure on the external ear than women.

- **Keywords:** Pressure discomfort threshold (PDT), moderate pressure discomfort (MPD), maximum pressure threshold (MPT), external ear-in-ear earphone

**J. G. Phillips, L. R. D. Pringle, B. Hughes & A. Van Gemmert. *Cursor movements to targets labelled "stop": a kinematic analysis.* Pages: 1369-1381.**

The label 'Stop' potentially generates conflict—signifying important corrective action, or a warning not to touch. To examine potential conflict between an incongruent label (i.e. STOP) and an imperative command (i.e. MOVE!), 18 participants used a computer mouse to move a crosshair cursor to targets with superimposed labels. Trials systematically varied Imperative (blank or MOVE!), Label (+GO+ or STOP) and movement Distance. Kinematic analyses examined response latency, movement duration and accuracy. Incongruent labels had little impact upon response latencies, but they affected cursor deceleration and the variability of cursor placement. Although reading is assumed to be obligatory, the impact of written labels is not immediate, instead affecting cursor deceleration. Indeed, responses to controls labelled STOP were less accurate than those labelled +GO+. As labelled interfaces can create error versus command confusions,

enhancing the discriminability of controls to afford more obvious visible cues as to method of use is recommended. **Practitioner summary:** Emergency stop and shutdown controls can cause response conflict as their labels signify both urgent corrective actions and 'don't touch'. Response conflict caused by confusing superimposed labels is resolved as cursors near the target control and may result in reduced movement accuracy. Prior warnings may influence resolution of response conflict.

- **Keywords:** Emergency shutdown, response conflict, labels, Stroop effect, cursor control

**Vivek Kant. 'The spirit is willing, but the flesh is weak?': systemic unknown-knowns for ergonomics in India. Pages: 1382-1397.**

While the worldwide ergonomics community increases its sophistication in solving global problems, specific systemic challenges still plague Indians in urban mega-cities such as Mumbai. This paper aims to highlight the gaps using the knowns-unknowns framework, which exists in the Indian ergonomics community's *capability* to address such systemic challenges. Within this framework, the epistemological category of 'unknown-knowns' is explicated further using a case study of urban accidental deaths and injuries in Mumbai, India. These systemic casualties are essential to note because they are not only hidden from public awareness but can be avoided by proper ergonomics interventions. The article concludes with four main directions for the Indian ergonomics community in solving systemic problems in terms of, (a) capacity-building, (b) advocacy; (c) developing all realms of ergonomics with particular emphasis on complex systems; (d) developing India-centric pathways for ergonomics as a discipline. **Practitioner's summary:** This paper aims to highlight gaps in the *academic Indian ergonomics community's capacity* to solve public systemic problems. An India-centric way forward for awareness, engagement, and academic capacity building is suggested to develop a comprehensive national ergonomics mission.

- **Keywords:** Ergonomics, knowns-unknowns, institutionalisation, human factors, India

**Size Zheng, Qingguo Li & Tao Liu. Multi-phase optimisation model predicts manual lifting motions with less reliance on experiment-based posture data. Pages: 1398-1413.**

Optimisation-based predictive models are widely-used to explore the lifting strategies. Existing models incorporated empirical subject-specific posture constraints to improve the prediction accuracy. However, over-reliance on these constraints limits the application of predictive models. This paper proposed a multi-phase optimisation method (MPOM) for two-dimensional sagittally symmetric semi-squat lifting prediction, which decomposes the complete lifting task into three phases—the initial posture, the final posture, and the dynamic lifting phase. The first two phases are predicted with force- and stability-related strategies, and the last phase is predicted with a smoothing-related objective. Box-lifting motions of different box initial heights were collected for validation. The results show that MPOM has better or similar accuracy than the traditional single-phase optimisation (SPOM) of minimum muscular utilisation ratio, and MPOM reduces the reliance on experimental data. MPOM offers the opportunity to improve accuracy at the expense of efforts to determine appropriate weightings in the posture prediction phases. **Practitioner summary:** Lifting optimisation models are useful to predict and explore the human motion strategies. Existing models rely on empirical subject-specific posture constraints, which limit their applications. A multi-phase model for lifting motion prediction was constructed. This model could accurately predict 2D lifting motions with less reliance on these constraints.

- **Keywords:** Lifting, multi-phase optimisation, prediction accuracy, posture prediction, predictive models