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Vinita Venugopal, Adam Charles Roberts, Kian-Woon Kwok, George I. Christopoulos & Chee-Kiong Soh. *Employee experiences in underground workplaces: a qualitative investigation*. Pages: 1337-1349.

Underground workplaces (UWS) are increasingly being recognised as a sustainable solution to concerns regarding lack of space facing megacities. UWS can multiply available space by reducing urban sprawl thereby improving quality of life in cities. However, developing workplaces that respond to the needs and preferences of occupants will be a crucial factor in determining the success of this concept. We examine the experiences of existing full-time employees of a large underground facility in North America and analyse how these are related to company policies and other organisational factors. From in-depth interviews of 73 participants, three predominant themes emerged from the analyses: environmental effects (e.g. lack of sunlight), design (e.g. the unique working environment), and organisational factors and social dynamics (e.g. policies regarding breaks). We discuss these themes in relation with interventions that may improve employee comfort and retention and suggest that many factors are within organisational control. **Practitioner summary:** Underground workplaces are a sustainable solution to lack of urban space. However, developing effective workplaces is crucial to their success. We examine the experiences of existing employees of an underground facility in North America. We suggest that most negative attitudes towards underground spaces can be mitigated through simple organisational interventions.

- **Keywords:** Workplace study, underground, break, rooms, sustainable development, land use, interviews

Yali Xia, Shin-ichi Shikii & Yoshihiro Shimomura. *Determining how different levels of indoor carbon dioxide affect human monotonous task performance and their effects on human activation states using a lab experiment: a tracking task*. Pages: 1350-1358.

Different individuals respond differently to carbon dioxide (CO₂) levels in the local atmosphere. We aimed to determine whether brain activity changes with various CO₂ concentrations and whether this is correlated with heart rate and arterial oxygen saturation (SPO₂). We used electrocardiograms, SPO₂ measurements,

electroencephalograms, and task performance metrics in various CO₂ concentrations and studied the changes in these metrics. We found that SPO₂ did not change in various CO₂ conditions; elevations in CO₂ up to 4000 ppm had no measurable influence on ventilation and SPO₂, suggesting no effect on monotonous task performance seen in terms of the alpha wave band rate. However, heart rate increased as early as within 15 min. We found that some individuals who naturally have lower SPO₂ values tended to undergo faster lowering of arousal level. **Practitioner summary:** SPO₂ may be an individual characteristic that affects the human ability to maintain concentration in monotonous tasks in enclosed spaces, such as driving a car. This study highlights the fact that different individuals respond differently to various CO₂ levels, based on SPO₂ levels, as manifested by decreased concentration and brain activity.

Keywords: Carbon dioxide (CO₂), arterial oxygen saturation (SPO₂), monotonous tracking task, heart rate (HR)

Ju-Yeon Jung, Hwi-Young Cho & Chang-Ki Kang. *Brain activity during a working memory task in different postures: an EEG study.* Pages: 1359-1370.

While working is more comfortable in a supine position and healthier in a standing, most people work in a sitting. However, it is unclear whether there are differences in brain activity efficiency in different postures. Here, we, therefore, compared changes in brain activity across three different postures to determine the optimal posture for performing working memory tasks. Their effect on brain activity was examined using EEG signals together with the information of accuracy and reaction times during 2-back task in 24 subjects. Substantial differences in brain waves were observed at sitting and standing positions compared to the supine, especially in delta waves and frontal lobe, where is known to improve the modulation of brain activity efficiently. Brain efficiency was higher during standing and sitting than in a supine. These findings show that postural changes may affect the efficiency of brain activity during working memory tasks. **Practitioner summary:** Differences in brain efficiency between different postures during working memory tasks have not been explored. This study suggests that efficiency in several brain areas is higher during sitting and standing than in a supine position. This finding has important implications regarding workplace environments. Furthermore, this result would be useful to improve accomplishment and reduce negative effects of work posture.

- **Keywords:** Working memory, n-back postural change, EEG, sit/stand workstation

Ying-Yin Huang. *A sudden variation in the visual field reduces driver's accuracy in estimation of the speed of the car ahead.* Pages: 1371-1379.

We offer the hypothesis that a variation in the visual environment of a driver affects their performance in estimating the speed of a car in front. The hypothesis was tested in a driving simulator with 18 drivers by recording their ability to estimate the relative speed of a car ahead when exposed to sudden variations in the visual environment. The sudden variation was produced by briefly (200 ms) masking the driving environment with a grey frame. The results of our study confirm the hypothesis, as the flashed mask significantly lowered the drivers' accuracy in estimating the speed of a car ahead. The results also show that it is possible to cope with variations in the visual environment and to partially recover from the loss of accuracy. The findings are relevant to the layout of driving environments, such as the placement of dynamic advertisements along the side of the road or the entrance zones of tunnels, and to the training of drivers. **Practitioner summary:** In our driving simulator study, we showed that sudden transitions in the visual environment reduce a driver's performance in evaluating the speed of the car ahead and are therefore a factor in accidents and traffic jams. Transitions should be limited, and drivers should be prepared for the effect of transitions.

- **Keywords:** Driving safety, speed estimation, visual environment, car-following signal detection theory

Matthew J. M. Dunn, Brett R. C. Molesworth, Tay Koo & Gabriel Lodewijks. *Effects of auditory and visual feedback on remote pilot manual flying performance*. Pages: 1380-1393.

Remotely Piloted Aircraft Systems (RPAS) have facilitated new growth in civil aviation. Unlike manned aircraft, however, they are operated without auditory feedback and normally flown under two visual conditions: in direct visual-line-of-sight to the remote pilot (VLOS) and beyond VLOS with first-person-view imagery transmitted via onboard cameras (BVLOS). The present research examined the effectiveness of audiovisual cueing on remote pilot manual flying performance. Eighteen pilots (three female) completed six navigation and 12 spotting tasks. Their flying performance (horizontal accuracy, vertical accuracy and timeliness) was examined under three different visual display types (VLOS (Control), BVLOS-Monitor & BVLOS-Goggles), with and without real-time auditory feedback, and two wind component (no wind and wind) conditions. Horizontal deviation and timeliness improved in the BVLOS-Monitor condition navigation task, while auditory feedback produced nuanced examples of improved and degraded pilot performance. These results indicate how the specificity of the task, combined with different levels of audiovisual feedback influences remote pilot performance. These findings support the rationalisation for the provision of multimodal dynamic sensory cueing in future RPAS. **Practitioner summary:** Accuracy and timeliness of remote pilot manual flying performance was measured under a combination of audiovisual feedback in calm and wind shear conditions. The inclusion of real-time auditory feedback as an additional sensory cue is uncommon; this study demonstrated nuanced examples of improved and degraded manual flying performance. The provision of dynamic sensory cueing made available to remote pilots in future RPAS should be considered.

- **Keywords:** RPA, drones, noise, audiovisual, feedback

Sahar Arab, Daniel Imbeau, Denise Dubeau, Philippe-Antoine Dubé & Isabelle Auger. *Comparison of nine heart rate-based models to predict work metabolism of Forest workers*. Pages: 1394-1413.

Predicted work metabolism (WM) from 9 heart rate (HR)-based models were compared to measured WM obtained during work in 39 forest workers. Using measured (i.e. raw) HR in these models can overestimate actual WM since the HR increase associated with body heat accumulation is non-metabolic. Hence, accuracy of WM prediction was assessed on all possible combinations of models using raw HR and corrected HR (thermal component removed) and with five different estimates of maximum work capacity (MWC) for the models that require it as an input. The 50 model combinations produced a wide range of WM estimates. Three models using individual calibration produced the lowest RMSE and narrowest LoA with corrected HR (rRMSE \leq 13%; LoA [rBias $<$ 5% \pm 25%]). One of the models that requires neither determination of the thermal component nor individual calibration performed very well (rRMSE = 18%; LoA [rBias = 1% \pm 36%]). **Practitioner summary:** These results provide a better understanding of the accuracy of various HR-based work metabolism (WM) estimation models. This information should prove particularly useful to ergonomics professionals wishing to select a method that provides accurate estimation of WM from HR measurements during work in varied thermal environments.

- **Keywords:** Work metabolism, energy expenditure, heart rate, methods comparison, maximum work capacity, field measurements

Xiaojing Chen, Zhiguo Li & Yuqing Wang. *Effect of object and human-factor characteristics on the preference of thumb-index finger grasp type*. Pages: 1414-1424.

This work is to investigate the factors affecting the preference of human thumb-index finger grasping type. A multinomial logistic regression analysis shown that the object characteristics (equivalent diameter and shape) and human-factor characteristics (hand-used, finger-length sum and finger-length ratio) had significant contributions on the preference of thumb-index finger grasp type ($p < 0.05$) but the gender had not ($p > 0.05$). Subsequently, two mathematical equations were proposed for predicting the probability at which the precision-pinch and power-grasp were chosen for grasping an object. The probability at which the precision-pinch was chosen gradually decreased with the increase in the equivalent diameter of objects, but it is opposite for the power-grasp case. The shorter the finger-length sum, the more likely the participant was to select the power-grasp for grasping an object compared to the precision-pinch. The power-grasp was the most frequently chosen for the finger-length ratios of 1.0–1.25 and 1.75–2.0. **Practitioner summary:** This fruitful study gave explanation of the relationship between the object and human-factor characteristics and the preference of human thumb-index finger grasp type, which would be helpful to make intelligent grasping planning strategies for two-finger bionic mechanical hands.

- **Keywords:** Thumb-index finger, object characteristics, human-factor characteristics, grasping type, robotic hand

Zachary Merrill, Charles Woolley & Rakié Cham. *Impact of the seated height to stature ratio on torso segment parameters*. Pages: 1425-1433.

Ergonomic modelling programmes such as the Three Dimensional Static Strength Prediction Programme (3DSSPP) are valuable tools for assessing strength capabilities and risk assessment. These tools rely on accurate, representative inputs in the form of body segment parameters (BSPs). The upcoming version of 3DSSPP will employ BSPs for the torso, split into thoracic, lumbar and pelvis segments in order to more precisely determine spinal forces and injury risks. This study determines the impacts of age, body mass index and the estimated seated height to stature ratio (SHS) on these full and split torso parameters in a sample of working American adults. The results show that all of these metrics have significant relationships with the BSPs of interest, indicating that they must be accounted for when determining these parameters. A sensitivity analysis performed in 3DSSPP demonstrates that varying the parameters inputs will have large effects on L5/S1 compression force calculations. **Practitioner summary:** Current anthropometric data sets for ergonomic applications do not account for wide ranges of age, BMI and overall body shape on segment parameter calculations. This study quantifies the associations of age, BMI and the seated height to stature ratio on full and split torso segment parameters.

- **Keywords:** Ageing, body mass index, anthropometry, body segment parameters

Yuyuan Shi, Hong Shen, Lindsey Waterton Taylor & Vien Cheung. *The impact of age and body mass index on a bra sizing system formed by anthropometric measurements of Sichuan Chinese females*. Pages: 1434-1441.

Existing bra sizing systems are based only on bust and underbust girths, which do not guarantee an accurate fit or comfort for consumers. This study presents a comprehensive investigation of the impact of age and body mass index (BMI) on bra sizing systems, and the distributions of band and cup sizes based on anthropometric measurement data. The first four principal components were extracted by principal component analysis, and the

factor loadings of age and BMI were found to be significant determinants of bra size along with 12 other variables. Furthermore, chi-square analysis revealed that bra size allocations were significantly influenced by age and BMI. Thus, we propose that age and BMI should be considered as auxiliary criteria for the bra sizing system. Taken together, these findings will be of value to designers and bra manufacturers in developing well-fitting bras for their target consumers, and to consumers for selecting well-fitting bras with confidence. **Practitioner summary:** This study contributes to an understanding of how bra sizing systems are affected by age and BMI. This understanding is valuable to bra designers, manufacturers, and retailers, as it will enable the adjustment of bra sizes for different target markets and in turn improve consumer confidence in selecting proper fitting and comfortable bras.

- **Keywords:** Bra sizing system, principal component analysis, age, body mass index

Alexander Wolf, Jörg Miehling & Sandro Wartzack. [Challenges in interaction modelling with digital human models: a systematic literature review of interaction modelling approaches](#). Pages: 1442-1458.

Digital human models (DHM) allow for a proactive ergonomic assessment of products by applying different models describing the user-product interaction. In engineering design, DHM tools are currently not established as computer-aided ergonomics tools, since (among other reasons) the interaction models are either cumbersome to use, unstandardised, time-demanding or not trustworthy. To understand the challenges in interaction modelling, we conducted a systematic literature review with the aim of identification, classification and examination of existing interaction models. A schematic user-product interaction model for DHM is proposed, abstracting existing models and unifying the corresponding terminology. Additionally, nine general approaches to proactive interaction modelling were identified by classifying the reviewed interaction models. The approaches are discussed regarding their scope, limitations, strength and weaknesses. Ultimately, the literature review revealed that prevalent interaction models cannot be considered unconditionally suitable for engineering design since none of them offer a satisfactory combination of genuine proactivity and universal validity. **Practitioner summary:** This contribution presents a systematic literature review conducted to identify, classify and examine existing proactive interaction modelling approaches for digital human models in engineering design. Ultimately, the literature review revealed that prevalent interaction models cannot be considered unconditionally suitable for engineering design since none of them offer a satisfactory combination of genuine proactivity and universal validity.

- **Keywords:** Computer-aided ergonomics, digital human models, interaction modelling, engineering design, posture and movement prediction