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Tirza Jung, Christina Kaß, Thomas Schramm & Dieter Zapf. *So what really is user experience? An experimental study of user needs and emotional responses as underlying constructs*. Pages: 1601-1620.

This driving simulator study extended knowledge on user experience using a strategy to mitigate distraction resulting from the use of in-vehicle information systems (IVISs). It examined the impact of system restrictions on users' needs, emotions and consequences of users' experience in terms of psychological reactance. In a repeated measures design, we asked 53 participants to perform secondary tasks with an IVIS while driving. Three versions of the system varied with respect to the number of operable functionalities. The more functionalities that were disabled while driving, the more negatively users rated the systems. Multilevel regression analyses of at least $n = 155$ data points revealed that drivers' need fulfilment predicted their emotions. Reactance depended on users' need fulfilment and emotions. Experienced autonomy mediated the relation between functional limitations and reactance. When developing interactive systems, one should focus on needs and be aware of potential unwanted consequences such as psychological reactance. **Practitioner Summary:** This driving simulator study highlights the importance of considering need fulfilment and users' emotions when developing an interactive system that provides high user experience. System restrictions could have negative consequences as users might show psychological reactance.

- **Keywords:** User experience constructs, distraction mitigation, psychological reactance, hierarchical linear model

Carolyn H. Dawson, Jamie B. Mackrill & Rebecca Cain. *Assessing user acceptance towards automated and conventional sink use for hand decontamination using the technology acceptance model*. Pages: 1621-1633.

Hand hygiene (HH) prevents harmful contaminants spreading in settings including domestic, health care and food handling. Strategies to improve HH range from behavioural techniques through to automated sinks that ensure hand surface cleaning. This study aimed to assess user experience and acceptance towards a new automated sink, compared to a normal sink. An adapted version of the technology acceptance model

(TAM) assessed each mode of handwashing. A within-subjects design enabled *N* = 46 participants to evaluate both sinks. Perceived Ease of Use and Satisfaction of Use were significantly lower for the automated sink, compared to the conventional sink (*p* < 0.005). Across the remaining TAM factors, there was no significant difference. Participants suggested design features including jet strength, water temperature and device affordance may improve HH technology. We provide recommendations for future HH technology development to contribute a positive user experience, relevant to technology developers, ergonomists and those involved in HH across all sectors. **Practitioner Summary:** The need to facilitate timely, effective hand hygiene to prevent illness has led to a rise in automated handwashing systems across different contexts. User acceptance is a key factor in system uptake. This paper applies the technology acceptance model as a means to explore and optimise the design of such systems.

- **Keywords:** Technology acceptance model, public health, hand hygiene, user experience

Dunxing Wang, Qin Gao, Zhizhong Li, Fei Song & Liang Ma. *Developing a taxonomy of coordination behaviours in nuclear power plant control rooms during emergencies*. Pages: 1634-1652.

This study aims to develop a taxonomy of coordination behaviours during emergencies in nuclear power plants (NPPs). We summarised basic coordination behaviours from literature in aviation, health care and nuclear field and identified coordination behaviours specific to the nuclear domain by interviewing and surveying control crew operators. The established taxonomy includes 7 workflow stages and 24 basic coordination behaviours. To evaluate the reliability and feasibility of the taxonomy, we analysed 12 videos of operators' training sessions by coding coordination behaviours with the taxonomy and the inter-rater reliability was acceptable. Further analysis of the frequency, the duration and the direction of the coordination behaviours revealed four coordination problems. This taxonomy provides a foundation of systematic observation of coordination behaviours among NPP crews, advances researchers' understanding of the coordination mechanism during emergencies in NPPs and facilitate the possibility to deepen the understanding of the relationships between coordination behaviours and team performance. **Practitioner Summary:** A taxonomy of coordination behaviours during emergencies in nuclear power plants was developed. Reliability and feasibility of the taxonomy was verified through the analysis of 12 training sessions. The taxonomy can serve as an observation system for analysis of coordination behaviours and help to identify coordination problems of control crews.

- **Keywords:** Coordination, taxonomy, control crew, emergency, nuclear power plant

Xiaojun Wu, Manrong She, Zhizhong Li, Fei Song & Wei Sang. *Effects of integrated designs of alarm and process information on diagnosis performance in digital nuclear power plants*. Pages: 1653-1666.

In the main control rooms of nuclear power plants (NPPs), operators frequently switch between alarm displays and system-information displays to incorporate information from different screens. In this study, we investigated two integrated designs of alarm and process information – integrating alarm information into process displays (denoted as Alarm2Process integration) and integrating process information into alarm displays (denoted as Process2Alarm integration). To analyse the effects of the two integration approaches and time pressure on the diagnosis performance, a laboratory experiment was conducted with ninety-six students. The results show that compared with the non-integrated case, Process2Alarm integration yields better diagnosis performance in terms of diagnosis accuracy, time required to generate correct hypothesis and completion time. In contrast, the Alarm2Process integration leads to higher levels of workload, with no

improvement in diagnosis performance. The diagnosis performance of Process2Alarm integration was consistently better than that of Alarm2Process integration, regardless of the levels of time pressure. **Practitioner Summary:** To facilitate operator's synthesis of NPP information when performing diagnosis tasks, we proposed to integrate process information into alarm displays. The laboratory validation shows that the integration approach significantly improves the diagnosis performance for both low and high time-pressure levels.

- ▪ **Keywords:** Alarm display, integrated displays, diagnosis performance, time pressure, advanced control rooms

Na Liu & Ruifeng Yu. *Influence of social presence on eye movements in visual search tasks*. Pages: 1667-1681.

This study employed an eye-tracking technique to investigate the influence of social presence on eye movements in visual search tasks. A total of 20 male subjects performed visual search tasks in a 2 (target presence: present vs. absent) × 2 (task complexity: complex vs. simple) × 2 (social presence: alone vs. a human audience) within-subject experiment. Results indicated that the presence of an audience could evoke a social facilitation effect on response time in visual search tasks. Compared with working alone, the participants made fewer and shorter fixations, larger saccades and shorter scan path in simple search tasks and more and longer fixations, smaller saccades and longer scan path in complex search tasks when working with an audience. The saccade velocity and pupil diameter in the audience-present condition were larger than those in the working-alone condition. No significant change in target fixation number was observed between two social presence conditions. **Practitioner Summary:** This study employed an eye-tracking technique to examine the influence of social presence on eye movements in visual search tasks. Results clarified the variation mechanism and characteristics of oculomotor scanning induced by social presence in visual search.

- ▪ **Keywords:** Visual search, social facilitation, eye movement, search strategy, performance

Donghyun Beck, Minho Lee & Woojin Park. *A comparative evaluation of in-vehicle side view displays layouts in critical lane changing situation*. Pages: 1682-1691.

This study conducted a driving simulator experiment to comparatively evaluate three in-vehicle side view displays layouts for camera monitor systems (CMS) and the traditional side view mirror arrangement. The three layouts placed two electronic side view displays near the traditional mirrors positions, on the dashboard at each side of the steering wheel and on the centre fascia with the two displays joined side-by-side, respectively. Twenty-two participants performed a time- and safety-critical driving task that required rapidly gaining situation awareness through the side view displays/mirrors and making a lane change to avoid collision. The dependent variables were eye-off-the-road time, response time, and, ratings of perceived workload, preference and perceived safety. Overall, the layout placing the side view displays on the dashboard at each side of the steering wheel was found to be the best. The results indicated that reducing eye gaze travel distance and maintaining compatibility were both important for the design of CMS displays layout. **Practitioner Summary:** A driving simulator study was conducted to comparatively evaluate three in-vehicle side view displays layouts for camera monitor systems (CMS) and the traditional side view mirror arrangement in critical lane changing situation. Reducing eye movement and maintaining compatibility were found to be both important for the ergonomics design of CMS displays layout.

- ▪ **Keywords:** Camera monitor systems (CMS), in-vehicle side view displays, displays layout, eye movement, compatibility

Dave Stynen, Nicole W. H. Jansen & IJmert Kant. *The impact of work-related and personal resources on older workers' fatigue, work enjoyment and retirement intentions over time*. Pages: 1692-1707.

This study aims to examine the impact of work-related and personal resources on older workers' retirement intentions by studying the pathways (fatigue and work enjoyment) from resources to retirement intentions, the buffering role of resources for psychological job demands, in a cross-sectional and longitudinal timeframe. Longitudinal results on a subsample of full-time, older workers ($n = 1642$) from the Maastricht Cohort Study suggest that over four years of follow-up personal resources like personal mastery and perceived health related to less (prolonged) fatigue and more work enjoyment. Personal mastery also related to later retirement intentions. A work-related resource like decision authority related to less prolonged fatigue. (Prolonged) fatigue related to earlier retirement intentions, suggesting that fatigue may be a pathway to early retirement. Finally, little evidence was found for effect modification by resources. This prospective study indicates that work-related and personal resources may be useful for prolonging working careers. **Practitioner Summary:** To date, the impact of work-related and personal resources on older workers' retirement intentions is rarely studied. As this prospective study shows that resources may impact older workers' (prolonged) fatigue, work enjoyment and retirement intentions, the monitoring and fostering of resources is of importance for prolonging their working careers.

- ▪ **Keywords:** Older worker, work-related resources, retirement intentions, fatigue, work enjoyment

Jade A. Chen, Clark R. Dickerson, Richard P. Wells & Andrew C. Laing. *Older females in the workforce – the effects of age on psychophysical estimates of maximum acceptable lifting loads*. Pages: 1708-1717.

The number of older workers in the workforce is increasing substantially, and advanced age is associated with factors that could influence musculoskeletal injury risk and work capacity. This study's goals were to test whether psychophysical estimates of maximum acceptable weight of lift (liftmax) differed between younger and older workers, and to examine potential explanatory factors. Twenty-four female workers (half 50 + years; half 20–32 years) self-adjusted a box's mass to their perceived liftmax during four lifting tasks. Older workers' liftmax values were significantly lower (by approximately 24%) than their younger counterparts. There were no age-related differences in resting heart rate, or peak joint angles and final heart rate during the lifting trials. However, the older group demonstrated lower grip strength (by 24%), and lower heart rate reserve during the trials (by 18%). These results question whether current maximum acceptable lifting weights based on psychophysical information are appropriately protective for female workers greater than 50 years of age. **Practitioner Summary:** This psychophysical study demonstrated that older female workers (aged 50–63 years) selected maximum acceptable lift masses that were (on average) 24% lower than younger workers (aged 20–32 years), which corresponded with lower grip strength and heart rate reserve. Current maximum acceptable lifting weights based on psychophysical information may not protect female workers greater than 50 years of age.

- ▪ **Keywords:** Ageing, manual handling, injury risks, physical work capacity, industrial ergonomics

Eva-Maria Burford, Rolf Ellegast, Britta Weber, Manuela Brehmen, David Groneberg, Andrea Sinn-Behrendt & Ralph Bruder. *The comparative analysis of postural and biomechanical parameters of preschool teachers pre- and post-intervention within the ErgoKiTa study*. Pages: 1718-1729.

The ErgoKiTa study aimed to determine the musculoskeletal strain of preschool teachers and to identify and evaluate suitable prevention measures to reduce this strain. A comprehensive work analysis using objective and subjective methods was performed to determine the present work situation in preschools in Germany, and the results were used to derive suitable intervention measures. The musculoskeletal strain was determined by means of a comprehensive analysis of postures, forces and movements using the CUELA system and calculated as cumulative shift workloads. The intervention measures were evaluated in a pre- and post-intervention assessment for 12 participants. Significant alterations in the duration of postures were determined, specifically for the daily duration of knee-straining postures as well as the degree of trunk flexion between 60° and 90°, which were reduced from 8.4 to 3.1% and from 3.7 to 2.4%, respectively, following the intervention. **Practitioner Summary:** Research has shown that preschool teachers are at risk of developing musculoskeletal disorders. The effects of a situation-orientated and behaviour-orientated intervention approach were assessed with regard to awkward working postures. Significant alterations in the duration of postures following the intervention were found, specifically for knee-straining postures.

- **Keywords:** Musculoskeletal strain, postural analysis, preschool teachers, intervention

Oguz Akkas, Cheng Hsien Lee, Yu Hen Hu, Carisa Harris Adamson, David Rempel & Robert G. Radwin. *Measuring exertion time, duty cycle and hand activity level for industrial tasks using computer vision*. Pages: 1730-1738.

Two computer vision algorithms were developed to automatically estimate exertion time, duty cycle (DC) and hand activity level (HAL) from videos of workers performing 50 industrial tasks. The average DC difference between manual frame-by-frame analysis and the computer vision DC was −5.8% for the Decision Tree (DT) algorithm, and 1.4% for the Feature Vector Training (FVT) algorithm. The average HAL difference was 0.5 for the DT algorithm and 0.3 for the FVT algorithm. A sensitivity analysis, conducted to examine the influence that deviations in DC have on HAL, found it remained unaffected when DC error was less than 5%. Thus, a DC error less than 10% will impact HAL less than 0.5 HAL, which is negligible. Automatic computer vision HAL estimates were therefore comparable to manual frame-by-frame estimates. **Practitioner Summary:** Computer vision was used to automatically estimate exertion time, duty cycle and hand activity level from videos of workers performing industrial tasks.

- **Keywords:** Computer vision, automated exposure analysis, repetitive motion, work related musculoskeletal disorders, exposure assessment

Patrick G. Dempsey, Jonisha Pollard, William L. Porter, Alan Mayton, John R. Heberger, Sean Gallagher, Leanna Reardon & Colin G. Drury. *Development of ergonomics audits for bagging, haul truck and maintenance and repair operations in mining*.Pages: 1739-1753.

The development and testing of ergonomics and safety audits for small and bulk bag filling, haul truck and maintenance and repair operations in coal preparation and mineral processing plants found at surface mine sites is described. The content for the audits was derived from diverse sources of information on ergonomics and safety deficiencies including: analysis of injury, illness and fatality data and reports; task analysis; empirical laboratory studies of particular tasks; field studies and observations at mine sites; and maintenance records. These diverse sources of information were utilised to establish construct validity of the modular audits that were developed for use by mine safety personnel. User and interrater reliability testing was carried out prior to finalising the audits. The audits can be implemented using downloadable paper versions or with a free

mobile NIOSH-developed Android application called ErgoMine. **Practitioner Summary:** The methodology used to develop ergonomics audits for three types of mining operations is described. Various sources of audit content are compared and contrasted to serve as a guide for developing ergonomics audits for other occupational contexts.

- **Keywords:** Mining, audit, observational method, maintenance, haulage vehicles

Eric B. Weston, Safdar N. Khan & William S. Marras. *Wheelchair pushing and turning: lumbar spine and shoulder loads and recommended limits*. Pages: 1754–1765.

The objective of this study was to determine how simulated manual wheelchair pushing influences biomechanical loading to the lumbar spine and shoulders. Sixty-two subjects performed simulated wheelchair pushing and turning in a laboratory. An electromyography-assisted biomechanical model was used to estimate spinal loads. Moments at the shoulder joint, external hand forces and net turning torque were also assessed. Multiple linear regression techniques were employed to develop biomechanically based wheelchair pushing guidelines relating resultant hand force or net torque to spinal load. Male subjects experienced significantly greater spinal loading ($p < 0.01$), and spine loads were also increased for wheelchair turning compared to straight wheelchair pushing ($p < 0.001$). Biomechanically determined maximum acceptable resultant hand forces were 17–18% lower than psychophysically determined limits. We conclude that manual wheelchair pushing and turning can pose biomechanical risk to the lumbar spine and shoulders. Psychophysically determined maximum acceptable push forces do not appear to be protective enough of this biomechanical risk. **Practitioner Summary:** This laboratory study investigated biomechanical risk to the low back and shoulders during simulated wheelchair pushing. Manual wheelchair pushing posed biomechanical risk to the lumbar spine (in compression and A/P shear) and to the shoulders. Biomechanically determined wheelchair pushing thresholds are presented and are more protective than the closest psychophysically determined equivalents.

- **Keywords:** Patient handling, Health care, low back, manual wheelchair, attendant-propelled wheelchair