Human Factors – rok 2022, roč. 64

Číslo 3 (May)

AT THE FOREFRONT OF HF/E

Wendy A. Rogers, Travis Kadylak, Megan A. Bayles. *Maximizing the Benefits of Participatory Design for Human-Robot Interaction Research With Older Adults*. S. 441–450.

Objective: We reviewed human-robot interaction (HRI) participatory design (PD) research with older adults. The goal was to identify methods used, determine their value for design of robots with older adults, and provide guidance for best practices. **Background:** Assistive robots may promote aging-in-place and quality of life for older adults. However, the robots must be designed to meet older adults' specific needs and preferences. PD and other user-centered methods may be used to engage older adults in the robot development process to accommodate their needs and preferences and to assure usability of emergent assistive robots. **Method:** This targeted review of HRI PD studies with older adults draws on a detailed review of 26 articles. Our assessment focused on the HRI methods and their utility for use with older adults who have a range of needs and capabilities. **Results:** Our review highlighted the importance of using mixed methods and including multiple stakeholders throughout the design process. These approaches can encourage mutual learning (to improve design by developers and to increase acceptance by users). We identified key phases used in HRI PD workshops (e.g., initial interview phase, series of focus groups phase, and presentation phase). These approaches can provide inspiration for future efforts. **Conclusion:** HRI PD strategies can support designers in developing assistive robots that meet older adults' needs, capabilities, and preferences to promote acceptance. More HRI research is needed to understand potential implications for aging-in-place. PD methods provide a promising approach.

- **Keywords:** human-robot interaction, participatory design, older adults, aging-in-place, assistive robots

ACCIDENTS, HUMAN ERROR

Junko Mitobe, Takahiro Higuchi. *Top-Down Processing of Drug Names Can Induce Errors in Discriminating Similar Pseudo-Drug Names by Nurses*. S. 451–465.

Background: One factor that could cause medical errors is confusing medicines with similar names. A previous study showed that nurses who have knowledge about drugs faced difficulty in discriminating a drug name from similar pseudo-drug names. To avoid such errors, finer-pointing and calling (FPC) has been recommended in Japan. **Objectives:** The present study had two aims. The first was to determine whether such difficulty was due to top-down processing, rather than bottom-up processing, being applied even for pseudo-names. The other was to investigate whether FPC affected error prevention for similar drug names. **Method:** In two experiments, nurses and non-health care professionals performed a choice reaction time task for drug names and common words, with or without FPC. Error rate and reaction time were analyzed. **Results:** When drug names were used, nurses showed difficulty discriminating target names from distractors. Furthermore, the error prevention effect of FPC was marginally significant for drug names. However, nurses showed no significant differences when similar drug names were used. There was no significant difference regarding the error rate for words. **Conclusions:** Nurses' knowledge of drug names activates top-down processing. As a result, the processing of drug names was not as accurate and quick as that for words for nurses, which caused difficulty in discriminating similar names. FPC may be applicable to reduce confusion errors, possibly by leading individuals to process drug names using bottom-up processing. **Application:** he present study advances current knowledge about error tendencies with similar drug names and the effects of FPC on error prevention.

- **Keywords:** drug names, knowledge, error prevention, nurse, finger-pointing and calling

BIOMECHANICS, ANTHROPOMETRY, WORK PHYSIOLOGY

Yumeng Yao, Subhash Rakheja, Christian Larivière, Pierre Marcotte. *Assessing Increased Activities of the Forearm Muscles Due to Anti-Vibration Gloves: Construct Validity of a Refined Methodology*. S. 466-481

Objective: The primary aim was to test the construct validity of a surface electromyography (EMG) measurement protocol, indirectly assessing the effects of anti-vibration (AV) gloves on activities of the forearm muscles. **Background:** AV gloves impose a relatively higher grip demand and thus a higher risk for musculoskeletal disorders. Consequently, activities of the forearm muscles should be considered when assessing AV glove performance. **Method:** Effects of AV gloves on activities of the forearm muscles (ECR: extensor carpi radialis longus; ED: extensor digitorum; FCR: flexor carpi radialis; FDS: flexor digitorum superficialis) were measured via EMG, while gripping a handle with two grip force levels. Fifteen subjects participated with 11 glove conditions, including one with bare hand. **Results:** Activities of ECR, FCR, mean of ECR and FCR (ECR_FCR), and mean of all four muscles were sensitive to wearing gloves. Compared with bare hand, combined ECR_FCR activities increased by 22%–78% (mean = 48%, SD = 28%) with gloves. The correlation coefficient (r) of ECR_FCR activities with glove thickness and manual dexterity scores were 0.74 ($p < .05$) and 0.90 ($p < .001$), respectively. **Conclusions:** A refined EMG methodology was the most sensitive to AV gloves with specific forearm muscles (ECR and FCR) and the 50-N handgrip force. Its construct validity was further substantiated by correlations with glove thickness and manual dexterity. **Application:** Assessment of the effect of AV gloves on activities of the

forearm muscles can yield design guidance for AV gloves to reduce grip exertion by the gloved hand.

- **Keywords:** anti-vibration gloves, activities of forearm muscles, electromyography, grip strength

Runyu L. Greene, Ming-Lun Lu, Menekse Salar Barim, Xuan Wang, Marie Hayden, Yu Hen Hu, Robert G. Radwin. *Estimating Trunk Angle Kinematics During Lifting Using a Computationally Efficient Computer Vision Method*. S. 482–498.

Objective: A computer vision method was developed for estimating the trunk flexion angle, angular speed, and angular acceleration by extracting simple features from the moving image during lifting. **Background:** Trunk kinematics is an important risk factor for lower back pain, but is often difficult to measure by practitioners for lifting risk assessments. **Methods:** Mannequins representing a wide range of hand locations for different lifting postures were systematically generated using the University of Michigan 3DSSPP software. A bounding box was drawn tightly around each mannequin and regression models estimated trunk angles. The estimates were validated against human posture data for 216 lifts collected using a laboratory-grade motion capture system and synchronized video recordings. Trunk kinematics, based on bounding box dimensions drawn around the subjects in the video recordings of the lifts, were modeled for consecutive video frames. **Results:** The mean absolute difference between predicted and motion capture measured trunk angles was 14.7°, and there was a significant linear relationship between predicted and measured trunk angles ($R2 = .80$, $p < .001$). The training error for the kinematics model was 2.3°. **Conclusion:** Using simple computer vision-extracted features, the bounding box method indirectly estimated trunk angle and associated kinematics, albeit with limited precision. **Application:** This computer vision method may be implemented on handheld devices such as smartphones to facilitate automatic lifting risk assessments in the workplace.

- **Keywords:** job risk assessment, kinematics, low back, manual materials handling, work physiology

COGNITION

Patrick P. Weis, Eva Wiese. *Know Your Cognitive Environment! Mental Models as Crucial Determinant of Offloading Preferences*. S. 499–513.

Objective: Human problem solvers possess the ability to outsource parts of their mental processing onto cognitive "helpers" (cognitive offloading). However, suboptimal decisions regarding which helper to recruit for which task occur frequently. Here, we investigate if understanding and adjusting a specific subcomponent of mental models-beliefs about task-specific expertise-regarding these helpers could provide a comparatively easy way to improve offloading decisions. **Background:** Mental models afford the storage of beliefs about a helper that can be retrieved when needed. **Methods:** Arithmetic and social problems were solved by 192 participants. Participants could, in addition to solving a task on their own, offload cognitive processing onto a human, a robot, or one of two smartphone apps. These helpers were introduced with either task-specific (e.g., stating that an app would use machine learning to "recognize faces" and "read emotions") or task-unspecific (e.g., stating that an app was built for solving "complex cognitive tasks") descriptions of their expertise. **Results:** Providing task-specific expertise information heavily altered offloading behavior for apps but much less so for humans or robots. This suggests (1) strong preexisting mental models of human and robot helpers and (2) a strong impact of mental model adjustment for novel helpers like unfamiliar smartphone

apps. **Conclusion:** Creating and refining mental models is an easy approach to adjust offloading preferences and thus improve interactions with cognitive environments. **Application:** To efficiently work in environments in which problem-solving includes consulting other people or cognitive tools ("helpers"), accurate mental models-especially regarding task-relevant expertise—are a crucial prerequisite.

- **Keywords:** cognitive offloading, mental models, distributed cognition, extended cognition, metacognition, strategy selection

HUMAN-ROBOT INTERACTION

Leif Johannsen, Karna Potwar, Matteo Saveriano, Satoshi Endo, Dongheui Lee. *Robotic Light Touch Assists Human Balance Control During Maximum Forward Reaching*. S. 514–526.

Objective: We investigated how light interpersonal touch (IPT) provided by a robotic system supports human individuals performing a challenging balance task compared to IPT provided by a human partner. **Background:** IPT augments the control of body balance in contact receivers without a provision of mechanical body weight support. The nature of the processes governing the social haptic interaction, whether they are predominantly reactive or predictive, is uncertain. **Method:** Ten healthy adult individuals performed maximum forward reaching (MFR) without visual feedback while standing upright. We evaluated their control of reaching behavior and of body balance during IPT provided by either another human individual or by a robotic system in two alternative control modes (reactive vs. predictive). **Results:** Reaching amplitude was not altered by any condition but all IPT conditions showed reduced body sway in the MFR end-state. Changes in reaching behavior under robotic IPT conditions, such as lower speed and straighter direction, were linked to reduced body sway. An Index of Performance expressed a potential trade-off between speed and accuracy with lower bitrate in the IPT conditions. **Conclusion:** The robotic IPT system was as supportive as human IPT. Robotic IPT seemed to afford more specific adjustments in the human contact receiver, such as trading reduced speed for increased accuracy, to meet the intrinsic demands and constraints of the robotic system or the demands of the social context when in contact with a human contact provider.

- **Keywords:** interpersonal light touch, robotic assistance, body balance, forward reaching

Jasmine K. Proud, Daniel T. H. Lai, Kurt L. Mudie, Greg L. Carstairs, Daniel C. Billing, Alessandro Garofolini, Rezaul K. Begg. *Exoskeleton Application to Military Manual Handling Tasks*. S. 527–554.

Objective: The aim of this review was to determine how exoskeletons could assist Australian Defence Force personnel with manual handling tasks. **Background:** Musculoskeletal injuries due to manual handling are physically damaging to personnel and financially costly to the Australian Defence Force. Exoskeletons may minimize injury risk by supporting, augmenting, and/or amplifying the user's physical abilities. Exoskeletons are therefore of interest in determining how they could support the unique needs of military manual handling personnel. **Method:** Industrial and military exoskeleton studies from 1990 to 2019 were identified in the literature. This included 67 unique exoskeletons, for which Information about their current state of development was tabulated. **Results:** Exoskeleton support of manual handling tasks is largely through squat/deadlift (lower limb) systems (64%), with the proposed use case for these being

load carrying (42%) and 78% of exoskeletons being active. Human-exoskeleton analysis was the most prevalent form of evaluation (68%) with reported reductions in back muscle activation of 15%–54%. **Conclusion:** The high frequency of citations of exoskeletons targeting load carrying reflects the need for devices that can support manual handling workers. Exoskeleton evaluation procedures varied across studies making comparisons difficult. The unique considerations for military applications, such as heavy external loads and load asymmetry, suggest that a significant adaptation to current technology or customized military-specific devices would be required for the introduction of exoskeletons into a military setting. **Application:** Exoskeletons in the literature and their potential to be adapted for application to military manual handling tasks are presented.

- **Keywords:** exosuits, wearable robotics, bio-mechatronics, biomechanics, assistive technologies, manual materials, industrial

INDIVIDUAL DIFFERENCES

Nadine Matton, Pierre-Vincent Paubel, Sébastien Puma*. Toward the Use of Pupillary Responses for Pilot Selection*. S. 555–567.

Objective: For selection practitioners, it seems important to assess the level of mental resources invested in order to perform a demanding task. In this study, we investigated the potential of pupil size measurement to discriminate the most proficient pilot students from the less proficient. **Background:** Cognitive workload is known to influence learning outcome. More specifically, cognitive difficulties observed during pilot training are often related to a lack of efficient mental workload management. **Method:** Twenty pilot students performed a laboratory multitasking scenario, composed of several stages with increasing workload, while their pupil size was recorded. Two levels of pilot students were compared according to the outcome after 2 years of training: high success and medium success. **Results:** Our findings suggested that task-evoked pupil size measurements could be a promising predictor of flight training difficulties during the 2-year training. Indeed, high-level pilot students showed greater pupil size changes from low-load to high-load stages of the multitasking scenario than medium-level pilot students. Moreover, average pupil diameters at the low-load stage were smallest for the high-level pilot students. **Conclusion:** Following the neural efficiency hypothesis framework, the most proficient pilot students supposedly used their mental resources more efficiently than the least proficient while performing the multitasking scenario. **Application:** These findings might introduce a new way of managing selection processes complemented with ocular measurements. More specifically, pupil size measurement could enable identification of applicants with greater chances of success during pilot training.

- **Keywords:** mental workload, eye behavior, individual differences, pilot training, neural efficiency

METHODS AND SKILLS

Colin D. McKinnon, Michael W. Sonne, Peter J. Keir. *Assessment of Joint Angle and Reach Envelope Demands Using a Video-Based Physical Demands Description Tool*. S. 568–578.

Background: Current methods for describing physical work demands often lack detail and format standardization, require technical training and expertise, and are time-consuming to complete. A video-based physical demands description (PDD) tool may

improve time and accuracy concerns associated with current methods. **Methods:** Ten simulated occupational tasks were synchronously recorded using a motion capture system and digital video. The tasks included a variety of industrial tasks from lifting to drilling to overhead upper extremity tasks of different cycle times. The digital video was processed with a novel video-based assessment tool to produce 3D joint trajectories (PDAi), and joint angle and reach envelope measures were calculated and compared between both data sources. **Results:** Root mean squared error between video-based and motion capture posture estimated ranged from 89.0 mm to 118.6 mm for hand height and reach distance measures, and from 13.5° to 21.6° for trunk, shoulder, and elbow angle metrics. Continuous data were reduced to time-weighted bins, and video-based posture estimates showed 75% overall agreement and quadratic-weight Cohen's kappa scores ranging from 0.29 to 1.0 compared to motion capture data across all posture metrics. **Conclusion and Application:** The substantial level of agreement between time-weighted bins for video-based and motion capture measures suggest that video-based job task assessment may be a viable approach to improve accuracy and standardization of field physical demands descriptions and minimize error in joint posture and reach envelope estimates compared to traditional pen-and-paper methods.

- **Keywords:** ergonomics, physical demands, posture, artificial intelligence

MOTOR BEHAVIOR

Carolyn A. Duncan, Nicole Bishop, Vicki Komisar, Scott N. MacKinnon, Jeannette M. Byrne. *The Effect of Wave Motion Intensities on Performance in a Simulated Search and Rescue Task and the Concurrent Demands of Maintaining Balance*. S. 579–588.

Objective: The purpose of this study was to examine how intensity of wave motions affects the performance of a simulated maritime search and rescue (SAR) task. **Background:** Maritime SAR is a critical maritime occupation; however, the effect of wave motion intensity on worker performance is unknown. **Methods:** Twenty-four participants (12 male, 12 female) performed a simulated search and rescue task on a six-degree-of-freedom motion platform in two conditions that differed in motion intensity (low and high). Task performance, electromyography (EMG), and number of compensatory steps taken by the individual were examined. **Results:** As magnitude of simulated motion increased, performance in the SAR task decreased, and was accompanied by increases in lower limb muscle activation and number of steps taken. **Conclusions:** Performance of an SAR task and balance control may be impeded by high-magnitude vessel motions. **Application:** This research has the potential to be used by maritime engineers, occupational health and safety professionals, and ergonomists to improve worker safety and performance for SAR operators.

- **Keywords:** search and rescue, moving environments, task performance, wave motions, muscle activation

SIMULATION AND VIRTUAL REALITY

Chen Li, Yue Tang, Yingshi Zheng, Paramsothy Jayakumar, Tulga Ersal. *Modeling Human Steering Behavior in Teleoperation of Unmanned Ground Vehicles With Varying Speed*. S. 589–600.

Objective: This paper extends a prior human operator model to capture human steering performance in the teleoperation of unmanned ground vehicles (UGVs) in path-following scenarios with varying speed. **Background:** A prior study presented a human operator model to predict human steering performance in the teleoperation of a passenger-sized UGV at constant speeds. To enable applications to varying speed scenarios, the model needs to be extended to incorporate speed control and be able to predict human performance under the effect of accelerations/decelerations and various time delays induced by the teleoperation setting. A strategy is also needed to parameterize the model without human subject data for a truly predictive capability. **Method:** This paper adopts the ACT-R cognitive architecture and two-point steering model used in the previous work, and extends the model by incorporating a far-point speed control model to allow for varying speed. A parameterization strategy is proposed to find a robust set of parameters for each time delay to maximize steering performance. Human subject experiments are conducted to validate the model. **Results:** Results show that the parameterized model can predict both the trend of average lane keeping error and its lowest value for human subjects under different time delays. **Conclusions:** The proposed model successfully extends the prior computational model to predict human steering behavior in a teleoperated UGV with varying speed. **Application:** This computational model can be used to substitute for human operators in the process of development and testing of teleoperated UGV technologies and allows fully simulation-based development and studies.

- **Keywords:** human performance modeling, teleoperation, driver behavior, ACT-R cognitive architecture, computational modeling

SURFACE TRANSPORTATION

Davide Maggi, Richard Romano, Oliver Carsten. *Transitions Between Highly Automated and Longitudinally Assisted Driving: The Role of the Initiator in the Fight for Authority*. S. 601–612.

Objective: A driving simulator study explored how drivers behaved depending on their initial role during transitions between highly automated driving (HAD) and longitudinally assisted driving (via adaptive cruise control). **Background:** During HAD, drivers might issue a take-over request (TOR), initiating a transition of control that was not planned. Understanding how drivers behave in this situation and, ultimately, the implications on road safety is of paramount importance. **Method:** Sixteen participants were recruited for this study and performed transitions of control between HAD and longitudinally assisted driving in a driving simulator. While comparing how drivers behaved depending on whether or not they were the initiators, different handover strategies were presented to analyze how drivers adapted to variations in the authority level they were granted at various stages of the transitions. **Results:** Whenever they initiated the transition, drivers were more engaged with the driving task and less prone to follow the guidance of the proposed strategies. Moreover, initiating a transition and having the highest authority share during the handover made the drivers more engaged with the driving task and attentive toward the road. **Conclusion:** Handover strategies that retained a larger authority share were more effective whenever the automation initiated the transition. Under driver-initiated transitions, reducing drivers' authority was detrimental for both performance and comfort. **Application:** As the operational design domain of automated vehicles (Society of Automotive Engineers [SAE] Level 3/4) expands, the drivers might very well fight boredom by taking over spontaneously, introducing safety issues so far not considered but nevertheless very important.

- **Keywords:** driver behavior, vehicle automation, intelligent vehicle systems, human-automation interaction, autonomous driving