# Human Factors – rok 2022, roč. 64

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## AUTOMATION, EXPERT SYSTEMS

### Melanie M. Boskemper, Megan L. Bartlett, Jason S. McCarley. *Measuring the Efficiency of Automation-Aided Performance in a Simulated Baggage Screening Task*. pp. 945–961

**Objective:** The present study replicated and extended prior findings of suboptimal automation use in a signal detection task, benchmarking automation-aided performance to the predictions of several statistical models of collaborative decision making. **Background:** Though automated decision aids can assist human operators to perform complex tasks, operators often use the aids suboptimally, achieving performance lower than statistically ideal.**Method :** Participants performed a simulated security screening task requiring them to judge whether a target (a knife) was present or absent in a series of colored X-ray images of passenger baggage. They completed the task both with and without assistance from a 93%-reliable automated decision aid that provided a binary text diagnosis. A series of three experiments varied task characteristics including the timing of the aid's judgment relative to the raw stimuli, target certainty, and target prevalence. **Results and Conclusion:** Automation-aided performance fell closest to the predictions of the most suboptimal model under consideration, one which assumes the participant defers to the aid's diagnosis with a probability of 50%. Performance was similar across experiments. **Application:** Results suggest that human operators' performance when undertaking a naturalistic search task falls far short of optimal and far lower than prior findings using an abstract signal detection task.

## AVIATION AND AEROSPACE

**Annemarie van den Hoed, Annemarie Landman, Dirk Van Baelen, Olaf Stroosma, M. M. (René) van Paassen, Eric L. Groen, Max Mulder. Leans *Illusion in Hexapod Simulator Facilitates Erroneous Responses to Artificial Horizon in Airline Pilots*. pp. 962–972.**

**Objective:** We tested whether a procedure in a hexapod simulator can cause incorrect assumptions of the bank angle (i.e., the "leans") in airline pilots as well as incorrect interpretations of the attitude indicator (AI). **Background:** The effect of the leans on interpretation errors has previously been demonstrated in nonpilots. In-flight, incorrect assumptions can arise due to misleading roll cues (spatial disorientation). **Method:** Pilots (n = 18) performed 36 runs, in which they were asked to roll to wings level using only the AI. They received roll cues before the AI was shown, which matched with the AI bank angle direction in most runs, but which were toward the opposite direction in a leans-opposite condition (four runs). In a baseline condition (four runs), they received no roll cues. To test whether pilots responded to the AI, the AI sometimes showed wings level following roll cues in a leans-level condition (four runs). **Results:** Overall, pilots made significantly more errors in the leans-opposite (19.4%) compared to the baseline (6.9%) or leans-level condition (0.0%). There was a pronounced learning effect in the leans-opposite condition, as 38.9% of pilots made an error in the first exposure to this condition. Experience (i.e., flight hours) had no significant effects. **Conclusion:** The leans procedure was effective in inducing AI misinterpretations and control input errors in pilots. **Application:** The procedure can be used in spatial disorientation demonstrations. The results underline the importance of unambiguous displays that should be able to quickly correct incorrect assumptions due to spatial disorientation.

## BIOMECHANICS, ANTHROPOMETRY, WORK PHYSIOLOGY

**Ruoliang Tang, Jay M. Kapellusch, Kurt T. Hegmann, Matthew S. Thiese, Inga Wang, Andrew S. Merryweather. *Evaluating Different Measures of Low Back Pain Among U.S. Manual Materials Handling Workers: Comparisons of Demographic, Psychosocial, and Job Physical Exposure*. pp. 973–996.**

**Objective:** To examine differences in demographic, psychosocial, and job physical exposure risk factors between multiple low back pain (LBP) outcomes in a prospective cohort of industrial workers. **Background:** LBP remains a leading cause of lost industrial productivity. Different case definitions involving pain (general LBP), medication use (M-LBP), seeking healthcare (H-LBP), and lost time (L-LBP) are often used to study LBP outcomes. However, the relationship between these outcomes remains unclear. **Method:** Demographic, health status, psychosocial, and job physical exposure risk factors were quantified for 635 incident-eligible industrial workers. Incident cases of LBP outcomes and pain symptoms were quantified and compared across the four outcomes. **Results:** Differences in age, gender, medical history, and LBP history were found between the four outcomes. Most incident-eligible workers (67%) suffered an LBP outcome during follow-up. Cases decreased from 420 for LBP (25.4 cases/100 person-years) to 303 for M-LBP (22.0 cases/100 person-years), to 151 for H-LBP (15.6 cases/100 person-years), and finally to 56 for L-LBP (8.7 cases/100 person-years). Conversely, pain intensity and duration increased from LBP to H-LBP. However, pain duration was relatively lower for L-LBP than for H-LBP. **Conclusion:** Patterns of cases, pain intensity, and pain duration suggest the influence of the four outcomes. However, few differences in apparent risk factors were observed between the outcomes. Further research is needed to establish consistent case definitions. **Application:** Knowledge of patterns between different LBP

outcomes can improve interpretation of research and guide future research and intervention studies in industry.

**Zeinab Kazemi, Adel Mazloumi, Navid Arjmand, Ahmadreza Keihani, Zanyar Karimi, Mohamad Sadegh Ghasemi, Ramin Kordi. *A Comprehensive Evaluation of Spine Kinematics, Kinetics, and Trunk Muscle Activities During Fatigue-Induced Repetitive Lifting*. pp. 997–1012.**

**Objective:** Spine kinematics, kinetics, and trunk muscle activities were evaluated during different stages of a fatigue-induced symmetric lifting task over time. **Background:** Due to neuromuscular adaptations, postural behaviors of workers during lifting tasks are affected by fatigue. Comprehensive aspects of these adaptations remain to be investigated. **Method:** Eighteen volunteers repeatedly lifted a box until perceived exhaustion. Body center of mass (CoM), trunk and box kinematics, and feet center of pressure (CoP) were estimated by a motion capture system and force-plate. Electromyographic (EMG) signals of trunk/abdominal muscles were assessed using linear and nonlinear approaches. The L5-S1 compressive force (Fc) was predicted via a biomechanical model. A two-way multivariate analysis of variance (MANOVA) was performed to examine the effects of five blocks of lifting cycle (C1 to C5) and lifting trial (T1 to T5), as independent variables, on kinematic, kinetic, and EMG-related measures. **Results:** Significant effects of lifting trial blocks were found for CoM and CoP shift in the anterior–posterior direction (respectively $p < .001$ and $p = .014$), trunk angle ($p = .004$), vertical box displacement ($p < .001$), and Fc ($p = .005$). EMG parameters indicated muscular fatigue with the extent of changes being muscle-specific. **Conclusion:** Results emphasized variations in most kinematics/kinetics, and EMG-based indices, which further provided insight into the lifting behavior adaptations under dynamic fatiguing conditions. **Application:** Movement and muscle-related variables, to a large extent, determine the magnitude of spinal loading, which is associated with low back pain.

**Suman K. Chowdhury, Yu Zhou, Bocheng Wan, Curran Reddy, Xudong Zhang. *Neck Strength and Endurance and Associated Personal and Work-Related Factors*. pp. 1013–1026.**

**Objective:** The present study aimed to establish a normative database of neck strength and endurance while exploring personal and work-related factors that can significantly influence neck strength and endurance. **Background:** A normative database combining both neck strength and endurance and delineating how they are affected by personal and work-related factors is currently lacking. It is needed for the development of tools and guidelines for designing work requiring head-neck exertions to contain the risk of occupational neck pain. **Methods:** Forty healthy participants (20 males and 20 females) performed sustained-till-exhaustion head-neck exertions, while seated, at 50% and 100% of their maximal efforts in anterior, anterior-superior, and posterior-superior directions in neutral, 40° extended, and 40° flexed neck postures. Exertion force and endurance time data from 38 participants were recorded and analyzed using regression models. **Results:** Overall, multiple regression analyses of the neck strength and endurance database revealed that head-neck posture is the most significant determinant of both neck strength and endurance. The time of day significantly influenced neck endurance. Among the personal factors, a significant sex effect on neck strength and significant age and body mass index (BMI) effects on neck endurance were identified. **Conclusion:** The work-related factors play a more significant role in shaping both neck strength and endurance than personal factors and therefore are more important modifiable factors in meeting the physical demands of work. **Application:** The study findings can aid in work design as well as in pre-employment screening to reduce the incidence of neck pain in the workplace.

## HUMAN-COMPUTER INTERACTION

### Sonja K. Ötting, Lisa Masjutin, Jochen J. Steil, Günter W. Maier. *Let's Work Together: A Meta-Analysis on Robot Design Features That Enable Successful Human-Robot Interaction at Work*. pp. 1027–1050

**Objective:** This meta-analysis reviews robot design features of interface, controller, and appearance and statistically summarizes their effect on successful human-robot interaction (HRI) at work (that is, task performance, cooperation, satisfaction, acceptance, trust, mental workload, and situation awareness). **Background:** Robots are becoming an integral part of many workplaces. As interactions with employees increase, ensuring success becomes ever more vital. Even though many studies investigated robot design features, an overview on general and specific effects is missing. **Method:** Systematic selection of literature and structured coding led to 81 included experimental studies containing 380 effect sizes. Mean effects were calculated using a three-level meta-analysis to handle dependencies of multiple effect sizes in one study. **Results:** Sufficient feedback through the interface, clear visibility of affordances, and adaptability and autonomy of the controller significantly affect successful HRI, whereas appearance does not. The features of the interface and controller affect performance and satisfaction but do not affect situation awareness and trust. Specific effects of adaptability on cooperation and acceptance, as well as autonomy on mental workload, could be shown. **Conclusion:** Robot design at work needs to cover multiple features of interface and controller to achieve successful HRI that covers not only performance and satisfaction, but also cooperation, acceptance, and mental workload. More empirical research is needed to investigate mediating mechanisms and underrepresented design features' effects. **Application:** Robot designers should carefully choose design features to balance specific effects and implementation costs with regard to tasks, work design aims, and employee needs in the specific work context.

## NEUROERGONOMICS

### Jiali Huang, Sanghyun Choo, Zachary H. Pugh, Chang S. Nam. *Evaluating Effective Connectivity of Trust in Human-Automation Interaction: A Dynamic Causal Modeling (DCM) Study*. pp. 1051–1069.

**Objective:** Using dynamic causal modeling (DCM), we examined how credibility and reliability affected the way brain regions exert causal influence over each other - effective connectivity (EC) - in the context of trust in automation. **Background:** Multiple brain regions of the central executive network (CEN) and default mode network (DMN) have been implicated in trust judgment. However, the neural correlates of trust judgment are still relatively unexplored in terms of the directed information flow between brain regions. **Method:** Sixteen participants observed the performance of four computer algorithms, which differed in credibility and reliability, of the system monitoring subtask of the Air Force Multi-Attribute Task Battery (AF-MATB). Using six brain regions of the CEN and DMN commonly identified to be activated in human trust, a total of 30 (forward, backward, and lateral) connection models were developed. Bayesian model averaging (BMA) was used to quantify the connectivity strength among the brain regions. **Results:** Relative to the high trust condition, low trust showed unique presence of specific connections, greater connectivity strengths from the prefrontal cortex, and greater network complexity. High trust condition showed no backward connections. **Conclusion:** Results indicated that trust and distrust can be two distinctive neural processes in human-automation interaction-distrust being a more complex network than trust, possibly due to the increased cognitive load. **Application:** The causal architecture of distributed brain regions inferred using DCM can help not only in the design of a balanced

human-automation interface design but also in the proper use of automation in real-life situations.

## SIMULATION AND VIRTUAL REALITY

### Anees Ahamed Kaleefathullah, Natasha Merat, Yee Mun Lee, Yke Bauke Eisma, Ruth Madigan, Jorge Garcia, Joost de Winter. *External Human-Machine Interfaces Can Be Misleading: An Examination of Trust Development and Misuse in a CAVE-Based Pedestrian Simulation Environment*. pp. 1070–1085.

**Objective:** To investigate pedestrians' misuse of an automated vehicle (AV) equipped with an external human–machine interface (eHMI). Misuse occurs when a pedestrian enters the road because of uncritically following the eHMI's message. **Background:** Human factors research indicates that automation misuse is a concern. However, there is no consensus regarding misuse of eHMIs. **Methods:** Sixty participants each experienced 50 crossing trials in a Cave Automatic Virtual Environment (CAVE) simulator. The three independent variables were as follows: (1) behavior of the approaching AV (within-subject: yielding at 33 or 43 m distance, no yielding), (2) eHMI presence (within-subject: eHMI on upon yielding, off), and (3) eHMI onset timing (between-subjects: eHMI turned on 1 s before or 1 s after the vehicle started to decelerate). Two failure trials were included where the eHMI turned on, yet the AV did not yield. Dependent measures were the moment of entering the road and perceived risk, comprehension, and trust. **Results:** Trust was higher with eHMI than without, and the −1 Group crossed earlier than the +1 Group. In the failure trials, perceived risk increased to high levels, whereas trust and comprehension decreased. Thirty-five percent of the participants in the −1 and +1 Groups walked onto the road when the eHMI failed for the first time, but there were no significant differences between the two groups. **Conclusion:** eHMIs that provide anticipatory information stimulate early crossing. eHMIs may cause people to over-rely on the eHMI and under-rely on the vehicle-intrinsic cues. **Application:** eHMI have adverse consequences, and education of eHMI capability is required.

## SURFACE TRANSPORTATION

### Starla M. Weaver, Stephanie M. Roldan, Tracy B. Gonzalez, Stacy A. Balk, Brian H. Philips. *The Effects of Vehicle Automation on Driver Engagement: The Case of Adaptive Cruise Control and Mind Wandering*. pp. 1086–1098.

**Objective:** This field study examined the effects of adaptive cruise control (ACC) on mind wandering prevalence. **Background:** ACC relieves the driver of the need to regulate vehicle speed and following distance, which may result in safety benefits. However, if ACC reduces the amount of attentional resources drivers must devote to driving, then drivers who use ACC may experience increased periods of mind wandering, which could reduce safety. **Methods:** Participants drove a prescribed route on a public road twice, once using ACC and once driving manually. Mind wandering rates were assessed throughout the drive using auditory probes, which occurred at random intervals and required the participant to indicate whether or not they were mind wandering. Measures of physiological arousal and driving performance were also recorded. **Results:** No evidence of increased mind wandering was found when drivers used ACC. In fact, female drivers reported reduced rates of mind wandering when driving with ACC relative to manual driving. Driving with ACC also tended to be associated with increased

physiological arousal and improved driving behavior. **Conclusion:** Use of ACC did not encourage increased mind wandering or negatively affect driving performance. In fact, the results indicate that ACC may have positive effects on driver safety among drivers who have limited experience with the technology. **Application:** Driver characteristics, such as level of experience with in-vehicle technology and gender, should be considered when investigating driver engagement during ACC use. Field research on vehicle automation may provide valuable insights over and above studies conducted in driving simulators.