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#### ACCIDENTS, SAFETY, AND HUMAN FACTOR

##### **Sean T. Osis, Jay T. Worobets, Darren J. Stefanyshyn. *Early Heelstrike Kinetics Are Indicative of Slip Potential During Walking Over a Contaminated Surface. S. 5-13.***

**Objective:** The objective of this study is to examine ground kinetics early in stance while walking on a contaminated surface and assess the potential of kinetics to quantify risk of slipping. **Background:** Prior studies of slipping have dismissed early ground kinetic data, and therefore no prior literature has been able to assess the viability of using these data to quantify slip potential. **Method:** A total of 11 healthy male participants volunteered to walk over a force plate that was at random times contaminated with soap. Ground kinetics were measured by the force plate (2400 Hz), and heel displacement was quantified using high-speed video cameras (240 Hz) and retro-reflective markers. **Results:** The results indicated a significant reduction in shear force as early as 0.42 ms after heelstrike for contaminated trials, whereas for utilized coefficient of friction, a significant reduction was not seen until 11.34 ms. Heel displacements considered "safe" in the literature (< 30 mm) demonstrated proportionally different thresholds for shear force and utilized coefficient of friction. **Conclusion:** The authors suggest that shear force in early stance shows more promise in quantifying slip potential as compared to utilized coefficient of friction given that (a) significant differences are seen earlier in shear than utilized coefficient of friction and (b) the threshold for utilized coefficient of friction, over which heel displacement stabilized to a "safe" value, exceeded values for utilized coefficient of friction that have been recommended as "safe." **Application:** These results have wide implications for standards related to the design and testing of interventions to prevent injuries because of slipping.

- **Keywords:** slips and falls, injury prevention, friction measurement

##### **Joceline Rogé, Evgueni Douissembekov, Fabrice Vienne. *Low Conspicuity of Motorcycles for Car Drivers : Dominant Role of Bottom-Up Control of Visual Attention or Deficit of Top-Down Control? S. 14-25.***

**Objective:** The aim of this study was to evaluate whether the low visibility of motorcycles is the result of their low cognitive conspicuity and/or their low sensory conspicuity for car drivers. **Background:** In several cases of collision between a car and a motorcycle, the car driver failed to detect the motorcyclist in time to avoid the collision. **Method:** To test the low cognitive conspicuity hypothesis, 42 car drivers (32.02 years old) including 21 motorcyclist motorists and 21 non-motorcyclist motorists carried out a motorcycle detection task in a car-driving simulator. To test the low sensory conspicuity

hypothesis, the authors studied the effect of the color contrast between motorcycles and the road surface on the ability of car drivers to detect motorcycles when they appear from different parts of the road. **Results:** A high level of color contrast enhanced the visibility of motorcycles when they appeared in front of the participants. Moreover, when motorcyclists appeared from behind the participants, the motorcyclist motorists detected oncoming motorcycles at a greater distance than did the non-motorcyclist motorists. Motorcyclist motorists carry out more saccades and rapidly capture information (on their rearview mirrors and on the road in front of them). **Conclusion:** The results related to the sensory conspicuity and cognitive conspicuity of motorcycles for car drivers are discussed from the viewpoint of visual attention theories. **Application:** The practical implications of these results and future lines of research related to training methods for car drivers are considered.

- **Keywords:** sensory conspicuity, cognitive conspicuity, color contrast, car-driving simulator

## **AGING AND INDIVIDUAL DIFFERENCES**

**Christopher M. Kelley, Anne Collins McLaughlin. *Individual Differences in the Benefits of Feedback for Learning. S. 26-35.***

**Objective:** Research on learning from feedback has produced ambiguous guidelines for feedback design—some have advocated minimal feedback, whereas others have recommended more extensive feedback that highly supported performance. The objective of the current study was to investigate how individual differences in cognitive resources may predict feedback requirements and resolve previous conflicted findings.

**Method:** Cognitive resources were controlled for by comparing samples from populations with known differences, older and younger adults. To control for task demands, a simple rule-based learning task was created in which participants learned to identify fake Windows pop-ups. Pop-ups were divided into two categories—those that required fluid ability to identify and those that could be identified using crystallized intelligence.

**Results:** In general, results showed participants given higher feedback learned more. However, when analyzed by type of task demand, younger adults performed comparably with both levels of feedback for both cues whereas older adults benefited from increased feedback for fluid ability cues but from decreased feedback for crystallized ability cues.

**Conclusion:** One explanation for the current findings is feedback requirements are connected to the cognitive abilities of the learner—those with higher abilities for the type of demands imposed by the task are likely to benefit from reduced feedback.

**Application:** We suggest the following considerations for feedback design: Incorporate learner characteristics and task demands when designing learning support via feedback.

- **Keywords:** individual differences, aging, fluid ability, feedback, crystallized intelligence, learning

## **ATTENTIONAL PROCESSES**

**Gregory J. Funke, Benjamin A. Knott, Eduardo Salas, Davin Pavlas, Adam J. Strang. *Conceptualization and Measurement of Team Workload : A Critical Need. S. 36-51.***

**Objective:** The purpose of this article is to present and expand on current theories and measurement techniques for assessing team workload. **Background:** To date, little research has been conducted on the workload experienced by teams. A validated theory describing team workload, which includes an account of its relation to individual workload, has not been articulated. **Method:** The authors review several theoretical approaches to team workload. Within the team research literature, attempts to evaluate team workload have typically relied on measures of individual workload. This assumes

that such measures retain their validity at the team level of measurement, but empirical research suggests that this method may lack sensitivity to the drivers of team workload. **Results:** On the basis of these reviews, the authors advance suggestions concerning a comprehensive theory of team workload and methods for assessing it in team settings. The approaches reviewed include subjective, performance, physiological, and strategy shift measures. Theoretical and statistical difficulties associated with aggregating individual-level workload responses to a team-level measure are discussed. **Conclusion:** Conception and measurement of team workload have not significantly matured alongside developments in individual workload. **Application:** Team workload remains a complex research area without simple measurement solutions, but as a research domain it remains open for contributions from interested and enterprising researchers.

- **Keywords:** team workload, measurement, subjective measures, performance measures, physiological measures, strategy shift measures

## **BIOMECHANICS, ANTHROPOMETRY, WORK PHYSIOLOGY**

**Matthieu B. Trudeau, Tawan Udtamadilok, Amy K. Karlson, Jack T. Dennerlein. *Thumb Motor Performance Varies by Movement Orientation, Direction, and Device Size During Single-Handed Mobile Phone Use.* S. 52-59.**

**Objective:** The aim of this study was to determine if thumb motor performance metrics varied by movement orientation, direction, and device size during single-handed use of a mobile phone device. **Background:** With the increased use of mobile phones, understanding how design factors affect and improve performance can provide better design guidelines. **Method:** A repeated measures laboratory experiment of 20 right-handed participants measured the thumb tip's 3-D position relative to a phone during reciprocal tapping tasks across four phone designs and four thumb tip movement orientations. Each movement orientation included two movement directions: an "outward" direction consisting in CMC (carpometacarpal) joint flexion or abduction movements and an "inward" direction consisting in CMC joint extension or adduction movements. Calculated metrics of the thumb's motor performance were Fitts' effective width and index of performance. **Results:** Index of performance varied significantly across phones, with performance being generally better for the smaller devices. Performance was also significantly higher for adduction-abduction movement orientations compared to flexion-extension, and for "outward" compared to "inward" movement directions. **Conclusion:** For single-handed device use, adduction-abduction-type movements on smaller phones lead to better thumb performance. **Application:** The results from this study can be used to design new mobile phone devices and keypad interfaces that optimize specific thumb motions to improve the user-interface experience during single-handed use.

- **Keywords:** Biomechanics, Fitts' law, motor kontrol, textil, keypad interface

## **COGNITIVE PROCESSES**

**Francis T. Durso, Kaitlin M. Geldbach, Paul Corballis. *Detecting Confusion Using Facial Electromyography.* S. 60-69.**

**Objective:** The ability to detect confusion using facial electromyography (EMG) was evaluated. **Background:** Facial EMG has been useful in detecting various emotional states. Another state potentially detectable from facial musculature is confusion. Confusion reflects a loss of understanding or, in a dynamic environment, a loss of situation understanding or situation awareness. **Method:** For this study, 24 participants listened to a confusing and a neutral audio passage while they were monitored with EMG.

Electrical activity of the right and left corrugator supercilii, the right zygomaticus major, and right depressor anguli oris was recorded. Participants also reported whether they felt confused during the experimental passage. Finally, they were asked to pose facial expressions. Two raters assessed responses in the graphed EMG data for evidence of activation near a confusing sentence in the passage. **Results:** EMG revealed confusion in 21 of 24 (87.5%) participants, even in some participants who did not admit confusion. Posed expressions of confusion differed somewhat from spontaneous expressions elicited during the experimental passage. **Conclusion:** EMG was effective in detecting confusion, regardless of operator self-report. Not all muscles in the face were important for the detection of confusion: The zygomaticus major led to a large number of false positives. **Application:** EMG can be an effective addition to a sensor suite designed to monitor the cognitive state of operators of systems.

- **Keywords:** augmented cognition, biocognition, cognitive processes, comprehension, neuroergonomics

**Sébastien Tremblay, François Vachon, Daniel Lafond, Chelsea Kramer. *Dealing With Task Interruptions in Complex Dynamic Environments : Are Two Heads Better Than One?* S. 70-83.**

**Objective:** This study examined whether teaming up mitigates individual vulnerability to task interruptions in complex dynamic situations. **Background:** Omnipresent in everyday multitasking environments, task interruptions are usually detrimental to individual performance. This is particularly crucial in dynamic command and control (C2) safety-critical contexts because of the additional challenge imposed by the continually evolving situation during the interruption. **Method:** We employed a firefighting microworld to simulate C2 in the context of supervisory control to examine the relative impact of interruptions on participants working in a functional dyad versus operators working alone. **Results:** Although task interruption was detrimental to participants' efficacy of monitoring resources, the negative impact of interruption was reduced for those working in teams. Teaming up translated into faster resumption time, but only if both teammates were interrupted simultaneously. Interrupting only one team member was associated with increased postinterruption communications and slower resumption time. **Conclusion:** These findings suggest that in complex dynamic situations working in a small team confers more resistance to task interruption than working alone by virtue of the reduced individual workload typical of teamwork. The benefit of collaborative work seems nevertheless mediated by the coordination and communication overhead associated with teamwork. **Application:** The present findings have practical implications for operators dealing with unexpected events such as task interruptions in C2 environments.

- **Keywords:** task interruption, teamwork, shared workload, complex dynamic situations, microworld, command and control

**Jessica L. Wildman, Amanda L. Thayer, Davin Pavlas, Eduardo Salas, John E. Stewart, William R. Howse. *Team Knowledge Research : Emerging Trends and Critical Needs.* S. 84-111.**

**Objective:** This article provides a systematic review of the team knowledge literature and guidance for further research. **Background:** Recent research has called attention to the need for the improved study and understanding of team knowledge. Team knowledge refers to the higher level knowledge structures that emerge from the interactions of individual team members. **Method:** We conducted a systematic review of the team knowledge literature, focusing on empirical work that involves the measurement of team knowledge constructs. For each study, we extracted author degree area, study design type, study setting, participant type, task type, construct type, elicitation method, aggregation method, measurement timeline, and criterion domain. **Results:** Our

analyses demonstrate that many of the methodological characteristics of team knowledge research can be linked back to the academic training of the primary author and that there are considerable gaps in our knowledge with regard to the relationships between team knowledge constructs, the mediating mechanisms between team knowledge and performance, and relationships with criteria outside of team performance, among others. We also identify categories of team knowledge not yet examined based on an organizing framework derived from a synthesis of the literature. **Conclusion:** There are clear opportunities for expansion in the study of team knowledge; the science of team knowledge would benefit from a more holistic theoretical approach. **Application:** Human factors researchers are increasingly involved in the study of teams. This review and the resulting organizing framework provide researchers with a summary of team knowledge research over the past 10 years and directions for improving further research.

- **Keywords:** shared mental models, transactive memory, cognition, group, methodology

## COMPUTER SYSTEMS

**Joseph B. Lyons, Charlene K. Stokes. *Human–Human Reliance in the Context of Automation*. S. 112-121.**

**Objective:** The current study examined human–human reliance during a computer-based scenario where participants interacted with a human aid and an automated tool simultaneously. **Background:** Reliance on others is complex, and few studies have examined human–human reliance in the context of automation. Past research found that humans are biased in their perceived utility of automated tools such that they view them as more accurate than humans. Prior reviews have postulated differences in human–human versus human–machine reliance, yet few studies have examined such reliance when individuals are presented with divergent information from different sources. **Method:** Participants ( $N = 40$ ) engaged in the Convoy Leader experiment. They selected a convoy route based on explicit guidance from a human aid and information from an automated map. Subjective and behavioral human–human reliance indices were assessed. Perceptions of risk were manipulated by creating three scenarios (low, moderate, and high) that varied in the amount of vulnerability (i.e., potential for attack) associated with the convoy routes. **Results:** Results indicated that participants reduced their behavioral reliance on the human aid when faced with higher risk decisions (suggesting increased reliance on the automation); however, there were no reported differences in intentions to rely on the human aid relative to the automation. **Conclusion:** The current study demonstrated that when individuals are provided information from both a human aid and automation, their reliance on the human aid decreased during high-risk decisions. **Application:** This study adds to a growing understanding of the biases and preferences that exist during complex human–human and human–machine interactions.

- **Keywords:** human–human reliance, trust in automation, vulnerability, risk perceptions

## PSYCHOMOTOR PROCESSES

**Namal Thibbotuwawa, Ravindra S. Goonetilleke, Errol R. Hoffmann. *Constrained Path Tracking at Varying Angles in a Mouse Tracking Task*. S. 138-150.**

**Objective:** This study was aimed to determine the effects of direction and path length on movement time when traversing a constrained path of width,  $W$ , in a mouse tracking task. **Background:** Tracking within constrained paths has been demonstrated to hold in many applications. Movement time and velocity of movement have shown very similar

relationships, possibly because of the lack of extreme testing conditions. Most previous research evaluated conditions with only constant path length ( $A$ ) of movement. **Method:** A total of 15 participants performed a mouse steering task within a constrained path at various angles. The independent variables were track width ( $W$ ), path length, and path angle. Movement time was the dependent variable. **Results:** Analyses showed a significant effect of movement direction on movement time, and the relationship was approximately sinusoidal and symmetrical about the horizontal axis. Path length had a significant effect on speed of movement, which was not that apparent on movement time. At low  $A/W$  values, movements appeared to be ballistic. **Conclusion:** Tracking within constrained paths can be modeled to account for the effect of path angle. **Application:** Vertical hand movements, especially within constrained paths, may not be ideal from a performance and biomechanical standpoint. The performance curve gradients are a good way to evaluate and standardize the testing of input devices and to define acceptable speeds for various tolerances in computer and industrial tasks that involve angular motions. The results of this experiment will help designers to optimize products and training programs.

- **Keywords:** constrained cracking, Drury's law, cracking, angular cracking, hand movements, ballistic movement