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AUTOMATION, EXPERT SYSTEMS

Eric T. Chancey, James P. Bliss, Yusuke Yamani, Holly A. H. Handley. *Trust and the Compliance–Reliance Paradigm: The Effects of Risk, Error Bias, and Reliability on Trust and Dependence*. pp. 333–345.

Objective: This study provides a theoretical link between trust and the compliance–eliance paradigm. We propose that for trust mediation to occur, the operator must be presented with a *salient choice*, and there must be an element of *risk* for dependence. **Background:** Research suggests that false alarms and misses affect dependence via two independent processes, hypothesized as trust in signals and trust in nonsignals. These two trust types manifest in categorically different behaviors: compliance and reliance. **Method:** Eighty-eight participants completed a primary flight task and a secondary signaling system task. Participants evaluated their trust according to the informational bases of trust: performance, process, and purpose. Participants were in a high- or low-risk group. Signaling systems varied by reliability (90%, 60%) within subjects and error bias (false alarm prone, miss prone) between subjects. **Results:** False-alarm rate affected compliance but not reliance. Miss rate affected reliance but not compliance. Mediation analyses indicated that trust mediated the relationship between false-alarm rate and compliance. Bayesian mediation analyses favored evidence indicating trust did not mediate miss rate and reliance. Conditional indirect effects indicated that factors of trust mediated the relationship between false-alarm rate and compliance (i.e., purpose) and reliance (i.e., process) but only in the high-risk group. **Conclusion:** The compliance–reliance paradigm is not the reflection of two types of trust. **Application:** This research could be used to update training and design recommendations that are based upon the assumption that trust causes operator responses regardless of error bias.

BIOMECHANICS, ANTHROPOMETRY, WORK PHYSIOLOGY

Brennan J. Thompson, Matt S. Stock, Victoria K. Banuelas. *Effects of Accumulating Work Shifts on Performance-Based Fatigue Using Multiple Strength Measurements in Day and Night Shift Nurses and Aides*. pp. 346–356.

Objective: This study aimed to examine the effects of accumulating nursing work on maximal and rapid strength characteristics in female nurses and compare these effects in day versus night shift workers. **Background:** Nurses exhibit among the highest nonfatal injury rates of all occupations, which may be a consequence of long, cumulative work shift schedules. Fatigue may accumulate across multiple shifts and lead to performance impairments, which in turn may be linked to injury risks. **Method:** Thirty-seven nurses and aides performed isometric strength-based performance testing of three muscle groups, including the knee extensors, knee flexors, and wrist flexors (hand grip), as well as countermovement jumps, at baseline and following exposure to three 12-hour work shifts in a four-day period. Variables included peak torque (PT) and rate of torque development (RTD) from isometric strength testing and jump height and power output. **Results:** The rigorous work period resulted in significant decreases (-7.2% to -19.2%) in a large majority (8/9) of the isometric strength-based measurements. No differences were noted for the day versus night shift workers except for the RTD at 200 millisecond variable, for which the night shift had greater work-induced decreases than the day shift workers. No changes were observed for jump height or power output. **Conclusions:** A compressed nursing work schedule resulted in decreases in strength-based performance abilities, being indicative of performance fatigue. **Application:** Compressed work schedules involving long shifts lead to functional declines in nurse performance capacities that may pose risks for both the nurse and patient quality of care. Fatigue management plans are needed to monitor and regulate increased levels of fatigue.

COGNITION

Daphne E. Whitmer, Valerie K. Sims, Michael E. Torres. *Assessing Mental Models of Emergencies Through Two Knowledge Elicitation Tasks*. pp. 357–376.

Objective: The goals of this study were to assess the risk identification aspect of mental models using standard elicitation methods and how university campus alerts were related to these mental models. **Background:** People fail to follow protective action recommendations in emergency warnings. Past research has yet to examine cognitive processes that influence emergency decision-making. **Method:** Study 1 examined 2 years of emergency alerts distributed by a large southeastern university. In Study 2, participants listed emergencies in a thought-listing task. Study 3 measured participants' time to decide if a situation was an emergency. **Results:** The university distributed the most alerts about an armed person, theft, and fire. In Study 2, participants most frequently listed fire, car accident, heart attack, and theft. In Study 3, participants quickly decided a bomb, murder, fire, tornado, and rape were emergencies. They most slowly decided that a suspicious package and identify theft were emergencies. **Conclusion:** Recent interaction with warnings was only somewhat related to participants' mental models of emergencies. Risk identification precedes decision-making and applying protective actions. Examining these characteristics of people's mental representations of emergencies is fundamental to further understand why some emergency warnings go ignored. **Application:** Someone must believe a situation is serious to categorize it as an emergency before taking the protective action recommendations in an emergency warning. Present-day research must continue to examine the problem of people ignoring warning communication, as there are important cognitive factors that have not yet been explored until the present research.

Franklin P. Tamborello, J. Gregory Trafton. *Human Error as an Emergent Property of Action Selection and Task Place-Holding*. pp. 377–392.

Objective: A computational process model could explain how the dynamic interaction of human cognitive mechanisms produces each of multiple error types. **Background:** With increasing capability and complexity of technological systems, the potential severity of consequences of human error is magnified. Interruption greatly increases people's error

rates, as does the presence of other information to maintain in an active state. **Method:** The model executed as a software-instantiated Monte Carlo simulation. It drew on theoretical constructs such as associative spreading activation for prospective memory, explicit rehearsal strategies as a deliberate cognitive operation to aid retrospective memory, and decay. **Results:** The model replicated the 30% effect of interruptions on postcompletion error in Ratwani and Trafton's Stock Trader task, the 45% interaction effect on postcompletion error of working memory capacity and working memory load from Byrne and Bovair's Phaser Task, as well as the 5% perseveration and 3% omission effects of interruption from the UNRAVEL Task. **Conclusion:** Error classes including perseveration, omission, and postcompletion error fall naturally out of the theory. **Application:** The model explains post-interruption error in terms of task state representation and priming for recall of subsequent steps. Its performance suggests that task environments providing more cues to current task state will mitigate error caused by interruption. For example, interfaces could provide labeled progress indicators or facilities for operators to quickly write notes about their task states when interrupted.

Brittany L. Anderson-Montoya, Mark W. Scerbo, Dana E. Ramirez, Thomas W. Hubbard. *Running Memory for Clinical Handoffs: A Look at Active and Passive Processing*. **pp. 393–406.**

Objective: The goal of the present study was to examine the effects of domain-relevant expertise on running memory and the ability to process handoffs of information. In addition, the role of active or passive processing was examined. **Background:** Currently, there is little research that addresses how individuals with different levels of expertise process information in running memory when the information is needed to perform a real-world task. **Method:** Three groups of participants differing in their level of clinical expertise (novice, intermediate, and expert) performed an abstract running memory span task and two tasks resembling real-world activities, a clinical handoff task and an air traffic control (ATC) handoff task. For all tasks, list length and the amount of information to be recalled were manipulated. **Results:** Regarding processing strategy, all participants used passive processing for the running memory span and ATC tasks. The novices also used passive processing for the clinical task. The experts, however, appeared to use more active processing, and the intermediates fell in between. **Conclusion:** Overall, the results indicated that individuals with clinical expertise and a developed mental model rely more on active processing of incoming information for the clinical task while individuals with little or no knowledge rely on passive processing. **Application:** The results have implications about how training should be developed to aid less experienced personnel identify what information should be included in a handoff and what should not.

Elliot E. Entin, Daniel Serfaty. *Sequential Revision of Belief, Trust Type, and the Order Effect*. **pp. 407–419.**

Objective: To investigate how people's sequential adjustments to their position are impacted by the source of the information. **Background:** There is an extensive body of research on how the order in which new information is received affects people's final views and decisions as well as research on how they adjust their views in light of new information. **Method:** Seventy college-aged students, 60% of whom were women, completed one of eight different randomly distributed booklets prepared to create the eight different between-subjects treatment conditions created by crossing the two levels of information source with the four level of order conditions. Based on the information provided, participants estimated the probability of an attack, the dependent measure. **Results:** Confirming information from an expert intelligence officer significantly increased the attack probability from the initial position more than confirming information from a longtime friend. Conversely, disconfirming information from a longtime friend decreased the attack probability significantly more than the same information from an intelligence officer. **Conclusion:** It was confirmed that confirming and disconfirming evidence were

differentially affected depending on information source, either an expert or a close friend. The difference appears to be due to the existence of two kinds of trust: cognitive-based imbued to an expert and affective-based imbued to a close friend. **Application:** Purveyors of information need to understand that it is not only the content of a message that counts but that other forces are at work such as the order in which information is received and characteristics of the information source.

HUMAN-COMPUTER INTERACTION, COMPUTER SYSTEMS

Zahid Maqbool, Nidhi Makhijani, V. S. Chandrasekhar Pammi, Varun Dutt. *Effects of Motivation: Rewarding Hackers for Undetected Attacks Cause Analysts to Perform Poorly*. pp. 420–431.

Objective: The aim of this study was to determine how monetary motivations influence decision making of humans performing as security analysts and hackers in a cybersecurity game. **Background:** Cyberattacks are increasing at an alarming rate. As cyberattacks often cause damage to existing cyber infrastructures, it is important to understand how monetary rewards may influence decision making of hackers and analysts in the cyber world. Currently, only limited attention has been given to this area. **Method:** In an experiment, participants were randomly assigned to three between-subjects conditions ($n = 26$ for each condition): equal payoff, where the magnitude of monetary rewards for hackers and defenders was the same; rewarding hacker, where the magnitude of monetary reward for hacker's successful attack was 10 times the reward for analyst's successful defense; and rewarding analyst, where the magnitude of monetary reward for analyst's successful defense was 10 times the reward for hacker's successful attack. In all conditions, half of the participants were human hackers playing against Nash analysts and half were human analysts playing against Nash hackers. **Results:** Results revealed that monetary rewards for human hackers and analysts caused a decrease in attack and defend actions compared with the baseline. Furthermore, rewarding human hackers for undetected attacks made analysts deviate significantly from their optimal behavior. **Conclusions:** If hackers are rewarded for their undetected attack actions, then this causes analysts to deviate from optimal defend proportions. Thus, analysts need to be trained not become overenthusiastic in defending networks. **Application:** Applications of our results are to networks where the influence of monetary rewards may cause information theft and system damage.

SENSORY AND PERCEPTUAL PROCESSES

Cheryl Sihui Tay, Thorsten Sterzing, Chen Yen Lim, Rui Ding, Pui Wah Kong. *Overall Preference of Running Shoes Can Be Predicted by Suitable Perception Factors Using a Multiple Regression Model*. pp. 432–441.

Objective: This study examined (a) the strength of four individual footwear perception factors to influence the overall preference of running shoes and (b) whether these perception factors satisfied the nonmulticollinear assumption in a regression model. **Background:** Running footwear must fulfill multiple functional criteria to satisfy its potential users. Footwear perception factors, such as fit and cushioning, are commonly used to guide shoe design and development, but it is unclear whether running-footwear users are able to differentiate one factor from another. **Methods:** One hundred casual runners assessed four running shoes on a 15-cm visual analogue scale for four footwear perception factors (fit, cushioning, arch support, and stability) as well as for overall preference during a treadmill running protocol. **Results:** Diagnostic tests showed an absence of multicollinearity between factors, where values for tolerance ranged from .36 to .72, corresponding to variance inflation factors of 2.8 to 1.4. The multiple regression model of these four footwear perception variables accounted for 77.7% to 81.6% of variance in overall preference, with each factor explaining a unique part of the total

variance. **Conclusion:** Casual runners were able to rate each footwear perception factor separately, thus assigning each factor a true potential to improve overall preference for the users. The results also support the use of a multiple regression model of footwear perception factors to predict overall running shoe preference. **Application:** Regression modeling is a useful tool for running-shoe manufacturers to more precisely evaluate how individual factors contribute to the subjective assessment of running footwear.

SIMULATION AND VIRTUAL REALITY

Hanna Bellem, Malte Klüver, Michael Schrauf, Hans-Peter Schöner, Heiko Hecht, Josef F. Krems. *Can We Study Autonomous Driving Comfort in Moving-Base Driving Simulators? A Validation Study*. pp. 442–456.

Objective: To lay the basis of studying autonomous driving comfort using driving simulators, we assessed the behavioral validity of two moving-base simulator configurations by contrasting them with a test-track setting. **Background:** With increasing level of automation, driving comfort becomes increasingly important. Simulators provide a safe environment to study perceived comfort in autonomous driving. To date, however, no studies were conducted in relation to comfort in autonomous driving to determine the extent to which results from simulator studies can be transferred to on-road driving conditions. **Method:** Participants ($N = 72$) experienced six differently parameterized lane-change and deceleration maneuvers and subsequently rated the comfort of each scenario. One group of participants experienced the maneuvers on a test-track setting, whereas two other groups experienced them in one of two moving-base simulator configurations. **Results:** We could demonstrate relative and absolute validity for one of the two simulator configurations. Subsequent analyses revealed that the validity of the simulator highly depends on the parameterization of the motion system. **Conclusion:** Moving-base simulation can be a useful research tool to study driving comfort in autonomous vehicles. However, our results point at a preference for subunity scaling factors for both lateral and longitudinal motion cues, which might be explained by an underestimation of speed in virtual environments. **Application:** In line with previous studies, we recommend lateral- and longitudinal-motion scaling factors of approximately 50% to 60% in order to obtain valid results for both active and passive driving tasks.

SURFACE TRANSPORTATION

Sebastian Hergeth, Lutz Lorenz, Josef F. Krems. *Prior Familiarization With Takeover Requests Affects Drivers' Takeover Performance and Automation Trust*. pp. 457–470.

Objective: The objective for this study was to investigate the effects of prior familiarization with takeover requests (TORs) during conditional automated driving on drivers' initial takeover performance and automation trust. **Background:** System-initiated TORs are one of the biggest concerns for conditional automated driving and have been studied extensively in the past. Most, but not all, of these studies have included training sessions to familiarize participants with TORs. This makes them hard to compare and might obscure first-failure-like effects on takeover performance and automation trust formation. **Method:** A driving simulator study compared drivers' takeover performance in two takeover situations across four prior familiarization groups (no familiarization, description, experience, description and experience) and automation trust before and after experiencing the system. **Results:** As hypothesized, prior familiarization with TORs had a more positive effect on takeover performance in the first than in a subsequent takeover situation. In all groups, automation trust increased after participants experienced the system. Participants who were given no prior familiarization with TORs reported highest automation trust both before and after experiencing the

system. **Conclusion:** The current results extend earlier findings suggesting that prior familiarization with TORs during conditional automated driving will be most relevant for takeover performance in the first takeover situation and that it lowers drivers' automation trust. **Application:** Potential applications of this research include different approaches to familiarize users with automated driving systems, better integration of earlier findings, and sophistication of experimental designs.

Katja Kircher, Christer Ahlstrom. *Minimum Required Attention: A Human-Centered Approach to Driver Inattention*. pp. 471–484.

Objective: To propose a driver attention theory based on the notion of driving as a satisficing and partially self-paced task and, within this framework, present a definition for driver inattention. **Background:** Many definitions of driver inattention and distraction have been proposed, but they are difficult to operationalize, and they are either unreasonably strict and inflexible or suffer from hindsight bias. **Method:** Existing definitions of driver distraction are reviewed and their shortcomings identified. We then present the minimum required attention (MiRA) theory to overcome these shortcomings. Suggestions on how to operationalize MiRA are also presented. **Results:** MiRA describes which role the attention of the driver plays in the shared "situation awareness of the traffic system." A driver is considered attentive when sampling sufficient information to meet the demands of the system, namely, that he or she fulfills the preconditions to be able to form and maintain a good enough mental representation of the situation. A driver should only be considered inattentive when information sampling is not sufficient, regardless of whether the driver is concurrently executing an additional task or not. **Conclusions:** The MiRA theory builds on well-established driver attention theories. It goes beyond available driver distraction definitions by first defining what a driver needs to be attentive to, being free from hindsight bias, and allowing the driver to adapt to the current demands of the traffic situation through satisficing and self-pacing. MiRA has the potential to provide the stepping stone for unbiased and operationalizable inattention detection and classification.

Marco Costa, Leonardo Bonetti, Manuela Bellelli, Claudio Lantieri, Valeria Vignali, Andrea Simone. *Reflective Tape Applied to Bicycle Frame and Conspicuity Enhancement at Night*. pp. 485–500.

Objective: Four studies were conducted to assess bicyclist conspicuity enhancement at night by the application of reflective tape (ECE/ONU 104) to the bicycle rear frame and to pedal cranks. **Background:** Previous studies have tested the benefits of reflective markings applied to bicyclist clothing. Reflective jackets however need to be available and worn while reflective markings enhance conspicuity without any active behavior by the bicyclist. **Method:** In the first study, reflective tape was applied to the rear frame. Detection distance was compared in four conditions: control, rear red reflector, high visibility jacket, and reflective tape. In the second study, the same conditions were studied with night street lighting on and off. In the third study, detection and recognition distances were evaluated in rainy conditions. In the fourth study, visibility was assessed with the reflective tape applied to pedal cranks. **Results:** In the first study, the application of reflective markings resulted in a detection distance of 168.28 m. In the second study, the detection distance with reflective markings was 229.74 m with public street light on and 256.41 m with public street light off. In rainy conditions, detection distance using the reflective markings was 146.47 m. Reflective tape applied to pedal cracks resulted in a detection distance of 168.60 m. **Conclusion:** Reflective tape applied to the rear bicycle frame can considerably increase bicyclist conspicuity and safety at night. **Application:** Reflective tape is highly recommended to complement anterior and rear lights in bicycle riding at night.