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SPECIAL SECTIONS ISSUE

Anthony D. McDonald, Nilesh Ade, S. Camille Peres. *Predicting Procedure Step Performance From Operator and Text Features: A Critical First Step Toward Machine Learning-Driven Procedure Design*. pp. 701–717.

Objective: The goal of this study is to assess machine learning for predicting procedure performance from operator and procedure characteristics. **Background:** Procedures are vital for the performance and safety of high-risk industries. Current procedure design guidelines are insufficient because they rely on subjective assessments and qualitative analyses that struggle to integrate and quantify the diversity of factors that influence procedure performance. **Method:** We used data from a 25-participant study with four procedures, conducted on a high-fidelity oil extraction simulation to develop logistic regression (LR), random forest (RF), and decision tree (DT) algorithms that predict procedure step performance from operator, step, readability, and natural language processing-based features. Features were filtered using the Boruta approach. The algorithms were trained and optimized with a repeated 10-fold cross-validation. After training, inference was performed using variable importance and partial dependence plots. **Results:** The RF, DT, and LR algorithms with all features had an area under the receiver operating characteristic curve (AUC) of 0.78, 0.77, and 0.75, respectively, and significantly outperformed the LR with only operator features (LROP), with an AUC of 0.61. The most important features were experience, familiarity, total words, and character-based metrics. The partial dependence plots showed that steps with fewer words, abbreviations, and characters were correlated with correct step performance. **Conclusion:** Machine learning algorithms are a promising approach for predicting step-level procedure performance, with acknowledged limitations on interpolating to nonobserved data, and may help guide procedure design after validation with additional data on further tasks. **Application:** After validation, the inferences from these models can be used to generate procedure design alternatives.

P. A. Hancock, Ann Crichton-Harris, Abigail Sellen,Thomas B. Sheridan, Gabriella M. Hancock. *A Distracted Scientist: The Life and Contributions of John Senders*. pp. 718–722.

Objective: To provide an evaluative and personal overview of the life and contributions of Professor John Senders and to introduce this Special Issue dedicated to his memory. **Background:** John Senders made many profound contributions to HF/E. These various topics are exemplified by the range of papers which compose the Special Issue. Collectively, these works document and demonstrate the impact of his many valuable research works. **Method:** The Special Issue serves to summarize Senders' collective body of work as can be extracted from archival sources. This introductory paper recounts a series of remembrances derived from personal relationships, as well as the products of cooperative investigative research. **Results:** This collective evaluative process documents Senders' evident and deserved status in the highest pantheon of HF/E pioneers. It records his extraordinary life, replete with accounts of his insights and joie de vivre in exploring and explaining the world which surrounded him. **Applications:** Senders' record of critical contributions provides the example, par excellence, of the successful and fulfilling life in science. It encourages all, both researchers and practitioners alike, in their own individual search for excellence.

Y. B. Eisma, P. A. Hancock, J. C. F. de Winter. *On Senders's Models of Visual Sampling Behavior*. pp. 723–736.

Objective: We review the sampling models described in John Senders's doctoral thesis on "visual sampling processes" via a ready and accessible exposition. **Background:** John Senders left a significant imprint on human factors/ergonomics (HF/E). Here, we focus on one preeminent aspect of his career, namely visual attention. **Methods:** We present, clarify, and expand the models in his thesis through computer simulation and associated visual illustrations. **Results:** One of the key findings of Senders's work on visual sampling concerns the linear relationship between signal bandwidth and visual sampling rate. The models that are used to describe this relationship are the periodic sampling model (PSM), the random constrained sampling model (RCM), and the conditional sampling model (CSM). A recent replication study that used results from modern eye-tracking equipment showed that Senders's original findings are manifestly replicable. **Conclusions:** Senders's insights and findings withstand the test of time and his models continue to be both relevant and useful to the present and promise continued impact in the future. **Application:** The present paper is directed to stimulate a broad spectrum of researchers and practitioners in HF/E and beyond to use these important and insightful models.

Ting Zhang, Jing Yang, Nade Liang, Brandon J. Pitts, Kwaku Prakah-Asante, Reates Curry, [...]. *Physiological Measurements of Situation Awareness: A Systematic Review*. pp. 737–758.

Objective: The goal of this systematic literature review is to investigate the relationship between indirect physiological measurements and direct measures of situation awareness (SA). **Background:** Across different environments and tasks, assessments of SA are often performed using techniques designed specifically to directly measure SA, such as SAGAT, SPAM, and/or SART. However, research suggests that indirect physiological sensing methods may also be capable of predicting SA. Currently, it is unclear which particular physiological approaches are sensitive to changes in SA. **Method:** Seven databases were searched using the PRISMA reporting guidelines. Eligibility criteria included human-subject experiments that used at least one direct SA assessment technique, as well as at least one physiological measurement. Information extracted from each article was the physiological metric(s), the direct SA measurement(s), the correlation between these two metrics, and the experimental task(s). All studies

underwent a quality assessment. **Results:** Twenty-five articles were included in this review. Eye tracking techniques were the most commonly used physiological measures, and correlations between conscious aspects of eye movement measures and direct SA scores were observed. Evidence for cardiovascular predictors of SA were mixed. EEG studies were too few to form strong conclusions, but were consistently positive. **Conclusion:** Further investigation is needed to methodically collect more relevant data and comprehensively model the relationships between a wider range of physiological measurements and direct assessments of SA. **Application:** This review will guide researchers and practitioners in methods to indirectly assess SA with sensors and highlight opportunities for future research on wearables and SA.

E. Leslie Cameron, Per Møller, Keith S. Karn. *Effects of COVID-19 on Sense of Smell: Human Factors/Ergonomics Considerations*. pp. 759–765

Objective: We review the effects of COVID-19 on the human sense of smell (olfaction) and discuss implications for human-system interactions. We emphasize how critical smell is and how the widespread loss of smell due to COVID-19 will impact human-system interaction. **Background:** COVID-19 reduces the sense of smell in people who contract the disease. Thus far, olfaction has received relatively little attention from human factors/ergonomics professionals. While smell is not a primary means of human-system communication, humans rely on smell in many important ways related to both quality of life and safety. **Method:** We briefly review and synthesize the rapidly expanding literature through September 2020 on the topic of smell loss caused by COVID-19. We interpret findings in terms of their relevance to human factors/ergonomics researchers and practitioners. **Results:** Since March 2020 dozens of articles have been published that report smell loss in COVID-19 patients. The prevalence and duration of COVID-19-related smell loss is still under investigation, but the available data suggest that it may leave many people with long-term deficits and distortions in sense of smell. **Conclusion:** We suggest that the human factors/ergonomics community could become more aware of the importance of the sense of smell and focus on accommodating the increasing number of people with reduced olfactory performance. **Application:** We present examples of how olfaction can augment human-system communication and how human factors/ergonomics professionals might accommodate people with olfactory dysfunction. While seemingly at odds, both of these goals can be achieved.

Barry Strauch. *John Senders, Human Error, and System Safety*. pp. 766–778.

Objective: I examine John Senders' work and discuss his influence on the study of error causation,error mitigation, and sociotechnical system safety. **Background:** John Senders' passing calls for an evaluation of the impact of his work. **Method:** I review literature and accident investigation findings to discuss themes in Senders' work and potential associations between that work and error causation and system safety. **Results:** Senders consistently emphasized empirical rigor and theoretical exploration in his research, with the desire to apply that work to enhance human performance. He has contributed to changing the way error has been viewed, and to developing and implementing programs and techniques to mitigate error. While a causal relationship between Senders' work and safety cannot be established, an association can be drawn between his research and efforts to mitigate error. **Conclusion:** Because of Senders' work, we have a better understanding of error causation and enhanced ways of mitigating system errors. However, new sources of error, involving advanced systems and operators' knowledge and understanding of their functionalities can, if not addressed, degrade system safety. **Application:** Modifications to advanced automation and operator training are suggested, and research to improve operator expertise in interacting with automated systems proposed.

Auður Anna Jónsdóttir, Ziho Kang, Tianchen Sun, Saptarshi Mandal, Ji-Eun Kim. *The Effects of Language Barriers and Time Constraints on Online Learning Performance: An Eye-Tracking Study*. pp. 779–791.

Objective: The goal of this study is to model the effect of language use and time pressure on English as a first language (EFL) and English as a second language (ESL) students by measuring their eye movements in an on-screen, self-directed learning environment. **Background:** Online learning is becoming integrated into learners' daily lives due to the flexibility in scheduling and location that it offers. However, in many cases, the online learners often have no interaction with one another or their instructors, making it difficult to determine how the learners are reading the materials and whether they are learning effectively. Furthermore, online learning may pose challenges to those who face language barriers or are under time pressure. **Method:** The effects of two factors, language use (EFL vs. ESL) and time constraints (high vs. low time pressure), were investigated during the presentation of online materials. The effects were analyzed based on eye movement measures (eye fixation rate—the total number of eye fixations divided by the task duration and gaze entropy) and behavioral measures (correct rate and task completion time). **Results:** The results show that the ESL students had higher eye fixation rates and longer task completion times than the EFL students. Moreover, high time pressure resulted in high fixation rates, short task completion time, low correct rates, and high gaze entropy. **Conclusion and Application:** The results suggest the possibility of using unobtrusive eye movement measures to develop ways to better assist those who struggle with learning in the online environment.

Tuomo Kujala, Katja Kircher, Christer Ahlström. *A Review of Occlusion as a Tool to Assess Attentional Demand in Driving*. pp. 792–808.

Objective: The aim of this review is to identify how visual occlusion contributes to our understanding of attentional demand and spare visual capacity in driving and the strengths and limitations of the method. **Background:** The occlusion technique was developed by John W. Senders to evaluate the attentional demand of driving. Despite its utility, it has been used infrequently in driver attention/inattention research. **Method:** Visual occlusion studies in driving published between 1967 and 2020 were reviewed. The focus was on original studies in which the forward visual field was intermittently occluded while the participant was driving. **Results:** Occlusion studies have shown that attentional demand varies across situations and drivers and have indicated environmental, situational, and inter-individual factors behind the variability. The occlusion technique complements eye tracking in being able to indicate the temporal requirements for and redundancy in visual information sampling. The proper selection of occlusion settings depends on the target of the research. **Conclusion:** Although there are a number of occlusion studies looking at various aspects of attentional demand, we are still only beginning to understand how these demands vary, interact, and covary in naturalistic driving. **Application:** The findings of this review have methodological and theoretical implications for human factors research and for the development of distraction monitoring and in-vehicle system testing. Distraction detection algorithms and testing guidelines should consider the variability in drivers' situational and individual spare visual capacity.

Maryam Zahabi, Vanessa Nasr, Ashiq Mohammed Abdul Razak, Ben Patranella [...]. *Effect of Secondary Tasks on Police Officer Cognitive Workload and Performance Under Normal and Pursuit Driving Situations*. pp. 809–822.

Objective: The objective of this study was to assess the effects of single and multiple secondary tasks on officers' performance and cognitive workload under normal and pursuit driving conditions. **Background:** Motor vehicle crashes are a leading cause of

police line of duty injuries and deaths. These crashes are mainly attributed to the use of in-vehicle technologies and multi-tasking while driving. **Method:** Eighteen police officers participated in a driving simulation experiment. The experiment followed a within-subject design and assessed the effect of single or multiple secondary tasks (via the mobile computer terminal (MCT) and radio) and driving condition (normal vs. pursuit driving) on officers' driving performance, cognitive workload, and secondary task accuracy and reaction time. **Results:** Findings suggested that police officers are protective of their driving performance when performing secondary tasks. However, their workload and driving performance degraded in pursuit conditions as compared to normal driving situations. Officers experienced higher workload when they were engaged with secondary tasks irrespective of the task modality or type. However, they were faster but less accurate in responding to the radio as compared to the MCT. **Conclusion:** Police officers experience high mental workload in pursuit driving situations, which can reduce their driving performance and accuracy when they are engaged in some secondary tasks. **Application:** The findings might be helpful for police agencies, trainers, and vehicle technology manufacturers to modify the existing policies, training protocols, and design of police in-vehicle technologies in order to improve police officer safety.

Joseph A. Cafazzo, Abigail J. Sellen, Don Norman. *Defending Against Medical Error: Personal Reflections on the Legacy of John Senders*. pp. 823–832.

Objective: To honor the legacy of John Senders, a distinguished member of the Human Factors and Ergonomics Society, by a short, personal history of him, but then to honor his legacy by extending it through our own professional opinions, with an emphasis on the study of human error and its implications for healthcare systems—two topics in which he excelled. **Background:** The authors are familiar with the topic and subject matter. One was a friend of Senders for over 50 years. Another was a collaborator and joint author with Senders (as well as his stepdaughter). All three authors have extensive publications in the topic areas. **Method, Results, and Conclusion:** The authors used personal accounts of interactions with Senders at conferences, experiences living and working with him, and a brief review of his most personal, notable publications in healthcare. The reflections indicate a strong resonance on Senders' contributions to system design that are relevant today in healthcare's most challenging period in its history.

Missie Smith, Kiran Bagalkotkar, Joseph L. Gabbard, David R. Large, Gary Burnett. *Isolating the Effect of Off-Road Glance Duration on Driving Performance: An Exemplar Study Comparing HDD and HUD in Different Driving Scenarios*. pp. 833–845.

Objective: We controlled participants' glance behavior while using head-down displays (HDDs) and head-up displays (HUDs) to isolate driving behavioral changes due to use of different display types across different driving environments. **Background:** Recently, HUD technology has been incorporated into vehicles, allowing drivers to, in theory, gather display information without moving their eyes away from the road. Previous studies comparing the impact of HUDs with traditional displays on human performance show differences in both drivers' visual attention and driving performance. Yet no studies have isolated glance from driving behaviors, which limits our ability to understand the cause of these differences and resulting impact on display design. **Method:** We developed a novel method to control visual attention in a driving simulator. Twenty experienced drivers sustained visual attention to in-vehicle HDDs and HUDs while driving in both a simple straight and empty roadway environment and a more realistic driving environment that included traffic and turns. **Results:** In the realistic environment, but not the simpler environment, we found evidence of differing driving behaviors between display conditions, even though participants' glance behavior was similar. **Conclusion:**

Thus, the assumption that visual attention can be evaluated in the same way for different types of vehicle displays may be inaccurate. Differences between driving environments bring the validity of testing HUDs using simplistic driving environments into question. **Application:** As we move toward the integration of HUD user interfaces into vehicles, it is important that we develop new, sensitive assessment methods to ensure HUD interfaces are indeed safe for driving.

AUTOMATION, EXPERT SYSTEMS

Shayne Loft, Adella Bhaskara, Brittany A. Lock, Michael Skinner, James Brooks, Ryan Li, Jason Bell. *The Impact of Transparency and Decision Risk on Human–Automation Teaming Outcomes*. pp. 846–861.

Objective: Examine the effects of decision risk and automation transparency on the accuracy and timeliness of operator decisions, automation verification rates, and subjective workload. **Background:** Decision aids typically benefit performance, but can provide incorrect advice due to contextual factors, creating the potential for automation disuse or misuse. Decision aids can reduce an operator's manual problem evaluation, and it can also be strategic for operators to minimize verifying automated advice in order to manage workload. **Method:** Participants assigned the optimal unmanned vehicle to complete missions. A decision aid provided advice but was not always reliable. Two levels of decision aid transparency were manipulated between participants. The risk associated with each decision was manipulated using a financial incentive scheme. Participants could use a calculator to verify automated advice; however, this resulted in a financial penalty. **Results:** For high- compared with low-risk decisions, participants were more likely to reject incorrect automated advice and were more likely to verify automation and reported higher workload. Increased transparency did not lead to more accurate decisions and did not impact workload but decreased automation verification and eliminated the increased decision time associated with high decision risk. **Conclusion:** Increased automation transparency was beneficial in that it decreased automation verification and decreased decision time. The increased workload and automation verification for high-risk missions is not necessarily problematic given the improved automation correct rejection rate. **Application:** The findings have potential application to the design of interfaces to improve human–automation teaming, and for anticipating the impact of decision risk on operator behavior.

X. Jessie Yang, Christopher Schemanske, Christine Searle. *Toward Quantifying Trust Dynamics: How People Adjust Their Trust After Moment-to-Moment Interaction With Automation*. pp. 862–878.

Objective: We examine how human operators adjust their trust in automation as a result of their moment-to-moment interaction with automation. **Background:** Most existing studies measured trust by administering questionnaires at the end of an experiment. Only a limited number of studies viewed trust as a dynamic variable that can strengthen or decay over time. **Method:** Seventy-five participants took part in an aided memory recognition task. In the task, participants viewed a series of images and later on performed 40 trials of the recognition task to identify a target image when it was presented with a distractor. In each trial, participants performed the initial recognition by themselves, received a recommendation from an automated decision aid, and performed the final recognition. After each trial, participants reported their trust on a visual analog scale. **Results:** Outcome bias and contrast effect significantly influence human operators' trust adjustments. An automation failure leads to a larger trust decrement if the final outcome is undesirable, and a marginally larger trust decrement if the human operator succeeds the task by him/herself. An automation success engenders a greater trust

increment if the human operator fails the task. Additionally, automation failures have a larger effect on trust adjustment than automation successes. **Conclusion:** Human operators adjust their trust in automation as a result of their moment-to-moment interaction with automation. Their trust adjustments are significantly influenced by decision-making heuristics/biases. **Application:** Understanding the trust adjustment process enables accurate prediction of the operators' moment-to-moment trust in automation and informs the design of trust-aware adaptive automation.

BIOMECHANICS, ANTHROPOMETRY, WORK PHYSIOLOGY

Clark R. Dickerson, Alison C. McDonald, Jaclyn N. Chopp-Hurley. *Between Two Rocks and in a Hard Place: Reflecting on the Biomechanical Basis of Shoulder Occupational Musculoskeletal Disorders*. pp. 879–890.

Objective: The aim was to review the biomechanical origins of occupational shoulder damage, while considering the complexity of shoulder mechanics and musculoskeletal consequences of diverse task demands. **Background:** Accessible measures of physical exposures are the primary focus of occupational shoulder assessments and analyses. This approach has led to guidelines and intervention strategies that are often inadequate for mitigating shoulder disorders amongst the complexity of modern workplace demands. Integration of complex shoulder mechanics into occupational assessments, analyses, and interventions is critical for reducing occupational shoulder injury risk. **Method:** This narrative review describes shoulder biomechanics in the context of common injury mechanisms and consequent injuries, with a particular focus on subacromial impingement syndrome. Several modulators of shoulder injury risk are reviewed, including fatigue, overhead work, office ergonomics considerations, and pushing and pulling task configurations. **Results:** Relationships between work requirements, muscular demands, fatigue, and biomechanical tissue loads exist. This review highlights that consideration of specific workplace factors should be integrated with our knowledge of the intricate arrangement and interpersonal variability of the shoulder complex to proactively evaluate occupational shoulder demands and exposures. **Conclusion:** A standard method for evaluating shoulder muscle exposures during workplace tasks does not exist. An integrated approach is critical for improved work design and prevention of shoulder tissue damage and accompanying disability. **Application:** This review is particularly relevant for researchers and practitioners, providing guidance for work design and evaluation for shoulder injury prevention by understanding the importance of the unique and complex mechanics of the shoulder.

HUMAN-COMPUTER INTERACTION, COMPUTER SYSTEMS

Wendell C. Taylor, Jordan R. Williams, Lauren E. Harris, Ross Shegog. *Computer Prompt Software to Reduce Sedentary Behavior and Promote Physical Activity Among Desk-Based Workers: A Systematic Review*. pp. 891–908.

Objective: Do computer prompt software programs at the workplace reduce sitting time and/or increase physical activity at work? **Background:** Many products are promoted and being used in the workplace; however, their effectiveness and use are unknown or the evidence base that they work to change behavior is lacking. **Method:** We searched for relevant papers published between 2005 and 2020. The inclusion criteria were computer prompt software programs installed as behavioral change interventions; interventions implemented during work hours and delivered through a work personal

computer or laptop; and measures of sedentary behavior and/or physical activity. To minimize risk of bias, three recommended best-evidence synthesis criteria were used: random assignment, sample size, and external validity. Based on these criteria, articles were selected and evaluated. **Results:** Six publications met the quality threshold for review. Seven articles did not meet the quality threshold. Four of the six included publications found that computer prompt software programs decreased sedentary behavior and/or increased physical activity. Two publications reported inconsistent results. **Conclusions:** The promising results from this systematic review indicate that there is potential for computer prompt software programs to improve the health of desk-based workers. For conclusive findings, more high-quality, scientific studies are needed. **Application:** The best-evidence publications in this review can serve as a guide in selecting and implementing computer prompt software programs at the workplace to decrease sedentary behavior and increase physical activity.

HUMAN-ROBOT INTERACTION

Yilin Wang, Jing Qiu, Hong Cheng, Xiaojuan Zheng. *Analysis of Human–Exoskeleton System Interaction for Ergonomic Design*. pp. 909–922.

Objective: Lower-limb exoskeleton systems are defined as gait training or walking-assisting devices for spinal cord injury or hemiplegic patients. Crutches, straps, and baffles are designed to protect subjects from falling. However, skin abrasions occur when the interaction forces are too large. In this study, the interaction forces between the human body and an exoskeleton system named the AIDER were measured to confirm whether the design was ergonomic. **Background:** The AIDER system is a wearable lower-limb exoskeleton. It secures a subject by binding on the waist, thighs, shanks, and feet. **Method:** Eight healthy subjects participated in the study. The interaction forces of the waist strap, thigh baffles, shank baffles, and crutch handles were measured by pressure sensors. Ten repetitions were completed in this study. After one repetition, custom comfort questionnaires were completed by the subjects. **Results:** Although a few of the peak values of the maximum intensities of pressure between the hands and crutch handles reached the minimum value of the pain–pressure threshold (PPT), the average pressure intensities were much smaller than the PPT value. **Conclusions:** The results indicated that the mechanical structure and control strategy of the AIDER must be improved to be more ergonomic in the future.

MOTOR BEHAVIOR

Clara Ziane, Benjamin Michaud, Mickaël Begon, Fabien Dal Maso. *How Do Violinists Adapt to Dynamic Assistive Support? A Study Focusing on Kinematics, Muscle Activity, and Musical Performance*. pp. 923–941.

Objective: Assessing violinists' motor and musical performance adaptations to dynamic assistive support (DAS) provided by a passive device, using a force-field adaptation paradigm. **Background:** Up to 93% of instrumentalists are affected by musculoskeletal injuries and particularly violinists. The repetitive nature of their work may lead to muscle fatigue, an injury risk factor. DAS has been used in occupational settings to minimize muscle activations and limit fatigue accumulation. DAS may however affect motor and musical performance. **Method:** Fifteen expert violinists were equipped with reflective markers and surface and intramuscular electromyography (EMG) sensors. Movements, muscle activations, and sound were recorded while participants completed three experimental conditions for which they continuously played a 13-s musical excerpt: Control (no DAS), Adaptation (DAS), and Washout (no DAS). DAS was applied at the left

elbow (violin-holding side). Conditions were repeated 1 week later. Participants later listened to their own audio recordings playing with and without DAS and blindly assessed their performances. Linear mixed models were used to compare DAS and no-DAS conditions' kinematic, EMG, and musical performance data. **Results:** DAS perturbed user kinematics but reduced mean activations of left medial deltoid and superior trapezius. Joint kinematic and muscle activation patterns between DAS and no DAS conditions however remained similar. Musical performance was unchanged with DAS. **Conclusion:** Though DAS modified violinists' upper-limb configurations, resulting kinematics were not detrimental to musical performance. Reduced muscle activations with DAS could contribute to lessening muscle fatigue. **Application:** Although its effect on muscle fatigue should be further investigated, DAS might be useful in preventing violinists' injuries.

SENSORY AND PERCEPTUAL PROCESSES

Steven W. Savage, Lily Zhang, Garrett Swan, Alex R. Bowers. *Head Scanning Behavior Predicts Hazard Detection Safety Before Entering an Intersection*. pp. 942–955.

Objective: We conducted a driving simulator study to investigate scanning and hazard detection before entering an intersection. **Background:** Insufficient scanning has been suggested as a factor contributing to intersection crashes. However, little is known about the relative importance of the head and eye movement components of that scanning in peripheral hazard detection. **Methods:** Eleven older (mean 67 years) and 18 younger (mean 27 years) current drivers drove in a simulator while their head and eye movements were tracked. They completed two city drives (42 intersections per drive) with motorcycle hazards appearing at 16 four-way intersections per drive. **Results:** Older subjects missed more hazards (10.2% vs. 5.2%). Failing to make a scan with a substantial head movement was the primary reason for missed hazards. When hazards were detected, older drivers had longer RTs (2.6s vs. 2.3s), but drove more slowly; thus, safe response rates did not differ between the two groups (older 83%; younger 82%). Safe responses were associated with larger (28.8° vs. 20.6°) and more numerous (9.4 vs. 6.6) gaze scans. Scans containing a head movement were stronger predictors of safe responses than scans containing only eye movements. **Conclusion:** Our results highlight the importance of making large scans with a substantial head movement before entering an intersection. Eye-only scans played little role in detection and safe responses to peripheral hazards. **Application:** Driver training programs should address the importance of making large scans with a substantial head movement before entering an intersection.

SIMULATION AND VIRTUAL REALITY

Patricia R. DeLucia, Adam M. Braly, Bria R. Savoy. *Does the Size-Arrival Effect Occur With an Active Collision-Avoidance Task in an Immersive 3D Virtual Reality Environment?* pp. 956–965.

Objective: Determine whether the size-arrival effect (SAE) occurs with immersive, 3D visual experiences and active collision-avoidance responses. **Background:** When a small near object and a large far object approach the observer at the same speeds, the large object appears to arrive before the small object, known as the size-arrival effect (SAE), which may contribute to crashes between motorcycles and cars. Prior studies of the SAE were limited because they used two dimensional displays and asked participants to make

passive judgments. **Method:** Participants viewed approaching objects using a virtual reality (VR) headset. In an active task, participants ducked before the object hit them. In a passive prediction-motion (PM) judgment, the approaching object disappeared, and participants pressed a button when they thought the object would hit them. In a passive relative TTC judgment, participants reported which of two approaching objects would reach them first. **Results:** The SAE occurred with the PM and relative TTC tasks but not with the ducking task. The SAE can occur in immersive 3D environments but is limited by the nature of the task and display. **Application:** Certain traffic situations may be more prone to the SAE and have higher risk for collisions. For example, in left-turn scenarios (e.g., see Levulis, 2018), drivers make passive judgments when oncoming vehicles are far and optical expansion is slow, and binocular disparity putatively is ineffective. Collision-avoidance warning systems may be needed more in such scenarios than when vehicles are near and drivers' judgments of TTC may be more accurate (DeLucia, 2008).