Presentation Summaries

Session 1 – Lectures
Driver Behavior, Distraction and Crash Risk
Tuesday, June 25, 2019
10:00 am – 11:45 am

2. **In the Context of Whole Trips: New Insights Into Driver Management of Attention and Tasks (2)** Linda Angell, Sean Seaman, Rashmi Payyanadan, Wayne Biever *(Touchstone Evaluations, Inc.)*, Bobbie Seppelt, Bruce Mehler, Bryan Reimer *(Massachusetts Institute of Technology AgeLab, New England University Transportation Center)*

It is becoming increasingly important to understand how drivers strategically manage tasks and thread attention across time, as they drive through varying situations and conditions -- and as they have the opportunity to delegate tasks to vehicle automation while taking up other tasks themselves. To develop an understanding of these higher-level driver behaviors requires a research focus on longer periods of driving -- even on "whole trip" driving. It may also require new tools and methods. Therefore, to explore insights and implications of a "whole trip" focus, data from 10 drivers were analyzed using methods tailored for identifying patterns within larger sequences of driving data than single-task epochs. The results are reported, discussed, and contrasted with more conventional approaches based on single-task epochs.

3. **Mind-Wandering and Driving: Comparing Thought Report and Individual Difference Measures (3)** Heather Walker, Lana Trick *(University of Guelph – CANADA)*

Mind-wandering is a cognitive state in which attention is diverted from the main task and towards more personal thoughts, which can interfere with performance. This study investigated differences in patterns of mind-wandering and driving performance measured during thought-probe versus post-task self-report conditions, and further differentiated based on individual differences in working memory—as measured by the *Operation Span (OSPAN)* and *Sustained Attention to Response Task (SART)*. Participants completed two 30-minute drives. Those in the thought-probe condition were asked whether they were thinking of driving; the proportion of trials where they answered "no" was used as the index of mind-wandering. In the post-task condition participants estimated the percentage of time they had mind-wandered during each drive. Speed, steering variability, headway distance, and hazard response time to a lead vehicle braking were also measured. Results showed that the magnitude of mind-wandering captured in the thought-probe condition was greater than in the post-task condition, though hazard response times were also faster despite greater mind-wandering reports. Higher *OSPAN* scores were associated with greater reports of mind-wandering, but only in the post-task condition. Conversely, in the post-task condition those with low *SART* scores responded slower to hazards than those with high scores; in the thought-probe condition these groups did not differ. Findings indicate a differential impact of report-type on participant experience, emphasizing the need for more covert measures of mind-wandering—e.g., eye-tracking or electroencephalography—that provide accurate estimates of task engagement but don't interfere with task flow.

4. **Vehicle Familiarity and Relative Risk of Fatal Crash Involvement (4)** Brian C. Tefft, Aaron Benson, William Horrey *(AAA Foundation for Traffic Safety)*

Lack of familiarity with a vehicle has been associated with increased crash risk independent of overall driving experience (Perel, 1983). This may pose an underappreciated safety risk in the context of complex and rapidly evolving driver assistance technologies and driver-vehicle interfaces, especially when people drive newly purchased, rented, or borrowed vehicles. The current study estimates the relationship between vehicle ownership and responsibility for crashes using data from 231,056 drivers

involved in fatal crashes in the United States in years 2008-2017. A driver was considered responsible for the crash if police indicated that the driver's pre-crash actions contributed to the occurrence of the crash, and non-responsible otherwise. Driver-, vehicle-, and roadway factors that might also influence crash risk were controlled using logistic regression. Drivers of vehicles registered to another person and drivers of rental vehicles had 1.15 and 1.20 times the odds of responsibility for their crashes, respectively, compared with drivers of their own vehicles. If non-responsible drivers approximate a random sample of all drivers present at the times and places of fatal crashes, these results approximate ratios of responsible involvement in fatal crashes per unit of driving exposure. While ownership is an imperfect proxy for familiarity and may be associated with crash risk by other mechanisms unrelated to familiarity, results are consistent with the hypothesis that drivers of unfamiliar vehicles experience elevated crash risk.

5. **Recognition of Manual Driving Distraction Through Deep-Learning and Wearable Sensing (5)** Li Li, Ziyang Xie, Xu Xu *(North Carolina State University)*

The goal of this study is to design a novel framework incorporating deep-learning techniques and wearable sensors to recognize manual distractions during driving. Manual distraction is defined as hands off the wheel for any reason (e.g. trying to get a cell phone). In this preliminary study, participants were tasked to drive in city street and highway scenarios in a driving simulator. Verbal instructions prompted participants to perform various manual distraction tasks. The motion of driver's right wrist during driving was recorded by a wearable inertial measurement unit. A deep-learning technique called convolutional neural network (CNN) was then constructed and trained based on 72% of the experiment trials, and evaluated by the remaining 28% of trials. The results indicated that the convolutional neural network is able to recognize the type of manual distraction task based on the right wrist motion with 87.0% accuracy and F1-score of 0.87. The results indicated that there is a good potential to apply deep-learning techniques and wearable sensing to monitor driver's inattention status.

6. **The Relationship between Sensation Seeking and Speed Choice in Road Environments with Different Levels of Risk (6)** Tyron Louw, Foroogh Hajiseyedjavadi, Hamish Jamson, Richard Romano, Erwin Boer, Natasha Merat *(University of Leeds – UNITED KINGDOM)*

This paper presents the results of a driving simulator study conducted for the UK-funded HumanDrive project, which aims to develop natural, human-like autonomous vehicle control. As part of that effort, this paper examines whether the established relationship between different sensation seeking (SS) traits and speed choice holds true across a range of driving scenarios, with different levels of contextual risk. Risk was introduced by varying a number of factors, including the environment (rural/urban), and the road edge context (low risk, static risk, potentially dynamic risk). Correlation analysis was performed between sensation seeking and the 95th percentile of vehicle speed for roads with different levels of risk, also considering age and gender. The results indicated that, overall, SS was significantly positively correlated with the 95th percentile of vehicle speed, and particularly for drivers under 40 years. SS was also found to correlate positively with speed choice at all risk levels, however, the effect was more pronounced in road environments that were classified as less risky. These findings have design implications for the development of autonomous vehicle control models.

7. **Impact of Headlight Glare on Pedestrian Detection with Unilateral Cataract (7)** Sailaja Manda, Rachel Castle, Alex D. Hwang, Eli Peli *(Schepens Eye Research Institute, Harvard Medical School)*

   Detecting pedestrians while driving at night is difficult, and is further impeded by oncoming headlight glare (HLG). Cataracts increase intraocular light scattering, making the task even more challenging. We used a within-subjects repeated measures design to determine the impact of HLG on driving with unilateral cataract. Pedestrian detection performance of six young normal vision (NV) subjects was measured with clear lens glasses and with simulated unilateral cataract (a 0.8 Bangerter foil) glasses. The subjects drove night-time scenarios in a driving simulator with and without custom simulated headlight glare. With simulated unilateral cataracts, pedestrian detection rates decreased and response times increased with oncoming HLG. We verified these effects with six patients who already underwent cataract surgery for one eye and were scheduled to get cataract surgery in the other eye. We measured their performance before and after the second cataract surgery. The results were similar to those obtained with the simulated unilateral cataract, confirming that a negative impact of HLG persists with untreated cataract in one eye.

8. **MOVE-IT: Development and Evaluation of Efficient Training Procedures for Elderly Road Users to Support their Driving Competence (8)** Stefanie Schoch, Ruth Julier, Ramona Kenntner-Mabiala, Yvonne Kaussner *(Würzburg Institute for Traffic Sciences (WIVW) – GERMANY)*

   Evaluated training measures for improvement of elderly drivers' driving competency lead to a considerable better driving performance, but so far are time-consuming and costly, making its nationwide implementation difficult. The aim of the present project was to develop and evaluate a modular training program for elderly drivers, which is easy, low-cost and time efficient. Based on an individual profile including driving related performance deficits and the individual need for mobility, a personalized training program is compiled. It includes individualized driving exercises, group sessions to refresh knowledge of traffic rules, consultation regarding the compensation of age-related restrictions and the use of driver assistance systems. For evaluation, a pre-post-design with 30 subjects was realized. The driving performance was measured through different performance parameters and increased through participation. Driving instructors rated the program useful and feasible. Participants were very satisfied with the concept of the training and evaluated it as being helpful. Therefore, this training concept seems to be promising for future use beyond the project work. A scientifically accompanied introduction of the training concept to several driving schools is recommended.

9. **Real-Time Effects of Age-Related Cognitive Dysfunction on Driver Vehicle Control (9)** Jennifer Merickel, Robin R. High *(University of Nebraska Medical Center)*, Jeffrey D. Dawson *(University of Iowa)*, Matthew Rizzo *(University of Nebraska Medical Center)*

   This study tackles the need to understand how driver behavior deteriorates in advancing age, with the direct goal of improving real-world assessments of age-related cognitive dysfunction and safety in older drivers. Older drivers are at-risk for cognitive dysfunction, which may lead to dementia and elevates the risk of errors that may lead to crashes. Prior research on older drivers is critically limited by studying behavior in laboratory and controlled settings. To advance the field and overcome these limitations, we combine sensor-based technologies for continuous, real-world monitoring of driver behavior with comprehensive assessments of older drivers' cognitive function. We assess patterns of

vehicle control across each driver's personal profile of cognitive function and link age-related cognitive dysfunction to changes in safety-relevant vehicle control. We find that age-related cognitive dysfunction effects braking and accelerating behaviors, but not steering behaviors, across wide-spread driving environments. Older drivers with worse cognitive function drove less yet did not reduce exposure to specific environments that may carry greater risk. Exposure patterns suggest potential maladaptive compensatory behavioral tradeoffs that lessen older driver mobility without sufficiently mitigating safety risks. Results demonstrate that older driver behavior is highly context dependent, suggesting specific targets for interventions to improve safety while preserving mobility and quality of life, and underscore the value of using the vehicle for sensing and monitoring driver functional capacity and subsequent risk for age-related cognitive dysfunction.

10. **The Impact of Crosswalk Design on Driver Performance: Implications for Pedestrian Safety (10)** Huizhong Guo, Ning Li, Linda Ng Boyle *(University of Washington),* John K. Lenneman, Tina Sayer *(Toyota Collaborative Safety Research Center)*

Crosswalks are designed to enhance pedestrian visibility and right-of-way. This study examines driver performance at two different crosswalks with different pedestrian signal designs: (1) Rectangular Rapid Flashing Beacons (RRFBs) and (2) Pedestrian Hybrid Beacons (PHB). Mixed effects linear models showed that the drivers' speed significantly decreased when a signal was activated, with a larger decrease observed at a PHB signal when there was no lead vehicle. Mixed effects logistic models showed that drivers' likelihood to change distracting status was higher when a pedestrian signal was activated. The change could occur in both directions: from being engaged to not and from not engaged to distracted. Males and females responded differently to the RRFB in terms of speed differential and likelihood to engage in distractions from an undistracted state. In summary, PHB was able to decrease driver speed more effectively, while RRFB appeared to promote less travel delays for drivers.

11. **Dynamics of Pedestrian Crossing Decisions Based on Vehicle Trajectories in Large-Scale Simulated and Real-World Data (11)** Jack Terwilliger, Michael Glazer, Henri Schmidt *(Massachusetts Institute of Technology),* Josh Domeyer, Heishiro Toyoda *(Toyota Collaborative Safety Research Center),* Bruce Mehler, Bryan Reimer *(Massachusetts Institute of Technology AgeLab & New England University Transportation Center),* Lex Fridman *(Massachusetts Institute of Technology)*

Humans, as both pedestrians and drivers, generally skillfully navigate traffic intersections. Despite the uncertainty, danger, and the non-verbal nature of communication commonly found in these interactions, there are surprisingly few collisions considering the total number of interactions. As the role of automation technology in vehicles grows, it becomes increasingly critical to understand the relationship between pedestrian and driver behavior: how pedestrians perceive the actions of a vehicle/driver and how pedestrians make crossing decisions. The relationship between time-to-arrival (TTA) and pedestrian gap acceptance (i.e., whether a pedestrian chooses to cross under a given window of time to cross) has been extensively investigated. However, the dynamic nature of vehicle trajectories in the context of non-verbal communication has not been systematically explored. Our work provides evidence that trajectory dynamics, such as changes in TTA, can be powerful signals in the non-verbal communication between drivers and pedestrians. Moreover, we investigate these effects in both simulated and real-world datasets, both larger than have previously been considered in literature to the best of our knowledge.

12. **Drivers' Assessment of Hazard Perception (12)** Daniela Barragan, Yi-Ching Lee (*George Mason University*)

Encountering dangerous situations while driving is ubiquitous. Existing research suggest that specific populations such as, novice drivers are more prone to errors in detecting and responding to driving hazards. Hazard perception training programs have been developed in attempts to improve or accelerate the acquisition of such skills. However, drivers' attitudes and knowledge regarding vulnerable populations and hazard perception training programs remain largely unknown. Three-hundred-five participants completed an online survey assessing their beliefs about influential factors affecting hazard detection and response, perceived usefulness and preferred types of training programs, and self-assessment of driving skills. Although many existing training programs are computer-based, participants preferred on-road hazard perception training. Such findings may assist in improving existing programs, which currently fail to show near- and far-transfer effects. Similarly, novice drivers reported being most likely to engage in training programs – possibly linked to their reported high value of the usefulness of such programs and awareness of their vulnerability to commit errors. Although autonomous vehicles should mitigate these errors, researchers and government officials suggest automated vehicles will not be commercially available for 10 years. Therefore, the results of the present study provide insight into drivers' beliefs about dangerous situations, which may prove useful in developing and improving training programs aimed at mitigating crash risk.

13. **Withdrawn (13)**

14. **Hacking Nonverbal Communication between Pedestrians and Vehicles in Virtual Reality (14)** Henri Schmidt, Jack Terwilliger, Dina AlAdawy, Lex Fridman (*Massachusetts Institute of Technology)*

We use an immersive virtual reality environment to explore the intricate social cues that underlie non-verbal communication involved in a pedestrian's crossing decision. We "hack" non-verbal communication between pedestrian and vehicle by engineering a set of 15 vehicle trajectories, some of which follow social conventions and some that break them. By subverting social expectations of vehicle behavior we show that pedestrians may use vehicle kinematics to infer social intentions and not merely as the state of a moving object. We investigate human behavior in this virtual world by conducting a study of 22 subjects, with each subject experiencing and responding to each of the trajectories by moving their body, legs, arms, and head in both the physical and the virtual world. Both quantitative and qualitative responses are collected and analyzed, showing that, in fact, social cues can be engineered through vehicle trajectory manipulation. In addition, we demonstrate that immersive virtual worlds which allow the pedestrian to move around freely, provide a powerful way to understand both the mechanisms of human perception and the social signaling involved in pedestrian-vehicle interaction.

15. **Design and Evaluation of Adaptive Collision Avoidance Systems (15)** Husam Muslim, Makoto Itoh (*University of Tsukuba – JAPAN*)

Taking a human factors approach, the present study aims at improving driver interaction with automation by improving driver trust in and understanding of the system and enhancing system design. First, a driving experiment was conducted to investigate how driver understanding of the system capabilities effects driver performance and trust. The experiment compared two driver

assistance systems for avoiding collisions during critical lane change: one was a haptic steering control that manipulates the steering wheel friction torque, and the other was an automatic steering control that decouples the driver during critical conditions. The results indicate that, especially in critical situations when driver expectation of the system and system capabilities were not aligned, the driver-system interaction was significantly affected by the way control is allocated between agents. To improve system design in terms of functional allocation and capabilities, the study proposes an enhanced adaptive collision avoidance system in which control is allocated dynamically depending on the situation. This system was assessed in a second driving experiment. While the diver-system interactions significantly improved compared to the haptic and automatic steering control systems, in terms of safety, it did not perform as well as expected. A third experiment, using long term simulator training, was conducted to enhance drivers' understanding of and trust in the system. The training interaction revealed that drivers adapted more easily to the system, improving driver performance, system effectiveness, and safety. The findings highlight how user training can improve human-automation interaction.

16. **A Survey Study Measuring People's Preferences Towards Automated and Non-Automated Ridesplitting (16)** Fangda Zhang, Shannon Roberts (*University of Massachusetts Amherst*), Claudia Goldman *(General Motors Israel Advanced Technical Center – ISRAEL)*

Ridesplitting is both common and important as it facilitates daily transportation needs. Alongside an increase in ridesplitting is the introduction of automated driving systems, which together, bring out the possibility of automated ridesplitting. However, previous studies have identified resistance in the acceptance of automated driving systems. In light of past research on automated driving systems, we used a survey to compare people's preferences of automated ridesplitting to non-automated ridesplitting. Statistical and text mining techniques were leveraged to analyze the results. We found similarities in the numeric responses of important factors concerning automated and non-automated ridesplitting whereas there were large differences between automated and non-automated ridesplitting in the text responses. Additionally, people prioritized cost and time in both automated and non-automated ridesplitting. These results can be used in the design of future ridesplitting services, especially with respect to increasing acceptance of and trust in automated ridesplitting services.

17. **Dark Personality and Road Crashes: Mediating Role of Driver Vengeance and Violations (17)** Nebi Sümer (*Sabanci University – TURKEY*), Bahar Tümer, Uluğhan Ergin, Seda Merve Şahin (*Middle East Technical University – TURKEY*)

Aggressive driving and road rage are increasingly leading to Motor Vehicle Collisions (MVC), especially in the developing countries. Considering that malevolent personality characteristics, such as dark triad (narcissism, Machiavellianism, and psychopathy) create a tendency for vengeful and aggressive driving, we examined the power of personality variables in predicting MVC. Specifically, using Contextual Mediated Model (Sümer, 2003), we tested a double mediation model in which driving anger and vengeance mediate the relationships between personality characteristics (Big Five Traits and Dark Triad) and driving violations, and in turn, driving violations mediate the link between driving anger/vengeance and risky driving outcomes (MVC and traffic tickets). Turkish drivers (N = 485, female = %51) completed the measures of personality, aberrant driving behaviors, vengeance, and driving anger. Results of path analyses revealed that whereas narcissism and neuroticism are the critical predictors for aggressive driving Machiavellianism is the strongest predictor of driving vengeance. Moreover, Machiavellianism both directly and indirectly via driving vengeance and violations predicted MVC. Personality variables and mediating variables explained 21% and 26% of the variance in MVC and traffic tickets, respectively, values much higher than those previously reported in the past research. Findings have critical implications for the assessment of aggressive drivers and potential for road rage.

18. **Is Driving Simulation a Viable Method for Examining Drivers' Ethical Choices? An Exploratory Study (18)** Anuj Pradhan (*University of Massachusetts Amherst*), Heejin Jeong, Brittany Ross (*University of Michigan*)

Advanced vehicle technologies promise improved road safety but may still be subjected to situations where choices have to be made regarding safety impact to other road users. There is debate about the principles that should guide the programming of choices into automation algorithms, and an acknowledgment that choices made by automation may be subject to more scrutiny than those by humans. To better understand the landscape of decisions that human drivers encounter, it is important to examine the rationale, calculus, and motivations behind such choices. While there are various methods to examine human decision making, doing so in an ecologically valid manner is challenging, especially in this context of driving. To that end, this study was conducted to examine if driving simulation could help understand drivers' ethical choices. Participants drove a route in a driving simulator that was programmed to end in a crash situation, one that placed the driver in a position of choosing between two crash outcomes. Participants were asked, after the fact, about their perceptions of the simulation and their decisions. Results indicate that drivers generally accepted simulation as realistic, but their post-experiment choices did not align with their actual decisions during the drive. Findings may have implications for the experimental study of ethical behaviors.

19. **Drivers Fail to Calibrate to Optic Flow Speed Changes During Automated Driving, (19)** Callum Mole, Gustav Markkula, Oscar Giles (*University of Leeds – UNITED KINGDOM*), Yuki Okafuji (*Kobe University – JAPAN),* Richard Romano, Natasha Merat, Richard Wilkie (*University of Leeds – UNITED KINGDOM*)

The human perceptual-motor system remains well-calibrated during manual driving supporting successful steering despite changing conditions, such as alterations in vehicle speed. Automated vehicles may interrupt perceptual-motor calibration so that when a driver takes-over control they will not be prepared for the driving conditions. Optic flow is a powerful source of visual information for calibrating to speed changes during manual steering, but it is currently unclear whether humans are sensitive to changes in optic flow speed when they are not in active control of the vehicle (i.e. by relying upon vision alone). Here we used a driving simulator to examine sensitivity to changes in optic flow speed across active (manual steering) and passive (automated steering) modes of control. Optic flow speed was altered independent of vehicle speed. The mismatch between perceived speed and actual speed causes a well-calibrated motor system to be reliably biased. Drivers were asked to take-over manual steering control after a short (~10 s) period of automation. Results showed that manual steering was *not* biased when flow speed was manipulated only in the automated period. One interpretation is that drivers had trouble recalibrating to optic flow changes that occurred during automated driving. If so, this suggests that there will exist a period where the perceptual-motor system is miscalibrated in the early stages of take-over after automated vehicle control.

20. **The Effects of Chewing Gum on the Driving Performance of Emergency Medicine Residents After Overnight Shift Work (20)** Maricel Dela Cruz, Muhammad Masood Khalid, Ahmed Mostafa, Jeffrey Foster, Geoffrey Kaump, Rita G. McKeever, & Michael I. Greenberg (*Drexel University*)

This is a comparison study evaluating the influence of chewing gum on driving performance by computer simulation in emergency medicine residents doing overnight shift work. A total of eleven subjects were tested. Four simulations were randomized to each test subject at different points in the study. Data was analyzed comparing pre- and post-shift tests for each study group, as well as chewing gum versus non-chewing gum use during testing. Results showed no significant difference in lateral deviation, described as the root mean squared of lane departure measured in feet, or braking reaction time, defined as the time to break measured in seconds when triggered by a predetermined cue, in those using gum versus no gum. Between- and within-group differences were assessed by

split-plot analysis measures analysis of variance (ANOVA). Our study showed statistical significance in that divided attention response time, designated as the time in seconds to perform a secondary task while driving, was longer in those driving with chewing gum versus without chewing gum ($p < 0.05$). This pilot study serves as a potential foundation for further investigation into augmenting the driving performance of emergency medicine residents performing overnight shift work with chewing gum use.

21. **An Investigation of Measuring Driver Anger with Electromyography (21)** Christopher Saikalis, John Cliburn, Cedric Portea, Yi-Ching Lee (*George Mason University*)

This research explores a novel approach to measuring driver anger using facial electromyography (EMG) while completing a navigation task on a driving simulator. Participants' anger was induced by traffic events that were frustrating in nature as well as time pressure while having to follow navigational directions. Participants' feeling of anger was assessed multiple times via subjective self-reports while being continuously monitored through a facial EMG. Participants' trait driving anger was assessed using the Driving Anger Scale. Results showed that, compared to baseline measures, participants had significantly higher facial EMG activation values and subjective feelings of anger upon experiencing frustrating events, suggesting facial EMG as a reliable physiological measurement for inferring drivers' feelings of anger. This experimental protocol can be used to assess anger in navigational contexts in future studies.

22. **Effect of Alert Presentation Mode and Hazard Direction on Driver Takeover from an Autonomous Vehicle (22)** Benjamin Cortens, Blair Nonnecke, Lana M. Trick (*University of Guelph – CANADA*)

Autonomous vehicles are becoming increasingly common. Although the level of automation varies between vehicles even the most advanced occasionally require driver input when the driving situation is complex, or the quality of the sensory data is poor. If driver input is needed the system must alert drivers that they will have to take over but these alerts may vary in their effectiveness in prompting rapid driver takeover (time to grip the steering wheel, percentage of appropriate takeover maneuvers) and situational awareness (driver attention to the threat that necessitated take over and understanding for why take over is necessary). In this study, we used a driving simulator operating in autonomous mode to compare 2 alert types (audio-visual, and audio alone) in 3 different takeover scenarios where hazards emerged from the front (a construction zone) or the left or right side (erratic behaviour in another driver: a rogue vehicle heading toward the drivers' lane). We found that the takeover-time was faster after the audio-visual alert than the audio alert and situation awareness was better. The nature and direction of the hazard also had an effect. Situation awareness was poorer for hazards in front of the vehicle (a looming construction zone) as compared to the left and right of the driver (rogue vehicles heading toward the driver). These findings have important implications for interface design in autonomous vehicles.

23. **Effects of Inaccurate Gaze Behavior on Young Drivers' Hazard Anticipation (23)** Sarah Yahoodik (*Old Dominion University*), Nathan Hatfield (*Design Interactive, Inc.*), Yusuke Yamani *(Old Dominion University)*, Siby Samuel (*University of Waterloo – CANADA*)

A previous study (Yamani et al., 2018) demonstrated that the administration of expert eye movement videos following hazard anticipation training can improve the proportion of latent hazards anticipated by young drivers compared to control conditions. The current driving simulator study sought to examine whether the improvements observed in the previous study were merely due to drivers' exposure to videos of the simulated driving scenarios with expert eye movement overlays immediately prior to evaluation, or whether modeling the accuracy of eye movement behavior can lead participants to internalize hazard anticipation skills more effectively. In a between-subject design, 36 drivers (18-21 years) were assigned to one of three experimental conditions – training

only, training plus expert eye movements or training plus novice eye movements. All participants navigated four unique driving scenarios, each with their eye movements tracked and recorded. Analyses of the eye movement data showed that young drivers who saw the expert eye movement (accurate) videos immediately following training anticipated a substantially greater proportion of latent hazards compared to the young drivers that saw novice eye movement (inaccurate) videos following training. The data provide some evidence that drivers were able to successfully map and incorporate correct hazard anticipation glance behavior into their mental models. The findings present some implications for the design and evaluation of eye movement-based training interventions.

24. **Spatially Biased Eye Movements in Older Drivers with Glaucoma and Visual Field Defects (24)** David Anderson, Deepta A. Ghate, Sachin Kedar, Matthew Rizzo (*University of Nebraska Medical Center*)

Patients with glaucoma are at greater driving safety risk due to visual field defects. These driving safety risks may be mitigated by compensatory eye movements. We measured spatial allocation of eye movements in a panoramic driving simulator in 8 drivers with glaucoma and 5 with suspected glaucoma. All completed a driving simulator visual field task under three separate conditions: (1) parked with a naturalistic background (Baseline condition); (2) driving on a rural highway (Driving condition); and (3) driving and completing a competing auditory attention task (PASAT condition). Results showed that: (1) drivers with larger binocular visual field defects showed more restricted, spatially biased eye movements, and (2) greater task load led to more spatially biased eye movements in drivers with larger binocular visual field defects. Findings provide preliminary evidence of eye movement patterns that may reflect compensatory behaviors in drivers with glaucomatous visual fields. Better understanding of the relationship between visual field deficits, eye movement patterns, and driving in glaucoma can help inform countermeasures to improve safety and mobility in drivers with visual impairments.

25. **Comparing Performance when Using a New Style Large Touchscreen Compared to a Traditional In-Vehicle Touchscreen (25)** Timothy Brown, Dawn Marshall (*University of Iowa*), Neil Lerner (*Westat*)

New in-vehicle touch screen displays are increasing in size and complexity, and the effect on distraction to the driver associated with their use is unclear. Large touchscreen displays, such as those in the Tesla, provide a richer display environment as well as a larger area compared to traditional in-vehicle touchscreens even when the same capabilities are available. This simulator study examines how performing the same tasks on two different types on in-vehicle displays impacts glance behavior, vehicle control and workload. Results show that the large touchscreen results in longer average glance lengths, a greater percentage of glances of more than 2-seconds, but fewer glances. For vehicle control, there were no differences in lateral control, but the large touchscreen showed less variability in speed and speed range overall, but not uniformly across the tasks. Drivers did not report different levels of workload between the two interfaces. The results point to the need for careful design to minimize the likelihood of long glances as vehicle design moves to larger displays.

26. **Using a Driving Simulator to Create a Visual Search Test for Drivers with Parkinson's Disease (26)** Hannes Devos (*University of Kansas Medical Center*), Maud Ranchet (*IFSTTAR – FRANCE*), John C. Morgan (*Augusta University*), Abiodun E. Akinwuntan (*University of Kansas Medical Center*)

Visual search has been reported as one of the most important determinants of on-road driving in Parkinson's disease (PD). Yet, commonly used visual search tests are administered on paper or on a computer and have no to little face validity. This study aimed to (1) create a visual search test in a driving simulator; (2) investigate the convergent validity of the test against the dot cancellation (DC) test; and (3) compare performance on the test between 20 drivers with PD and 15 controls. Participants searched for a target road sign among a clutter of other road signs on three screens with $100°$ of horizontal visual field. Drivers with PD took longer to respond ($9s \pm 2$ vs $7s \pm 1$; $p = 0.001$) and missed more target road signs (1.50 ($0.5 - 7$) vs 0 ($0 - 1$); $p = 0.01$) than controls. No differences were found between groups on the DC test. Response time on the visual search test correlated strongly with DC time ($r = 0.52$; $p = 0.009$) and moderately with DC errors ($r = 0.37$; $p = 0.03$). Missed responses correlated moderately with DC time ($r = 0.49$; $p = 0.02$). Our findings suggest that the driving simulator visual search test offers a valid alternative to standard visual search tests. Future research is needed to investigate the validity of the new visual search test in predicting on-road driving performance in PD.

27. **Driving Simulator Performance in the Acute Post-Injury Phase Following a Mild Traumatic Brain Injury Among Young Drivers (27)** Despina Stavrinos (*University of Alabama at Birmingham*), Ginger Yang (*Nationwide Children's Hospital*), Thomas Kerwin (*Ohio State University*), Benjamin McManus, Tyler R. Bell (*University of Alabama at Birmingham*), Alison Newton, Bhavna Singichetti (*Nationwide Children's Hospital*)

While mild traumatic brain injury (mTBI) can lead to cognitive and functional impairments, little is known about how mTBI may affect driving, especially among young drivers who are at an increased risk of mTBI and motor vehicle collisions compared to other age groups. The objective of this multisite, pilot study was to examine the feasibility of assessing driving performance acutely post-injury (i.e., mTBI sustained < 2 weeks at assessment) among young drivers with and without mTBIs (N=42; n_{mTBI}= 21; $n_{control}$=21) using high-fidelity driving simulators. Driving performance was hypothesized to be significantly degraded, especially under conditions of high cognitive load, among drivers with mTBI compared to matched controls. Neurocognitive measures used in clinical assessment of mTBI (i.e., Cogstate Brief Battery) were hypothesized to correlate with driving simulator performance metrics. Risk management protocols were successful (i.e., no participants withdrew due to simulator sickness) and no significant increase in post-concussion symptoms was found from pre-assessment to immediately following driving assessment. Group differences on key driving variables did not emerge; however, drivers with mTBI showed a differential pattern of driving under high cognitive load. Neurocognitive correlates of simulated driving performance suggested processing speed, attention, and working memory are important functions for driving. Implications and future directions discussed.

28. **Task Analysis for Measuring Mobility and Recovery Following Right-Sided TKA: Toward Determining Driver Readiness (28)** Bethany Lowndes, Emily Frankel, Haley Kampschnieder, Jennifer Merickel, Kevin Garvin, Matthew Rizzo (*University of Nebraska Medical Center*)

Following a right-sided total knee arthroplasty (TKA), standard clinical recommendations for patients is to refrain from driving for 6 weeks. Clinical assessments of recovery include mobility tests but do not specifically assess fitness to drive. As a first step in assessment of driver readiness, this study aimed to compare vehicle entry behaviors and mobility assessments between TKA patients and healthy controls. 18 participants (9 TKA participants) completed three in-laboratory visits where they completed mobility tests and entered a full-cab car. Videos of vehicle entry were reviewed and annotated for time—timed vehicle entry (TVE)—and to categorize entry mode. TVE was significantly slower for TKA participants before surgery and 3 weeks after the procedure ($p < 0.05$) but not 6 weeks after ($p < 0.05$). TVE was positively correlated with timed up and go (TUG, $r = 0.65$, $p < 0.05$) and negatively correlated with right knee range of motion (ROM, $r = -0.5$, $p < 0.05$). Range of motion was not significantly different across entry modes between TKA participants and controls. This study was not conclusive to the utility of TVE to replace ROM and TUG for driver readiness; however, this work demonstrated the use of a real-world task that is related to driving for providing patient recovery and behavioral information.

29. **Magnetoencephalography during Simulated Driving: A New Paradigm for Driver Assessment (29)** Elizabeth Walshe (*University of Pennsylvania & Children's Hospital of Philadelphia*), Flaura K. Winston, Chelsea Ward McIntosh (*Children's Hospital of Philadelphia*), Dan Romer (*University of Pennsylvania*), Timothy Roberts, William Gaetz (*Children's Hospital of Philadelphia*)

Increasingly, vehicles are equipped with assistive devices and advanced warning systems to mitigate driver errors, which account for 94% of motor vehicle crashes. However, these technologies require humans to appropriately respond or take over the vehicle. If we want to design effective aids, we need to better understand the neural mechanisms underlying driver error and test how the brain responds to countermeasures. For this, we need sensitive measures of brain activity during driving. This paper present a new paradigm for driver assessment, using magnetoencephalographic (MEG) recording of whole cortex neural oscillatory activity while participants undergo an ecologically-relevant simulated driving experience of graded complexity. A pilot experiment set out to demonstrate that expected and motor cortex responses to basic driving-related movements (without salient cues) could be recorded, without significant artifact. Following this, a preliminary study of adults (n=5) explored if additional cognitive neural responses to increasing driving task demands can be identified. This paradigm was successfully piloted and preliminary results reveal localized brain regions of expected motor cortex activity, as well as power increases in the frontal lobe. This paradigm can be used to identify not only the neural mechanisms underlying driver errors, but also measure the impact of assistive and alert/warning technologies on these mechanisms in both typical and impaired populations of drivers.

30. **The Effect of a Concussion on the Hazard Anticipation Ability in Teen Drivers (30)** Atefeh Katrahmani, Matthew Romoser (*Western New England University*)

Driving after a brain injury is controversial. Since diagnosing a concussion and tracking the healing trend is challenging, whether or not a patient is fit-to-drive after the injury is open to interpretation. The primary purpose of the present research was to investigate the effect of a concussion on teen drivers' hazard anticipation skill. Twenty-four participants were recruited for this study in two groups: the concussed teen driver group and the non-concussed teen driver group. They were asked to wear an eye-tracker and drive with a driving simulator. The drive included several scenarios with potential latent hazards. While driving, the participants were expected to scan the latent hazards with their

eyes and fixate at the hazardous area. The results show significant differences ($p < 0.05$) in the hazard anticipation skills between the two groups on two primary aspects: 1). The concussed group showed more random eye movements while the non-concussed participants had more deliberate eye fixations with less distractions and saccadic jumping. 2) The concussed patients showed a significantly poorer performance in anticipating the potential hazards. In conclusion, results indicate concussions can affect the hazard prediction skills of the teens, which in turn makes the driving task riskier for this group of drivers.

Session 5 – Lectures
Methods and Data Analysis
Wednesday, June 26, 2019
10:45 am – 12:30 pm

31. **What You See is What You Get? Correspondence of Video and Interview Data on Secondary Task Engagement While Driving-A Naturalistic Driving Study (31)** Maria Kreusslein (*Chemnitz University of Technology – GERMANY*), Katja Schleinitz (*Chemnitz University of Technology, TÜV | DEKRA arge tp 21 – GERMANY*), Markus Schumacher (*Federal Highway Research Institute (BASt) – GERMANY*)

Numerous studies use questionnaires or interviews to investigate the prevalence of secondary task engagement while driving. This data may be subject to memory distortion. This study aims at investigating the extent to which interviews are valid instruments to assess secondary tasks. Therefore, we evaluated interviews and video data allowing the observation of secondary task engagement from a Naturalistic Driving Study. We equipped the vehicles of 94 subjects with cameras filming the driver's vehicle cabin. Video and interview data were collected twice within the study period of 3 days. We then determined hit rate, misses, false alarms, correct rejections, sensitivity, as well as specificity for 15 secondary tasks. We found 594 secondary tasks in the videos. In 10% of all comparisons (N_{all}=2.187 for 15 tasks) the interview correctly identified task engagement (hit). In 17% of the comparisons drivers missed to report a task. In 9% of the comparisons there was a false alarm and in 64% we found correct rejections. More conscious and long-lasting tasks (hands-free phoning, smoking) were remembered best. The interview method seems to be a valuable and valid tool to assess rather consciously conducted and legally prohibited secondary tasks while driving.

32. **Predicting a Driver's Personality from Daily Driving Behavior (32)** Yuichi Ishikawa, Akihiro Kobayashi, Atsunori Minamikawa, Chihiro Ono (*KDDI Research, Inc. – JAPAN*)

A wealth of literature has shown the predictive and preventive utility of the Big Five personality traits model (BIG5) for various kinds of unsafe driving. However, the commonly used method for BIG5 measurement requires subjects to answer long and stressful questionnaires, making its applicability limited. In this paper, we study the potential for predicting a driver's BIG5 traits from his/her daily driving behavior. We collected naturalistic driving data on (A) car usage behavior (driving frequency, distance, duration, etc.) and (B) driving operation behavior (operation of steering wheel, accelerator and brake pedal, etc.) from 140 Japanese subjects over two months. By analyzing the data while focusing on various specific driving conditions, we were able to find features which significantly correlate with BIG5 traits from both (A) and (B). In the evaluation, the features we found predicted whether the traits scores are above $\mu + \sigma$ or below $\mu - \sigma$ (μ: average, σ: standard deviation) at an accuracy of ROC-AUC 0.62~0.85, confirming the potential for predicting BIG5 traits from daily driving behavior.

33. **German Validation of the Prosocial and Aggressive Driving Inventory (PADI) (33)** Tanja Stoll, Mirjam Lanzer, Martin Baumann (*Ulm University – GERMANY*)

This paper presents the German adaptation of the Prosocial and Aggressive Driving Inventory (PADI) (Harris et al., 2014). The self-report questionnaire measures safe (prosocial) and unsafe (aggressive) driving behavior. The questionnaire was translated using a forward-backward method. The translation clarity and its applicability were tested in a pilot study. The German version was then validated online with $N = 291$ participants. Confirmatory factor analysis revealed the same factor structure as in the English original. Multiple regression analysis was employed to investigate existing connections between driving behavior and the Big Five personality traits. Aggressive driving behavior was associated with higher scores on Extraversion and lower scores on Agreeableness, Openness, and Conscientiousness. Prosocial driving behavior was associated with higher scores on Openness and Conscientiousness and with participants that were older and female. This questionnaire might be used to investigate effective forms of driving behavior.

34. **Using Markov Chains to Understand the Sequence of Drivers' Gaze Transitions During Lane-Changes in Automated Driving (34)** Rafael Gonçalves, Tyron Louw, Ruth Madigan, Natasha Merat (*University of Leeds – UNITED KINGDOM*)

This paper reports the results of a driving simulator study, which analyzed differences in drivers' raw gaze transition patterns during different stages of a lane-change maneuver, measured during manual, partially and conditionally automated driving. To understand whether the different levels of automation affected behaviour, and particularly how visual attention was distributed during a lane-change maneuver, a Markov chains approach was used to compare gaze transitions between the different information sources available in the surrounding road and cockpit environment, for each of the three drives. Results showed that drivers initiated fewer safety-related inspections (for example to the wing mirrors) during partial automation, throughout the whole lane change maneuver, possibly because they were focusing on how to the transition of control from automation. Drivers in this condition also had a higher probability of checking the system's HMI, to verify the automation's status. In contrast, during conditional automation, the lack of a need for vehicle control by the driver resulted in more gaze transitions between information sources, and fewer gazes to locations where a potential hazard could be present, when compared to manual. Finally, drivers generally only deviated their gaze towards information related to aspects of vehicle control they were responsible for, which we conclude could make them susceptible to missing hazards during both routine and safety-critical take-overs.

35. **The Heterogeneity Principle (35)** Ron Knipling (*Safety for the Long Haul, Inc.*), Anders E. af Wåhlberg (*Cranfield University – UNITED KINGDOM*)

The theoretical foundation of the Naturalistic Driving (ND) Mixed-Safety-Critical Event (SCE) methodology is found in the historical writings of H.W. Heinrich, a 20th century industrial safety engineer. Heinrich espoused the theory that serious accidents, minor ones, and even no-injury operator errors all had identical or highly similar causal mechanisms and that accident consequences were essentially unlinked to causes. This became the basis for today's ND Mixed-SCE method, whereby a variety of mostly non-crash avoidance maneuvers (e.g., hard braking, swerves) and other kinematic events (e.g., lane drifts) are aggregated by researchers to form a dependent variable dataset ostensibly representative of important and harmful crashes. This paper examines this approach and finds it to be invalidated by the pervasive causal heterogeneity of crashes and would-be surrogates. Crashes are heterogeneous horizontally by type and vertically by severity. This paper argues instead for the *heterogeneity principle* as the foundational assumption and guiding tenet for any effort to extrapolate causal evidence from surrogates (e.g., non-crashes or minor crashes) to a different and more important target crash population such as serious crashes.

36. **Where You Look During Automation Influences Where You Steer After Take-Over (36)**
Callum Mole, Oscar Giles, Natasha Merat, Richard Romano, Gustav Markkula, Richard Wilkie
(*University of Leeds – United Kingdom*)

When driving a vehicle, gaze direction (where the driver is looking) is tightly coupled with steering actions. For example, previous research has shown that gaze direction directly influences steering behavior. In the context of transitions of control from automated to manual driving, a new question arises: Does gaze direction before a transition influence the manual steering after it? Here we addressed this question in a simplified simulated driving scenario, for maximum experimental control. Participants (N=26) were driven around a constant curvature bend by an automated vehicle, which gradually drifted toward the outside of the bend. An auditory tone cued manual take-over of steering control and participants were required to correct the drift and return to the lane center. Gaze direction was controlled using an onscreen fixation point with a position that varied from trial to trial horizontally and/or vertically. The results showed that steering during manual control was systematically biased by gaze direction during the automated period, but notably in the opposite direction to what might have been expected based on previous research. Whilst further research is needed to understand the causal mechanisms, these findings do suggest that where a driver looks during the seconds preceding a transition to manual control may be critical in determining whether the subsequent steering actions are successful.

37. **Mapping Visual Fields in a Panoramic Driving Simulator Under Different Task Loads in Patients with Glaucoma (37)** Deepta Ghate, David Anderson, Jideofor Ndulue, Robin High, Lynette Smith, Matthew Rizzo *(University of Nebraska Medical Center)*

Glaucoma causes visual field loss, which may impair detection of objects and hazards during driving. Standard clinical visual field testing, developed to address status of disease, is not designed to capture the effects of visual field loss in ecological settings. To address this need, we developed a driving stimulus detection task (DSVF) similar to clinical perimetry for deployment in a panoramic driving simulator. The outcome measure is a gray scale map of the driver's response to visual test stimuli in the panoramic driving environment 22 glaucoma subjects and 18 controls completed the DSVF under: a) conditions similar to clinic perimetry with a fixation target; b) a no-driving condition with eye and head movements allowed; and c) while driving. The derived visual field index (DSVF-VFI) decreased with increasing task load in both groups, and more so in glaucoma. A predictive formula was generated that allows an estimate of the driver's available field of view under different task loads from clinical perimetry results.

38. **How Long Does It Take to Relax? Observation of Driver Behavior During Real-World Conditionally Automated Driving (38)** Kamil Omozik (*BMW Group, Technical University of Munich – GERMANY*), Yucheng Yang (*Technical University of Munich – GERMANY*), Isabella Kuntermann, Sebastian Hergeth (*BMW Group – GERMANY),* Klaus Bengler (*Technical University of Munich – GERMANY*)

Conditionally Automated Driving (CAD) may reduce drivers' mental load and provide the driver opportunities to engage in non-driving related tasks (NDRTs). Such systems can be expected to enter the market within the next few years and effects of automated driving need to be better understood first to maximize their potential benefit. A road-traffic study with N = 41 subjects was conducted using a Wizard-of-Oz vehicle to simulate CAD. We observed driver behavior during the initial use of CAD and set out to answer the question: How long does it take to relax? Gaze behavior, seating

position, NDRT and self-reported feedback helped in identifying the phases of initial contact and familiarization. The results showed that loose seating position, glance off the road, NDRT engagement and self-reports indicate a familiarization after 10 min of total CAD and correlated with gender and previous experience with advanced driver assistance systems (ADAS). No significant connection was found between subjective and objective data.

39. **Investigating Pedestrians' Crossing Behaviour During Car Deceleration Using Wireless Head Mounted Display: An Application Towards the Evaluation of eHMI of Automated Vehicles (39)** Yee Mun Lee, Jim Uttley, Albert S. Crusat, Oscar Giles, Richard Romano, Gustav Markkula, Natasha Merat (*University of Leeds – UNITED KINGDOM*)

This study investigated pedestrians' crossing behaviour in a virtual reality environment. One aim was to develop a framework for evaluating external Human-Machine Interfaces (eHMI) used by automated vehicles for future studies. Pedestrians were provided with a series of two approaching cars, which were travelling at either 25mph, 30mph, or 35mph, with eight manipulated time gaps in between cars, where the second car either decelerated or kept pace. These stimuli were presented in 3 blocks. Pedestrians' task was to cross (or not) naturally between the approaching cars. Data from decelerating trials were analysed. Results showed 51% of crossings happened before deceleration, 31% of crossings after the car had stopped and only 18% of the crossings during deceleration, leaving a great margin for evaluating the effect of eHMI and changing pedestrian crossing behaviour during deceleration. A learning effect was found, demonstrating a shift of decision making across blocks, whereby crossing increasingly occurred during the approaching vehicle's deceleration, rather than after it had come to a full stop. Further analyses were conducted to investigate the effect of speed on initiation time, crossing time and safety margin. This study provides guidelines in choosing the appropriate time gaps and speeds that may influence pedestrians' crossing decisions and behaviour while presenting different designs of eHMI in future studies. The results also provide guidance on how to evaluate safety, efficiency/receptivity and learning effects, when comparing different eHMI designs in VR experiments.

40. **Withdrawn (40)**

41. **Driving Simulator Assessment of Fitness-to-Drive Following Traumatic Brain Injury (41)**
Benjamin McManus, Tyler R. Bell, Despina Stavrinos (*University of Alabama at Birmingham*)

Returning to driving is a major goal for individuals recovering from a traumatic brain injury (TBI). Clinicians have a variety of tools to assess the ability to return to driving for TBI patients, including cognitive assessments, but on-road instrumented vehicle driving assessments have been considered the gold standard. However, these on-road assessments are limited in the ability to ethically expose drivers to certain driving situations or environments. The purpose of this study was to examine the ability of a high-fidelity driving simulator to assess driving performance in individuals who have sustained a moderate-to-severe TBI, as well as associate cognitive measures commonly used in this population with simulated driving outcomes. Fourteen participants from a TBI clinic were recruited to drive in a simulator through a series of increasingly complex diving modules: 1) basic vehicle operation; 2) secondary task engagement while driving; 3) car following; 4) divided attention; and 5) navigating left hand turns across oncoming traffic. Half ($n = 7$) had been released to return to drive and half ($n = 7$) were considered to never be able to return to driving. Although general trends suggest non-drivers exhibit slower driving and increased lane position variation, group differences driving were not shown likely due to small sample sizes. Differences in patterns of cognitive correlates with driving were found, with higher order cognitive processes, like working memory, being more associated with driving outcomes in active drivers. Suggestions for driving scenario development in this population are discussed.

42. **The Effect of Turn Signal Onset on Lateral Performance Measures When Overtaking a Lead Vehicle - Using Naturalistic Driving Environment (42)** Brian T.W. Lin (*University of Michigan Transportation Research Institute*), Shan Bao (*University of Michigan Transportation Research Institute, University of Michigan-Dearborn*)

Lane changes occur very frequently on freeways. For the development of automated vehicles (AV), the detection of the other vehicles' lane change maneuvers is an important task. Practically, turn signal is the most direct indicator to show the driver's intention to change lanes. This study explored the Safety Pilot field-operational-test (SPFOT) database to investigate the use of turn signal and the relationship between the turn signal onset time and lane change performance measures, in order to assist AV anticipating other road users' maneuvers. Driving data from 130 instrumented vehicles were extracted and 31,211 overtaking events were selected. It was found that the turn signal was used for about 70% of lane changes, and during half of those the turn signal was activated after the initiation of the lane change maneuver. Results showed that leftward overtaking maneuvers had longer lane change duration with slower lateral speed and lateral acceleration than rightward ones when the turn signal was not used. It was further found that the lane change duration can be estimated by the turn signal onset time. The shortest lane change durations of 5.33 s and 4.66 s occurred during those maneuvers when the turn signal was activated at 4.5 s and 5 s before the start of the leftward and rightward lane changes, respectively.

43. **Effects of Voluntary Handheld vs. Speech-Based Text Entry on Driving Performance in (Un)Predictable Critical Situations (43)** Katja Schleinitz (*Chemnitz University of Technology, TÜV | DEKRA arge tp 21 – GERMANY*), Tibor Petzoldt (*TU Dresden – GERMANY*)

It is often suggested that speech-based entry systems for text messages might provide a solution for the safety problems that arise because of handheld texting. However, although such systems have the advantage of allowing drivers to keep their eyes on the road, there is still a considerable portion of cognitive load associated with texting, which might impair the processing of relevant information. At the same time, drivers do not tend to text always and everywhere, but rather only in situations, they consider "suitable". The selection of relevant test scenarios, and the free choice to (not) text in these scenarios are key aspects in the investigation of the effects of texting that have often been neglected. The aim of this experiment was to investigate the consequences of voluntary visual-manual and speech-based text messaging on reaction time and crashes in critical situations that might or might not be anticipated with the help of an environmental cue. We conducted a driving simulator study in which at one point, a child crossed the road, sometimes preceded by a ball rolling across, sometimes not. Participants (82, three groups: handheld writing, speech-based entry, control group) were free to (not) engage in a texting task while driving. While the pre-information had a positive impact on brake reaction time, there were no significant differences between the different groups in either crash rate or brake reaction time. The results highlight the role the design of test scenarios plays for the effects of texting on driving performance.

44. **Improving Driver Engagement During L2 Automation: A Pilot Study (44)** Anuj Pradhan (*University of Massachusetts Amherst*), Jacob Crossman (*Soar Technology*), Adam Sypniewski (*Deepgram*)

Advanced technologies such as adaptive cruise control and lane keeping are key components of SAE Level 2 vehicle automation. As such automation becomes widespread, drivers may be less engaged in driving because they assume that vehicles can safely mitigate risks. However, L2 automation cannot handle the full spectrum of driving situations and will require manual control in many situations. Drivers unprepared to take control may make suboptimal, delayed, or dangerous decisions during and after reengaging with the driving task. This highlights the need for efficient ways to help drivers re-engage with driving. This paper describes an evaluation of a conceptual driver engagement system that combined driver data with contextual data to communicate appropriate information during L2

operations. The system was compared to a traditional, staged-alert system that only monitored driver gaze with no contextual information. Results indicate higher situation awareness, higher levels of trust and satisfaction, no increase in workload, with evidence of improve off-road glance behaviors when driving with the conceptual system. These findings can help inform further development and testing of driver engagement approaches using driver monitoring.

45. **Speed Anticipation Characteristic with Optical Flow for Driver Behavior Assessment of Older Drivers (45)** Hiroshi Yoshitake, Michinobu Nakanishi, & Motoki Shino (*The University of Tokyo – JAPAN*)

The objective of this study is to clarify the relationship between the speed anticipation characteristic with optical flow derived from self-motion and driver behavior of older drivers for future driver assessment. We focused on speed anticipation with optical flow because anticipated speed is assumed to influence behavior at unsignalized intersections with limited visibility, which is an accident-prone situation for the older drivers in Japan. To assess the characteristic, we constructed a novel test by revising a similar test. We conducted an experiment with older drivers that consisted of the novel test and an on-road driving test. The experiment results showed that the speed anticipation characteristic with optical flow had a significant effect on older drivers' behavior at intersections and drivers who anticipated speed faster drove slower and safer.

46. **Age and Secondary Task Engagement in Relation to Safe/Unsafe Driving Behavior and Crash/Non-Crash Events (46)** Jose Calvo, Carryl Baldwin (*George Mason University*), Brian Philips (*US DOT Federal Highway Administration Office of Safety R&D*)

Driver distraction is thought to play a causal role in automobile crashes. Younger and older drivers have the highest crash risk per mile driven. To get a better understanding of the risk associated with conducting secondary tasks while driving the Naturalistic Driving Study (NDS) dataset, part of the Second Strategic Highway Research Program (SHRP2) was used to run a log-linear model comparing age and secondary task involvement and their relation to Event Severity (Balanced Baseline vs Crash), as well as Maneuver Judgement (Safe vs Unsafe). A significant relationship was found between event severity and maneuver judgement. Additionally, age group and secondary task engagement had a significant effect on event severity, but no significant interaction between age and secondary task was found. Age had a significant effect on maneuver judgement, but secondary task did not. Therefore, maneuver judgement may not be a good substitute for event severity as an outcome variable for predicting crashes.

47. **Eye Contact between Pedestrians and Drivers (47)** Dina AlAdawy, Michael Glazer, Jack Terwilliger, Henri Schmidt (*Massachusetts Institute of Technology*), Josh Domeyer (*Toyota Collaborative Safety Research Center*), Bruce Mehler, Bryan Reimer (*Massachusetts Institute of Technology AgeLab & New England University Transportation Center),* Lex Fridman (*Massachusetts Institute of Technology*)

When asked a great number of people believe that, as pedestrians, they make eye contact with the driver of an approaching vehicle when making their crossing decisions. This work presents evidence that this widely held belief is false. We do so by showing that, in majority of cases where conflict is possible, pedestrians begin crossing long before they are able to see the driver through the windshield. In other words, we are able to circumvent the very difficult question of whether pedestrians choose to make eye contact with drivers, by showing that whether they think they do or not, they can't. Specifically, we show that over 90% of people in representative lighting conditions cannot determine the gaze of the driver at 15m and see the driver at all at 30m. This means that, for example, that given the common city speed limit of 25mph, more than 99% of pedestrians would have begun crossing before being able to see either the driver or the driver's gaze. In other words, from the perspective of the pedestrian, in most situations involving an approaching vehicle, the

crossing decision is made by the pedestrian solely based on the kinematics of the vehicle without needing to determine that eye contact was made by explicitly detecting the eyes of the driver.

48. **Posing Questions and Policy Suggestions: Autonomous Vehicles & Climate Change (48)**
Melody Barnard, Robert Hitt, Michael Norton, Yi-Ching Lee (*George Mason University*)

The introduction of autonomous vehicles (AVs) is projected to increase safety and efficiency of transportation. However, climate change poses a challenge to the smooth integration of AVs to current transportation infrastructure. Increased extreme weather events, higher precipitation and temperature, and damages to infrastructure are challenges AVs will face. Therefore, the authors advocate for Planned Adaptive Regulation, and raise questions that they feel policymakers and driving assessment should consider.

49. **A Methodical Approach to Examine Conflicts in Context of Driver - Autonomous Vehicle - Interaction (49)** Marcel Woide, Dina Stiegemeier, Martin Baumann (*Ulm University – GERMANY*)

Future autonomous vehicles will make their own maneuver decisions whereby situations will occur in which the maneuver performed by the autonomous vehicle contradicts the course of action preferred by the driver. In response, the uninformed driver takes over manual control of the vehicle and performs a potentially inappropriate and safety-critical maneuver due to a lack of information. To prevent such a behavior in future, a methodical paradigm is needed, which is able to create possible driver - autonomous vehicle - conflicts and examine preventive and cooperative solutions in a driving simulator. This study (n = 29) is a successful methodical approach to create possible, authentic and reproducible driver - autonomous vehicle - conflicts. Conflicts were caused by a combination of gradation of visibility by fog (full visibility, 150m, 100m, 50m) and a maneuver performed by the automation (overtaking, following) on a rural road. 83% of the drivers canceled an overtaking maneuver by the automation and took over manual control in the 50m condition compared to 2% in the full visibility condition (z=1.914, p<.00). If the automation performed a following maneuver in the full visibility condition, 95% of the drivers overtook manually, compared to only 6% at 50m visibility (z=2.069, p<.00).

Session 7 – Hybrids
Hybrid Presentations
Thursday, June 27, 2019
8:30 am – 10:30 am

50. **Driving with Foresight - Evaluating the Effect of Cognitive Distraction and Experience on Anticipating Events in Traffic (50)** Kristin Mühl (*Ulm University – GERMANY*), Valentin Koob (*Technische Universität* Berlin– *GERMANY*), Tanja Stoll, Martin Baumann (*Ulm University – GERMANY*)

Driving with foresight is essential for road safety. Anticipating upcoming events and intended maneuvers of other traffic participants requires the perception and processing of meaningful and valid cues. To provide insights into the cognitive mechanisms of anticipation, we investigated the effect of cognitive load, experience and cue characteristic on the anticipation of upcoming lane changes in urban driving scenarios. A two-step reaction method gathered low and high certainty anticipatory reactions of student and ambulance drivers. Results indicated that different anticipatory cues affected anticipatory performance. Target cues highly associated with the intended behavior of another traffic participant increased while context cues in the surrounding environment seemed to hamper anticipatory reactions. Furthermore, high cognitive load prolonged the latencies of low certainty anticipation but did not affect the performance quality. This initial intuition of an upcoming lane change was indicated earlier by experienced than by inexperienced drivers. These findings

enhance the understanding of the human process of anticipation in dynamic uncritical traffic situations.

51. **Driver Behavior in Overtaking Accidents as a Function of Driver Age, Road Capacity and Vehicle Speed: A Case Study in Iraq (51)** Husam Muslim, Makoto Itoh (*University of Tsukuba – JAPAN*)

Overtaking accidents are one of the most serious types of road traffic accidents in terms of personal injury. They are mostly caused by drivers' misjudgment of the situation due to human factors (e.g., limited skills and/or information processing abilities), speeding, roadway capacity, and weather condition. Although the overtaking maneuver can be necessary, drivers' use of it is often not justified. The present study aims to identify factors affecting driver behavior in critical overtaking maneuvers. The study collected and analyzed 4,902 real overtaking accidents that occurred on highways in Iraq for the years 2005-2016. Three categories of overtaking accidents were extracted and analyzed in terms of driver age, road capacity (number of lanes and curvature), and vehicles type and speed: 1) head-on collisions that occur when the overtaking vehicle strikes the front-end of an oncoming vehicle; 2) rear-end collisions that occur when the overtaking vehicle strikes the rear-end of a vehicle ahead; and 3) side-impact collisions that occur when the overtaking vehicle strikes or is struck by a vehicle in the adjacent lane. The results indicate that number and types of overtaking accidents were significantly affected by driver age, while the tendency of drivers to overtake was influenced by the type of leading vehicles. A significant interaction between driver age and road capacity was detected in terms of higher accident rates. Correlations between overtaking accidents types, road curvature, and overtaking speed were also identified. The findings have implications for the future design of drivers assistance systems.

52. **Are Driving Simulators Suitable to Measure the Driving Competence of Elderly Drivers? (52)** Ramona Kenntner-Mabiala, C. Maag, Yvonne Kaussner, S. Hoffmann (*Würzburg Institute of Traffic Sciences (WIVW) – GERMANY*), Markus Schumacher (*Federal Highway Research Institute (BASt) – GERMANY*)

The present project aimed to develop and validate a methodology for driving simulators to assess and diagnose driving ability of elderly drivers. A driving simulation course has been developed which covered a representative selection of driving tasks of moderate difficulty as well as scenarios which are particularly difficult for elderly drivers. Driving errors were semi-automatically registered and classified by a tablet PC application. Based on the registered driving errors, the driving competence of each driver was rated on an 11-point fitness-to-drive (FtD) rating scale by specifically trained raters. The driving course was validated on the basis of a 60-minute standardized driving test in real traffic. By including similar driving tasks, it was ensured that it was structurally comparable to the simulated course. 30 elderly drivers (> 70 years) and 30 control drivers (25-50 years) were assessed in the simulation and in real traffic. During the driving tests, more driving errors were registered for the elderly drivers than for the controls both in the simulator and in real traffic. FtD-ratings and total number of driving errors during the driving tests in the simulation correlated up to r = .80 with the FtD-ratings of the driving tests in real traffic. ROC-Analyses revealed at Sensitivity-Specificity Ratio of 85.71: 82.61 at best. Overall, driving simulation was well accepted by the subjects. The findings of the study confirm the validity of driving simulation as a tool to diagnose driving ability and argue for its introduction as a diagnostic tool.

53. **Can Virtual Reality Headsets be Used to Measure Accurately Drivers' Anticipatory Behaviors? (53)** Ganesh Pai Mangalore, Yalda Ebadi (*University of Massachusetts Amherst*), Siby Samuel (*University of Waterloo – CANADA*), Michael Knodler, Donald Fisher (*University of Massachusetts Amherst*)

VR headsets are several orders of magnitude less expensive than driving simulators. Their use in research and clinical settings could explode were it shown that the results obtained with VR headsets were similar to those obtained with more standard driving simulators. Towards this end, the current study expands on a previous initial validation study of VR headsets. In particular, it has been shown in conventional driving simulation and on-road studies that middle-aged drivers glance longer at latent hazards than their younger counterparts. In this study the total time middle-aged drivers spend glancing at a latent hazard and the average duration of each glance were compared to these same times for younger drivers using a VR headset and fixed-based driving simulator. The results indicate that the middle-aged participants glanced longer than their younger counterparts on both platforms at latent hazards, as measured by the total glance duration but had no difference when measured by the average glance duration. Moreover, the magnitude of the difference between middle-aged and younger drivers was the same across the two platforms. These results are in line with previous simulator studies. There appears here a real opportunity to expand the powers of simulation using VR headsets, both for purposes of research and clinical practice.

54. **Driving Simulation as Virtual Reality Exposure Therapy to Rehabilitate Patients with Driving Fear After Traffic Accidents (54)** Stefanie Schoch, Yvonne Kaussner (*Würzburg Institute of Traffic Sciences (WIVW) – GERMANY*), A.M. Kuraszkiewicz (*University of Würzburg – GERMANY*), S. Hoffmann (*Würzburg Institute of Traffic Sciences (WIVW) – GERMANY*), P. Markel, R. Baur-Streubel, P. Pauli (*University of Würzburg – GERMANY*)

Following a traffic accident, up to 30% of the involved persons suffer from stress related symptoms often coming along with enduring fear of driving. Virtual reality exposure therapy (VRET) offers major advantages for treating anxiety disorders, but with respect to fear of driving it has been hardly investigated so far. In the present study a driving simulator exposure treatment for patients with fear of driving after a traffic accident was developed and evaluated. The therapy followed a standardized manual of 13 sessions including anamnesis, medical examination, two preparative psychotherapy sessions, five virtual reality exposure (VRE) sessions, a final behavioral avoidance test in real traffic with a driving instructor, a closing session, plus follow-up phone calls after six and twelve weeks. The exposure scenarios were individually tailored to the patients' anxiety hierarchy. 14 patients were treated. Results indicate excellent treatment success. In the final behavioral avoidance test, all patients mastered driving tasks they had avoided before, 71% showed an adequate driving behavior as assessed by the driving instructor, 93% could maintain their treatment success until the second follow-up phone call. We conclude that VRET in a driving simulator is a highly promising tool to treat fear of driving. Major advantages are that traffic scenarios are highly controllable, safe and can be designed and presented to perfectly fit the individuals' anxieties.

55. **The Dynamic Merge: Using Traffic Volume Based Signing to Improve Workzone Throughput (55)** Starla Weaver (*Leidos*), Michelle Arnold (*US DOT Federal Highway Administration*), Tracy Gonzalez, Stacy Balk (*Leidos*)

Roadwork that results in a lane closure can reduce both the safety and efficiency of a roadway. The dynamic merge is a form of merge control designed to mitigate the potential hazards of lane closures by customizing the merge environment to suit the current level of traffic. When traffic is light, early merge signs encourages drivers to merge into the open lane prior to queue formation. When traffic is heavy, late merge signs encourages drivers to remain in the closed lane for as long as possible. The current study used a driving simulator to assess the independent effects of traffic volume and dynamic merge messaging on merge location and traffic throughput. Merge location was influenced

by merge environment, such that drivers in the early merge condition merged earlier than those in the late merge condition regardless of traffic volume. In addition, when traffic was heavy, participants in the late merge condition passed through the work zone more quickly than those in the early merge condition. The results are suggestive of the beneficial effects of the late merge on traffic throughput and the effectiveness of the dynamic merge messaging in influencing merging behavior.

56. **How Demanding is "Just Driving?" A Cognitive Workload - Psychophysiological Reference Evaluation (56)** Bruce Mehler, Bryan Reimer (*Massachusetts Institute of Technology AgeLab & New England University Transportation Center*)

Physiological arousal, measured as heart rate and skin conductance level, was recording during single-task highway driving (just driving), while driving and interacting with several voice-based and visual-manual infotainment user interfaces, while driving and engaging in multiple levels of a cognitive workload reference task (n-back), and while engaging in the same cognitive workload reference task under single-task (non-driving) conditions. Single-task highway driving was found to produce a level of physiological arousal in the same range as that of the relatively highly demanding 2-back task under non-driving conditions. While continuing innovations such as automatic transmission, power steering, as well as climate control, sound proofing and other comfort features, have reduced the overt demands of driving, these findings suggest that the remaining demand on resources during what has been thought of as "just driving" may be higher than many realize. The extent to which various implementations of longitudinal and lateral control driver assistance features being introduced change this dynamic is largely an open question.

57. **The Conspicuity Benefits of Bicycle Taillights in Daylight (57)** Darlene Edewaard, Ellen C. Szubski, Richard A. Tyrrell, & Andrew T. Duchowski (*Clemson University*)

Bicyclists risk being injured or killed in crashes with motor vehicles, even during the daytime. Therefore, cyclists must help approaching drivers detect and recognize their presence. The present study examined the conspicuity benefits of bicycle taillights during the daytime. Participants' eye movements were recorded as they searched for vulnerable road users in videos recorded from a driver's perspective in a moving vehicle. Five of the videos contained a bicyclist who displayed one of five taillight configurations. The distance from which each participant first glanced at the bicyclist was recorded, as was the distance from which the participant pressed a button to indicate that a bicyclist was present. The results indicated that the participants first fixated on the bicyclist at a distance that was 2.7 times greater than the distance at which they responded to recognizing the bicyclist. Additionally, the bicyclist was recognized from significantly greater distances when using a flashing or steady seat post-mounted taillight than when no taillight was displayed. These findings confirm earlier research that bicycle taillights can enhance drivers' ability to recognize bicyclists during daylight.

58. **Associations Between Cognitive Distortions in Moral Reasoning and Self-Reported Traffic Violations and Crashes for Different Road User Groups (58)** Erik Roelofs (*Cito – THE NETHERLANDS*), Pierro Hirsch (*Virage Simulation – CANADA*), Jan Vissers (*Royal HaskoningDHV – THE NETHERLANDS*)

The use of self-serving cognitive distortions measured by traffic-role specific versions of the Cognitive Distortions in Driving (CDD) test was explored for three Dutch road user groups: cyclists beginning to learn to drive (LDs) who were enrolled in a pro-social driving program (n=138); young novice drivers enrolled in a safety awareness program (n=1660), and; experienced professional bus drivers enrolled in a post-licensing training program (871). Associations between cognitive distortions and self-reported traffic behavior, fines and crashes were analyzed. Results show that about 20 per cent of the young novice drivers used self-serving cognitive distortions, compared to 8 per cent of the LDs and 5 per cent of the bus drivers. In addition, use of cognitive distortions was significantly correlated

with speed and traffic violations. Finally, a subgroup of cyclist LDs (n=38) who had been licensed for six months used fewer cognitive distortions when tested as drivers than the licensed young novice drivers without pro-social driver training. This shows that pro-social driver training can reduce cognitive distortions and may possibly increase safety.

59. **Comparison of Virtual Driving Test Performance and On-Road Examination for Licensure Performance: A Replication Study (59)** Elizabeth Walshe (*University of Pennsylvania & Children's Hospital of Philadelphia*), Natalie Oppenheimer (*Children's Hospital of Philadelphia*), Venk Kandadai (*Diagnostic Driving Inc.*), Flaura Winston (*Children's Hospital of Philadelphia*)

For novice drivers, passing the on-road examination (ORE) for licensure marks the transition from supervised to unsupervised driving. However, the first months post-licensure pose the highest lifetime risk of crashing. In partnership with the Ohio Bureau of Motor Vehicles (OBMV), we have developed a virtual driving test (VDT) to enhance new driver skills testing. Through simulation, license applicants were exposed to common serious crash scenarios too dangerous for inclusion in the ORE. In a previous study of an initial sample of 2,143 driver applicants in Ohio, the acceptability, feasibility and construct validity for the VDT was demonstrated: VDT performance variables (simulated traffic collisions and failing to stop at red lights and stop signs) were associated with failing the ORE (all p <0.001). In this study, we aimed to replicate these results with a second sample of 2,500 novice drivers. The findings were in line with the previous study: VDT performance variables and driving errors differentiated those who went on to pass and fail the ORE. Future work will build and validate a more comprehensive and robust set of performance metrics and examine the predictive ability of the VDT, both for licensing results and future crashes.

60. **Consumer Confusion with Levels of Vehicle Automation (60)** Bobbie Seppelt, Bryan Reimer, Luca Russo, Bruce Mehler (*Massachusetts Institute of Technology AgeLab & New England University Transportation Center*), Jake Fisher, David Friedman (*Consumer Reports*)

A consumer-facing automation taxonomy is proposed to address emergent issues of consumer confusion related to automation types and associated role responsibility. A set of surveys were fielded to help understand the extent to which consumers were able to accurately interpret a proposed consumer-facing taxonomy relative to the 6-level SAE J3016 taxonomy. Results show a mixed benefit of the proposed set over the J3016 set. For both term types and definitions, consumers were best able to differentiate the extremes of automation types, leading to the question of whether or not it may be beneficial to provide a simplified representation to communicate functionality. A binary framing ("driving" vs. "riding") in place of a 6-level taxonomy is proposed to ensure consumer understanding.

Session 8 – Lectures
Automation
Thursday, June 27, 2019
10:45 am – 12:30 pm

61. **Learning and Development of Mental Models during Interactions with Driving Automation: A Simulator Study, (61)** Yannick Forster (*BMW Group, Chemnitz University of Technology – GERMANY*), Sebastian Hergeth, Frederik Naujoks (*BMW Group – GERMANY*), Matthias Beggiato, Josef F. Krems (*Chemnitz University of Technology – GERMANY*), Andreas Keinath (*BMW Group – GERMANY*)

Higher level cognitive processes such as learning and mental models play a fundamental role in the success of automated driving, as technology can only be as good as our understanding and expectations of it. The present study investigated the development of these processes during interactions with driving automation. In a driving simulator study, N=52 participants completed

several transitions between manual and Society of Automotive Engineers (SAE) levels 2 and 3 automated driving. Self-reported learning progress and mental model development were assessed via questionnaires. In parallel, eye-tracking data were collected as a behavioral measure of higher level cognitive functions. The results demonstrated that self-reported learning and gaze behavior followed a power-law function; the power-law functions showed task specific parameter manifestations. The evolution of the mental models of the level 2 and level 3 human-machine interface continued up to the fifth contact, indicating a long lasting process. For researchers and practitioners, the present study implies that accurate mental models require up to 5 repeated interactions. Furthermore, learning progress with driving automation can be captured through gaze behavior.

62. **Understanding Lane-Keeping Assist: Does Control Intervention Enhance Perceived Capability? (62)** John Sullivan, Michael Flannagan (*University of Michigan Transportation Research Institute*)

Drivers of vehicles equipped with ADAS often show a flawed understanding of the limitations of these systems. In this study, two types of lane keeping assist (LKA) were investigated: a lane centering system that continuously repositioned the vehicle in the center of the lane, and a lane departure prevention system that intervened when the vehicle wandered near the lane edge. Driver knowledge of each LKA (and accompanied ACC) were tested over a series of five drives. Results suggest that greater capability may be attributed to the lane centering system, perhaps because its control intervention is more frequent and obvious than the lane departure prevention LKA.

63. **Consumer Comfort with Vehicle Automation: Changes Over Time (63)** Chaiwoo Lee, Bobbie Seppelt, Hillary Abraham, Bryan Reimer, Bruce Mehler, Joseph Coughlin (*Massachusetts Institute of Technology AgeLab & New England University Transportation Center*)

Higher levels of vehicle automation are forecast as a potential mobility solution for many, but understanding consumer comfort and acceptance of self-driving technologies remains an open question. Results from a series of surveys over three years showed a slight increase in the percentage of people comfortable with full self-driving automation in 2018, following a drop from 2016 to 2017. The recovery in comfort with higher levels of automation was most pronounced among younger adults between ages 25 and 44. However, the percentage of people only comfortable with no automation or features that activate only in certain situations such as in an emergency also increased in the past year, indicating a polarizing trend. Results from the survey also showed that acceptance of self-driving vehicles is conditional on people's ability to drive as well as having assurance regarding the safety of the technology. Responses also point to a possible misunderstanding among the public regarding the definition and availability of full self-driving technology, indicating a need for improved messaging and consumer education.

64. **Autonomous Vehicle Interactions with Other Road Users: Conflicts and Resolutions (64)** Michael Heymann (*Israel Institute of Technology – ISRAEL*), Asaf Degani (*General Motors R&D Center – ISRAEL*)

As autonomous vehicles, or AVs, enter the market, other road users will need to interact with them in an effective manner. Currently, in manually-driven cars, the effectiveness of this interaction is based on the rules of the road that define priorities as well as ad-hoc negotiations to resolve conflicts. To formalize the conflict issue, we introduce the concept of *legal zones* showing how the road space can be described as graph of these zones. We also introduce the concept of *operational regions* around a vehicle which must not be infringed upon by others (to avoid safety conflicts). Using these two concepts we show how it is possible to consider new rules for the management of conflict in AV operations. We first briefly describe a new protocol for lane changes and then focus our attention on a protocol for managing conflicts in a pedestrian crossing situation.

65. **Cognitive Load During Automation Affects Gaze Behaviours and Transitions to Manual Steering Control (65)** Richard Wilkie, Callum Mole, Oscar Giles, Natasha Merat, Richard Romano, Gustav Makkula (*University of Leeds – UNITED KINGDOM*)

Automated vehicles (AVs) are being tested on-road with plans for imminent large-scale deployment. Many AVs are being designed to control vehicles without human input, whilst still relying on a human driver to remain vigilant and responsible for taking control in case of failure. Drivers are likely to use AV control periods to perform additional non-driving related tasks, however the impact of this load on successful steering control transitions (from AV to the human) remains unclear. Here, we used a driving simulator to examine the effect of an additional cognitive load on gaze behavior during automated driving, and on subsequent manual steering control. Drivers were asked to take-over control after a short period of automation caused trajectories to drift towards the outside edge of a bending road. Drivers needed to correct lane position when there was no additional task ("NoLoad"), or whilst also performing an auditory detection task ("Load"). Load might have affected gaze patterns, so to control for this we used either: i) Free gaze, or ii) Fixed gaze (to the road center). Results showed that Load impaired steering, causing insufficient corrections for lane drift. Free gaze patterns were influenced by the added cognitive load, but impaired steering was also observed when gaze was fixed. It seems then that the driver state (cognitive load and gaze direction) during automation may have important consequences for whether the takeover of manual vehicle control is successful.