Meeting the Challenges of Safe Transportation in an Aging Society

Presentation Titles, Authors, and Abstracts

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Session I: Enhancing Transportation Infrastructure for an Aging Society
(Moderator: Jun-Seok Oh, Western Michigan University)

Safety Benefits of Selected Engineering Improvements for Older Drivers in Michigan
Valerian Kwigizile, Western Michigan University

In 2004, the Michigan Department of Transportation (MDOT) began a comprehensive program to implement engineering countermeasures to address the needs of road users, especially older drivers. The countermeasures included the use of Clearview Font on Guide Signs (freeway and non-freeway), installation of Box Span signals, installation of pedestrian countdown signals, use of Fluorescent Yellow Sheeting on warning signs, and use of arrow-per-lane on guide signs. This study evaluated safety benefits of the selected countermeasures through a perception survey of Michigan drivers and analysis of crash data. Where possible, Safety Performance Functions (SPF) for these improvements were developed as part of the study. Furthermore, Crash Modification Factors (CMFs) for each countermeasure were developed through the before-after analysis of crash data. Finally, the benefit-cost analysis of each countermeasure was performed.

Public Transit Service for Elderly Mobility
C. Scott Smith, Western Michigan University

While personal mobility in the United States relies heavily on the private automobile and associated infrastructure, numerous social, economic and environmental benefits can be achieved by fostering convenient and effective public transit systems. However, fostering public transit systems that are both safe and widely accessible to all requires considerable investment and sensitivity to individuals with special mobility needs. This study builds on the public transit quality of service, regional transit coordination and general transit feed system (GTFS) literatures to develop performance measures and analyses that are useful for evaluating, categorizing and potentially improving transit operations and services. This is carried out via a detailed case study that evaluates Americans with Disabilities Act (ADA)-compliant routing in Kalamazoo County, Michigan and, specifically, how multimodal (i.e. walking and public transit) access to healthcare varies for different segments of society. The study concludes with recommendations for improving the GTFS data structure to incorporate mobility challenges experienced by older people and/or those with physical and/or cognitive disabilities.

Potential Infrastructure Counter Measures for the Aging Drivers
Ron Van Houten, Western Michigan University

This presentation will examine human factors that can present challenging problems for aging drivers, and examine infrastructure countermeasures that could ameliorate these challenges. Infrastructure variables that will be considered are in vehicle countermeasures, routing countermeasures, and highway design countermeasures.

The Relationship between Transportation and Elderly Individuals' Access to Community Health Services
Keith Christensen, Utah State University

Older people are vulnerable to disparities in the environment. Access to transportation is essential for an older individual's engagement in their community; for obtaining goods and services, healthcare, and social interaction. Individuals encountering difficulties in accessing transportation are considered 'transportation disadvantaged' and include aging individuals. In particular, as a population, elderly individuals with fewer options for private transportation are less able to access necessary healthcare services which contribute to increase comorbidities. Often the elderly may depend on their social network to mitigate barriers in transportation access for healthcare, resulting in increased demand on elderly individuals already limited social networks. Transportation accessibility has been identified as one of the primary means to address elderly individuals' independence. Indeed, understanding the role of transportation access in healthcare is necessary to best assure the continuing quality of life of elderly individuals. The purpose of this study is to examine elderly individuals' access to transportation and its relationship with community health services.

Transportation Mobility for Older Adults in Low Density Urban Environments
Stephen Mattingly, Department of Civil Engineering, University of Texas at Arlington

This study takes a critical next step in understanding transportation mobility and its impact on quality of life among low-income, transportation disadvantaged older adults in a low-density urban environment. This study seeks to identify the transportation needs of older adults and recommend policies to address these needs. Elderly safety links closely with mobility because mobility appears relatively unimportant if the connections (e.g. pedestrian facilities) to this mobility do not provide adequate safety for elderly users. The study identifies desired activities and the reasons that some elderly citizens forego these activities using an innovative audio journaling strategy. By capturing the lived experiences of some elderly citizens, the researchers can assess the nature of the transportation gaps and challenges they face for accessing different types of activities. Furthermore, the researchers explore the impact that these gaps and the consequences have on the elderly's mental and physical health, sense of place/community, and overall well-being. The findings from this study can be used by community and public/governmental agencies to identify and prioritize the transportation needs of low income older adults. Finally, the study identifies the role that safety plays in contributing to transportation gaps.

Session II: Longitudinal Research on Aging Drivers (LongROAD) Part I (Moderator: Lisa J. Molnar, University of Michigan Transportation Research Institute)

Driving for Life: Age, Context, and Implications for Life Quality
Jacqui Smith and Lindsay H. Ryan
Institute for Social Research, University of Michigan

Driving is a fundamental aspect of life in contemporary communities. Across all age groups, adults drive to work, to shop, to visit family and friends, to obtain health care, and to participate

in many forms of leisure activities (e.g., attend sport or community events). The driver's license for many people is more than a legal permit to operate a motor vehicle: It's integral to feeling in control of their life, to being independent, and to feeling free to move around a geographical area whenever and how far they desire. It's typically only when something limits or interferes with driving that people realize how important it is to their life quality. Whereas short-term constraints are frustrating (e.g., a malfunctioning car), chronic and especially permanent limits are life changing especially for older drivers. In the 2012 wave of the Health and Retirement Study (HRS), for example, 71% of participants aged 80 and over (N = 2574) reported that they were drivers, and this subgroup also reported feeling much more satisfied with their life than their peers who no longer drove ($p < .001$). The LongROAD Study will provide new insight into how older drivers adapt to changes in their own health and functioning, changes in their own automobile and other vehicles on the road, and changes in driving contexts. This presentation provides a broad background to the relevance of driving to the lives of older adults and introduces the topics discussed in more detail by other speakers in the session.

Longitudinal Research on Aging Drivers (LongROAD): Study Design and Methods
Guohua Li, Department of Epidemiology, Columbia University Mailman School of Public Health

The Longitudinal Research on Aging Drivers (LongROAD) project is a prospective cohort study designed to generate empirical evidence for understanding the dynamics, mechanisms, and determinants of driving safety in older adults. A total of 3,000 active drivers aged 65–79 years are being recruited through clinics in five study sites located in CA, CO, MD, MI and NY. Consented participants are assessed at baseline with standardized protocols and instruments, including vehicle inspection, performance-based tests, questionnaires, and "brown-bag" medication reviews. The primary vehicle of each participant is instrumented with a small recording device to collect real-time driving data. Annual follow-up is conducted with questionnaire survey and with in-person assessment in alternate years for at least two years. Driving records, including crashes and violations, are collected through state motor vehicle departments. Pilot-testing was conducted on 56 volunteers during March-May 2015. Enrollment started in July 2015. As of September 1, 2016, the investigators have enrolled 2,113 study participants.

LongROAD Study: Recruitment and Enrollment at the University of Michigan
Linda Nyquist, University of Michigan Geriatrics Center

This presentation will focus on the approach, process, and challenges of recruitment and enrollment of older drivers in the LongROAD study. The goal of this study is to understand more about driving behavior and safe mobility as people grow older by integrating information on driving , functional capacity, psychosocial factors, and health collected over 4 years. The target group is adults aged 65-79 years who have a valid driver's license, drive at least one day a week, reside in the state at least 10 months of the year, and receive their medical care in one health system. We first obtained contact information for persons in the targeted age group who received primary care in the previous year within the University of Michigan Health and Hospital System. We then screened this information for completeness, geographic proximity, and co-residency. Recruitment entails a letter sent describing the LongROAD study and inviting participation.

These letters are followed with a phone call to answer questions and complete more detailed eligibility screening. Eligible and willing individuals are scheduled for their baseline study visit during these phone calls. We then mail a packet with appointment information, maps, and the informed consent document. Visit reminder calls are made one to two days before the baseline visit. Each of these recruitment processes and the challenges encountered will be discussed in more detail.

Vehicle Conditions and Features – Information from Direct Inspections and Self-Reports
David Strogatz (on behalf of the LongROAD Study Investigators), Director of the Center for Rural Community Health, Bassett Research Institute

The Longitudinal Research on Aging Drivers (LongROAD) Study is a new cohort study of factors to help understand changes in the driving patterns and driving outcomes of older adults. The cohort will consist of 3,000 adults 65-79 years of age recruited from primary care practices in five separate geographic locations in the United States. Data collection for the LongROAD Study includes inspection of each participant's primary vehicle in addition to an interviewer-administered survey in which participants report the presence and use of advanced technologies in their vehicle. Information from both modes of data collection (direct inspection and self-report) are available for technologies such as backup/parking assist; blind spot warning; forward collision warning; lane departure warning; navigator assistance; and voice control system. Recruitment and enrollment into the LongROAD Study cohort are ongoing, but preliminary data from one of the five LongROAD Study sites will be presented on the prevalence of selected advanced technologies, the reported use and perceived value of the technologies that are present, and the concordance between the separate measures (inspection, self-report) of the presence of each type of technology.

Driving Data Collection and Fleet/Device Monitoring--An Overview
Scott Bogard, University of Michigan Transportation Research Institute

This discussion presents an overview of the objective naturalistic driving data collected from subjects during their participation in the study. GPS position, speed, heading, and acceleration are collected once per second (1 Hz) using an electronic device connected to the vehicle diagnostic port. Distinct files are populated for each ignition cycle and transferred to a backend server via the cellular network. Files are processed to determine performance measures for each driver that include overall exposure, trip combinations, time-of-day, distance from home and road type, along with turning and extreme driving behavior. Special routines monitor the fleet/device state-of-health and identify if the subject is driving the vehicle using a Bluetooth identification card. Data are processed and loaded into a relational database for efficient analysis and mining across the entire collection. As of September 1st, 2016 a total of 9.6 million miles have been recorded in 1.4 million trips for 1959 subjects. Currently, the study is generating about 55,000 miles (1850 hours) of driving per day.

Session III: LongROAD Part II
(Moderator: David W. Eby, University of Michigan Transportation Research Institute)

An Overview of Cognitive Indicators: The LongROAD Study

Lindsay H. Ryan, Institute for Social Research, University of Michigan

Cognitive functioning is a critical factor associated with older adults' ability to remain independent. Maintaining cognitive abilities enables individuals to successfully interact with complex environments, such as correctly following complicated medication regimens, learning and using new and frequently changing technologies, navigating novel environments, and driving. Importantly, cognitive performance is not a single construct, but rather a combination of various domains that have unique associations with health and functioning outcomes as well as differential patterns of change over time. A major strength of the LongROAD Study is that we collect a range of validated cognitive measures overtime so that we will be able to examine the impact of level and change in cognitive domains on a variety of driving outcomes. The Telephone Inventory of Cognitive Status (TICS) is included in the driving and health questionnaire which is administered every wave of the study, providing longitudinal data on the general cognitive status of our participants (whether likely impaired or not). More detailed information is collected in-person at baseline and in the biannual follow-up on a variety of other cognitive domains, including perceptual speed (verbal fluency, Digit Symbol), working memory (word recall), and attention/executive function (Trails, Clock Drawing). Specific cognitive domains and assessments were selected based on their theoretical links to driving outcomes. In addition, many of the cognitive assessments included in LongROAD are also included in large, national studies of aging (e.g. The Health and Retirement Study), which provides the potential to benchmark against population-representative samples. This presentation will provide detail regarding the selection and administration of specific cognitive domains and assessments.

Assessment of the Physical Health Domain in LongROAD: Self-Report and Performance-Based

Thelma Mielenz, Columbia University Mailman School of Public Health

Maintaining good physical health is associated with continued motor vehicle driving, although, the evidence is yet to be definitive. In the LongROAD study, we endorse the broad physical health domain close to the World Health Organization and Patient-Reported Outcomes Measurement Information System (PROMIS) frameworks' but expand to include subdomains relevant to older adult drivers. More specifically, the subdomains for the self-report measures, include: physical function, fatigue, pain interference, sleep disturbance, sleep-related impairment, use of assistive devices, falls, frailty and physical activity. We utilize self-report PROMIS measures and measures from other aging longitudinal cohorts (i.e., National Health and Aging Trends and the Health and Retirement Studies). For the performance-based measures, we refer to the physical health domain as the motor domain. The Short Physical Performance Battery which assesses balance and physical functioning, expressly the subdomain of lower extremity function. The Rapid Pace walking also assesses lower extremity function. Grip Strength and the 9-hole Peg Dexterity Test measure upper extremity function. The Marottoli Method measures neck range of motion and peripheral vision. The self-report physical health measures are collected yearly and the performance-based measures are collected every other year. We know that physical health can improve with exercise and physical activity in aging

populations. Additional research with longitudinal and clinical trials study designs are needed to provide definitive evidence on how future interventions should target increasing physical health to prolong positive driving outcomes in older adults. We are using state-of-the-art measures to cover the physical health domain with the ultimate goal of informing these future interventions.

Review of Prescription and Other Medications and Supplements
Renée M. St. Louis, University of Michigan Transportation Research Institute

As people age, they are more likely to use medications to treat conditions associated with the aging process. The impact of medication use and polypharmacy on driving is an important issue to consider in an aging society that continues to see increasing percentages of older adults on the road. To address this, data collection for the LongROAD Study includes documenting detailed information on the use of medications and supplements from its 3,000 participants at their in-person assessments. This presentation provides an overview of the procedures for documenting medication and supplement use of participants. The process by which these data are collected is called a "Brown Bag Medication Review", wherein participants bring all medications and supplements to their in-person assessment and go through a series of questions regarding their use with a research assistant. Examples of medication labels will be shown to highlight how this information is collected. There will also be discussion of how this information can be used to answer several questions related to driving and medication use in the older adult population.

Medical Conditions and Healthcare Utilization: Data Collection for the LongROAD Study
Linda Hill, Anne-Marie Engler, Steele Fors, Wasan Majeed, and Frances Fu
University of California, San Diego

The over 65 population is the fastest growing group in the US, including 35 million drivers. Older adults are more likely to experience health and functional impairments than their younger counterparts, which may interfere with their ability to drive safely, and have been found to be associated with driving cessation. Physical and mental changes, including reduced visual acuity, decreased strength, and cognitive impairment, medications, and other health conditions can directly and indirectly result in age-related driving issues and cessation. Health care utilization patterns reflect the quantity and acuity of medical conditions. The LongROAD study is a five-year, five city prospective observational study of 3000 older adults. The medical conditions and health care utilization section of the study will provide information on the relationships of these variables with driving behavior, driving safety, and cessation. Medical records are reviewed through access to electronic health records at each of the five participating sites. Baseline data is collected, as well as the previous 5 years. At each of the 5 subsequent years of study participation, records are reviewed annually. Diagnosis codes are obtained based on the problem list. Up to 50 ICD-9/10 diagnoses are collected. The number and types of surgical procedures are extracted, including name and CPT code; up to 25 are recorded. Health care utilization information is obtained from the electronic health record for primary care visits, specialty care visits, emergency department visits, and inpatient hospitalizations. Number of visits and dates are recorded. Data is abstracted and entered on paper forms, which are kept as part of the site-specific file. De-identified data is entered into the central database from each site.

Driving Status, Violations, and Crashes: Data from State Records
Jennifer Zakrajsek, University of Michigan Transportation Research Institute

Data collection for the LongROAD Study includes review of participants' state driving records. The five study sites obtain records from their states' motor vehicle departments. An initial driving record review is conducted after each participant's baseline appointment to confirm participants have a current, valid driver's license and to record participants' moving violations and crashes during the last five years before baseline. Subsequent record reviews are conducted annually to record changes in participants' licensing status and post-baseline moving violations and crashes. The driving record review components include: driving status, administrative violations, moving violations, criminal offenses, crash records, and crash-related injuries. An overview of the specific driving variables collected will be presented. Baseline and annual driving record reviews are ongoing, but preliminary data from one of the LongROAD Study site's baseline record reviews will be presented as an example of driving history data collection.

Session IV: Stakeholder Perspectives
(Moderator: Laura Higgins, Texas A&M Transportation Institute)

Ten Facts about Older Drivers You Can Bank On
Michel Bédard[1], Judith Charlton[2], Lisa Molnar[3], Jennie Oxley[2]
[1] Centre for Research on Safe Driving, Lakehead University
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[3]University of Michigan Transportation Research Institute

Research on older drivers has flourished in recent years. A simple PubMed search with the key words "older drivers" revealed a near-exponential increase in peer-reviewed articles, from two in 1975, seven in 1985, 23 in 1995, 66 in 2005, and 177 in 2015. This literature informs practice and policy, and ongoing research. We aim, with this presentation, to highlight 10 facts we can build future research on. Consensus was developed by four researchers supported by evidence from a mini-literature review. The ten facts we selected to include (in no particular order): 1) mobility is a right, driving is a privilege, 2) the proportion of older drivers is increasing in developed countries, 3) it is simplistic and misleading to say that we have an "older driver problem", 4) cohort effects are emerging, 5) no current screening approach can identify safe/unsafe drivers with accuracy for general use in older populations, 6) some medical conditions may adversely affect safe driving, 7) safe driving results from a combination of appropriate skill, behavior, and decision-making, 8) crashes involving older drivers differ from those involving other age cohorts, 9) healthy older drivers can improve their performance, and 10) driving is important to older adults' quality of life. We presented a number of facts that help us frame the progress achieved by previous research. More facts could be added, and some researchers may dispute the evidence used to tabulate these facts. Importantly, the statement about cohort effects reminds us that what is true today might not hold in the future. Furthermore, technological changes may revolutionize road safety in years ahead. Nonetheless, our message is that we should invest our research energy and resources in ways that extend beyond the extant literature to further enhance the safe mobility older drivers.

Integrated Assessment of Safety, Accessibility and Reliability for Aging Roadway Users: Case Studies in Florida

Eren Erman Ozguven, Florida State University

Surface transportation systems can be effectively utilized to solve transportation safety and accessibility issues facing older adults. These issues center on older adults' need for longer travel time and their heightened health and safety risks. Central to meeting these needs are new aging-focused methodologies that will provide agencies with complete, practical, and efficient transportation management and operations procedures. The first challenge in obtaining such novel methodologies is to extensively evaluate different datasets, including those describing not only older adults' transportation needs and sociodemographics but also traffic and roadway crash patterns. The second challenge is to integrate them, in order to generate a comprehensive safety-focused model that jointly considers all these databases. Our research addresses these challenges by developing a set of Geographical Information Systems (GIS)-based methodologies to assess the roadway networks, focusing on aging populations' transportation needs and their exposure to transportation-related health and safety risks. The application of the proposed methodologies is presented, focusing on various critical issues related to older drivers. In particular, we address the following problems: (a) identifying the crash hotspots for older drivers; (b) assessing the accessibility of those hotspots with respect to critical facilities, such as hospitals; (c) evaluating the travel time reliability of the roadways in and around those hotspots; and (d) linking this information with aging-related transportation needs and sociodemographic characteristics. Several scenarios are studied to show the applicability of the proposed methodologies. Findings of this work can assist in strategic planning efforts for developing appropriate intervention and prevention programs to improve safety and enhance mobility for aging road users. The knowledge gained from this research can contribute to the development of more reliable aging-focused safety plans and models.

Interactive Driving Simulators: Implications for Clinical Use

Anne Dickerson, East Carolina University

Interactive driving simulators have the potential to be an effective and efficient tool for assessment and intervention for older adults. Drawbacks include simulator sickness as well as decisions being made about fitness to drive while the individual is still adjusting to a process that is different than a "real" vehicle. Thus, this study examined the driving performance of healthy older adults on the driving simulator. Fifty-seven community living healthy older adults between 60 and 79 years of age drove the interactive driving simulator for at least one scenario. The outcome measures: 1) data was extracted from the simulator report (e.g., reaction times, number of crashes, lane maintenance, 2) a developed 5-point scale based on the critical incidents, and 3) on road performance. The data was analyzed to examine if there was any difference between the groups in terms of age, gender, or familiarity with technology using both sets of data. Nine participants (ongoing collection) returned after at least 7 days to explore if their performance changed after practice on the simulator. Scores from the first drive were compared against the scores from the second drive. Preliminary data indicates that there are few difference between

the older adults in terms of the two age groups, familiarity with technology, or gender with either outcome measure. In terms of the nine participants who repeated the drives, the total score for the observational tool was significantly different as well as select critical incidents. Even community living healthy older adults, who perform safely on a drive evaluation, will make mistakes on the simulator and performance is not based on age, gender or familiarity with technology. The results suggest a learning effect with the simulator. Implications will be discussed.

Training Law Enforcement in the Identification of Medical Impairment in Aging Drivers

Linda Hill, Jill Rybar, and Jana Jahns
Training, Research and Education for Driving Safety
School of Medicine, University of California, San Diego

With the aging US population, law enforcement officers need the skills to recognize and manage medically and cognitively impaired drivers. With support from the California Office of Traffic Safety (OTS), Training, Research and Education for Driving Safety (TREDS) partnered with the California Highway Patrol (CHP) and the California Department of Motor Vehicles (DMV) to train law enforcement officers in the CHP Border Division, which encompasses four counties in Southern California. A training curriculum was based on NHTSA's 'Law Enforcement Training on Older Drivers', followed by major course revisions, including tailoring content specific to state law and officers' needs. The two-hour curriculum is Peace Officer Standardized Training (POST) certified. The curriculum covers the following: introduction to training and older drivers; medical conditions and methods for assessment (including: vision, frailty, cognitive impairment, hypo- and hyperglycemia); strategies to employ during traffic contacts, including observation, questioning, use of a screening tool (described below), and communication and referral; utilization of the DMV reporting mechanism; and community resources for driver evaluation and re-education. A roadside screening tool to aid in the identification of disorientation was developed, validated with a sample of persons with dementia compared to cognitively normal controls, and deployed in the training. A total of 2,018 police officers received instruction at 103 trainings. At baseline, only 26% of officers reported drivers to the Department of Motor Vehicles in the last six months. After training, 96% stated they were likely to use reporting forms, and 90% reported that they were likely to use the roadside screening tool. In the follow-up interviews two years after training, 90% (n = 54) of officers reported routinely carrying the state reporting form in their patrol vehicles, and 67% (n = 40) indicated that they still had the DOSCI card in their possession. 23% (n = 14) indicated they had used the DOSCI tool to evaluate an older driver for disorientation, and all respondents indicated that the tool was practical and easy to use. Nearly all respondents (n = 58) indicated that the training had better prepared them to handle encounters with older drivers. The certified training and tool were well received and resulted in changes to knowledge, attitudes and intention to change behavior. TREDS has developed a 'train the trainer' curriculum for training officers in law enforcement to facilitate the dissemination of the training.

An Investigation of the Low Mileage Bias using Naturalistic Driving Study Data
Jon Antin, Virginia Tech Transportation Institute

We evaluated the low mileage bias (LMB) phenomenon for senior drivers using data mined from the Second Strategic Highway Research Program (SHRP 2) Naturalistic Driving Study. Supporters of the LMB postulate that it is only those seniors who drive the lowest annual mileage that are primarily responsible for the increased crash rates traditionally attributed to this population in general, and they have cited much self report data to support this idea. The current analysis included 802 participants, all aged 65 or older who were involved in 163 property damage and injury crashes, and deemed to be at-fault in 123 (75%) of those instances. Poisson regression models were used to evaluate the association between annualized mileage driven and crash risk. Results will be discussed.

Session V: Technology
(Moderator: John Sobanjo, Florida State University)

Vehicle Automation and the Driver Age: Human Factors implications
Anuj K. Pradhan, University of Michigan Transportation Research Institute

Automated vehicle technologies are leading to vehicle designs in which safety-critical control functions can occur without direct input from the driver. These advances hold promise for increased vehicle safety. However, vehicle automation can lead to new types of risks and errors in drivers, especially given the differences in driving abilities and behaviors of older and younger novice drivers from the average driver. In fact there is an important research gap in the understanding of human behavior and interaction with automation, especially in the context of age and experience. One important example is the question of transitioning, or transfer of control, between automated and manual control in an automated vehicle. This abstract will present ongoing research examining age-related differences in the issues related to transfer of control in automated vehicles. An advanced high-fidelity driving simulator is being used to provide an immersive automated driving experience to participants of different age groups, where they experience multiple instances of transfer of control. Outcome measures collected include driving behaviors and reaction times from the driving simulator, visual behaviors collected from an integrated eye tracking system, and subjective measures collected from structured interviews. The data-collection is ongoing. The research focuses on age differences in driving behavior related to transfer of control. Teens and older drivers are at a higher risk of motor vehicle crashes, and automated vehicle technologies will play an important role in reducing crashes and injuries in these sub-groups. Since little is known about the age-specific issues related to automated vehicles, this research seeks to provide a foundation knowledge that, through effective dissemination, can expand knowledge in this area. In particular, issues of driver expectation, trust, acceptance and self-perceived performance may be important predictors for actual performance during the transition process.

An Approach to Customize Haptic Guidance for the Aged Power-Wheelchair Riders

Han U. Yoon and Pilwon Hur
Department of Mechanical Engineering, Texas A&M University

The aged power-wheelchair riders often need guidance not only to control the speed and direction of the wheelchair but also to navigate through obstacle-free path. However, simultaneous consideration of both criteria to determine a guidance policy of the power-wheelchair has not been considered yet. To address this problem, we propose an approach to modeling rider's strategy to optimize driving-related features such a speed/steering control and boundary/obstacle avoidance. The modeled cost functions via inverse optimal control techniques can provide customized haptic force feedback for each user. Thirty nine adults participated in this study. A custom-developed simulator of a power-wheelchair was used which can provide haptic feedback to users. Subjects were seated at the simulator which provides visual display and force feedback by a monitor screen and a 2D haptic interface, respectively. Subjects were given tasks in which they drive a virtual power-wheelchair as fast and safe as possible while avoiding obstacles and boundaries under various scenarios. In the first session, each subject's driving characteristics with no haptic feedback was identified. In the second session, subjects' task-completion times under three haptic-assistance modes (no assist, customized assistance, and non-customize assistance) were recorded. The result showed that not all subjects' task-completion times were improved with customized haptic feedback. However, subjects whose completion times improved with customized assistance had slower baseline completion times and higher completion time variability than those whose completion times did not improve with customized assistance. These findings imply that customized haptic guidance may work either as disturbances for skilled subjects or as beneficial assistances to novice subjects. For the novice subjects, nonetheless, the customized guidance outperform non-customized guidance.

The Older Driver and Advanced Driver Assistance Systems: Insights from a Naturalistic Driving Field Operational Test

Shan Bao[1], Ruigeng Zhang[2,1], Lidia Kostyniuk[1], Cao Libo[2,1]
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In a society where the population is aging and mobility and driving are often equated with independence, problems of older driver safety is of increasing concern. At the same time advances in automotive technology promise to simplify the driving task and it more safe. How these systems affect older drivers, and whether they can compensate for some of the age-related declines in the ability to drive safety are still open questions. This study investigates the effect of a set of advanced driver assistance systems (ADAS) on older drivers' travel patterns and compares these patterns to those of younger drivers. Naturalistic driving data from the Integrated In-vehicle-based Safety program (IVBSS) are examined for changes in a set of driving measures including those associated with exposure such as the amount of driving, travel times, road types,

and specific driving maneuvers such as speeds, lane-keeping, passing, and vehicle following. Linear mixed models are used to analyze the significance of the effects of the ADAS systems on driving measures and to compare these across age groups. This study objectively confirmed many differences between older drivers and younger drivers with respect to where, when and how much they travel, as well as choice of speeds and headways. Results also indicate that the lane-keeping was a greater problem for older drivers than younger drivers and a lane-departure warning system was a significant help for them. The implications of the findings on older driver safety are discussed.

Improving Safe Transportation for Older Adults in a Socially-Mobile Environment

Paul Fancher[1], Maria Rachel de Araujo Russo[2], and Sergio Tadeu Gonçalves Muniz[3]

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This study introduces the benefits of transformational research procedures for planning, designing, and developing controller units which will aid older drivers in fulfilling purposes associated with safety and mobility. We will explain how to design and develop computerized information and control systems as needed to create and develop controller units for augmenting human capabilities in perceptual awareness, decision making, and the operational aspects of driving. Benefits enabled by using wireless communication hardware to enhance information flow to and from the controller in the interests of safety, timely access, traffic flow, and energy conservation will be discussed. Data from previous studies in which older drivers have dealt successfully with the motions of other vehicles (and stationary objects) in the traffic stream are used in designing controller units that take the driver's capabilities and functional purposes into account. Since the controller unit determines what the vehicle will do in its environment as a trip progresses, procedures for simulating the overall performance of the driving system are contemplated with emphasis on the role of the controller unit. The basic result is the design of a controller unit specially adapted to improve the transportation process for older drivers. The design process involves using strategic, tactical, and operational considerations to implement functional purposes associated with safety-related constraints on velocities, time/clearance gaps, and decelerations as well as satisfying the individual's transportation goals regarding access, mobility, and safety. The design procedures presented here represent a beginning stage of transformational research into a human-centered, purpose-oriented, adaptive-control approach to safe transportation in an aging society. Researchers from diverse disciplines with special expertise now have examples of electronic versions of these types of controller units to advance their research aimed at improving safe transportation.

Session VI: Prospective Changes in the Candrive/Ozcandrive Older Driver Cohorts (Moderator: Shawn C. Marshall, Ottawa Hospital Research Institute, University of Ottawa)

The Candrive Older Driver Study: Prospective Changes in Health Characteristics and Impact on Driving over 5 Years

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The CIHR Team in Driving in Older Persons (Candrive II) Research Program began enrolment of 928 older drivers in 2009 with the aim of prospectively following drivers over age 70 for 5 years. The objective of this study is to describe the health related function and quality of life changes in older drivers over the course of the five years of the study. There were 928 drivers age 70 and older recruited across 6 Canadian sites. Participants underwent comprehensive 2 hour annual assessments including measures of health, driving attitudes, habits and comfort, physical and cognitive screening measures. Participant vehicles were instrumented with in car recording devices. Changes in health related variables were examined using participants who completed Years 1 through 5 assessments. Of the potential 928 participants, 574 (62%) were still enrolled in the study at the 5 year mark. Participants demonstrated significant changes in health status with increased number of health conditions reported ($p<0.001$) and number of medications used ($p<0.001$). There were declines on tests of physical functioning including the Rapid Pace Walk Test ($p<0.001$). Significantly declining values were demonstrated for average km/ day driven, average trip distance, average speed, and also average number of weekly trips. Total convictions comparing Year 1 to year 5 for the 574 participants significantly decreased from 70 convictions for year 1 to 32 for Year 5. At 5 years post enrollment, the Candrive cohort demonstrates statistically significant changes in function, physical measures, driving comfort and perceived

driving abilities. This change in health status has significantly affected changes in driving patterns such as distance driven and speed. Changes were most salient for those who withdrew from the study and cognitive performance remained relatively stable for all participants. These current findings indicate that declines in physical function, health status and driving patterns occurred with the aging older driver cohort.

How Do Driving Patterns of Older Australians Change over Time? Early Findings from the Candrive/Ozcandrive Older Driver Cohort Study

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This paper investigates the driving patterns of older Australians participating in the five-year Candrive/Ozcandrive older driver cohort study. Data for a subset of Ozcandrive participants aged 75+ years (n=164, 68.9% male; Mean age = 79.5 years at Year 1, SD = 3.4, Range: 75– 88 years) were included for Years 1-3. In-vehicle data-loggers installed in participants' own vehicles monitored spatio-temporal characteristics of driving trips (ignition on/off). On average, in Years 1 and 2, participants drove 1,276 (SD = 479) and 1,307 (SD = 564) trips, respectively, totalling 9,468 (SD = 5,215) and 9,336 (SD = 5,371) kilometres annually, decreasing significantly to 1,175 (SD = 541) trips and 8,253 (SD = 4,813) kilometres in Year 3. Mean trip distance declined marginally across the study [M (SD):7.5 (3.2), 7.3 (3.4), 7.2 (3.5) km, Years 1-3, respectively]. The proportion of night trips declined significantly in Year 3 [M (SD) = 7.8% (6.2)] compared with Year 1 [M (SD) = 8.5% (6.2)], with similar but weaker effects for peak hour trips. The majority (60-65%) of trips were within 5 km from home across the study. Differences were observed for age group (80+ vs. 75-80 years), gender and for a sub-group who discontinued for health reasons. Early findings suggest a driving pattern comprising relatively short trips, close to home over a three year period. Reduced driving was observed across the study, with more marked declines in Year 3. Reductions in annual distances, night driving, and to a lesser extent, peak hour driving were suggestive of increased self-regulation, and this was more pronounced in: 1) the older sub-group, 2) women and 3) those who discontinued for health reasons. Results are considered in terms of implications for safe mobility. Recommendations are made to further explore associations between changing driving patterns and driving comfort, health and functional measures.

Simulator Driving Performance Is Associated with Subsequent Cognitive Decline Over Time: Preliminary Evidence from the Candrive Study

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Past research has indicated that safe driving in older adults is associated with cognitive, functional and health status. Older drivers have been found to be healthier than older adults who have ceased driving. However, it is unknown whether 'poorer' driving ability in older drivers is associated with cognitive decline over time. In this study, we examined whether simulated driving performance indicators are predictive of cognitive declines over time. A sub-sample of the Candrive cohort was recruited from Thunder Bay and Ottawa (N=76, mean age at baseline= 75 years old, SD= 4.25) and tested during year 3 (T3) of the Candrive study. For this study, driving performance was tested using a driving simulation targeting car handling where participants had to drive in a construction zone bordered by cones. Using the number of cones crashes as the driving related outcome variable, we compared high frequency cone crashers (1 SD above the average) to low frequency cone crashers. We found that high frequency cone-crashers (N=13) drove faster than the low frequency cone-crashers (N=64; $t(74)=1.92$, $p = 0.059$). Interestingly, the groups were comparable in terms of age, socioeconomic status, driving habits, cognitive and health status. However, a comparison of cognitive measures collected at year 5 of Candrive study (i.e., 2 years after simulator testing) indicated that MMSE scores differed statistically significantly such that the high frequency cone crashers (M=27.8, SD=1.4) had a lower MMSE score than the non-crashers (M=28.71, SD=1.32; $t(64)=2.01$, $p=.048$). Similarly, change in MMSE scores over time was found to be statistically significantly larger in high frequency cone crashers. Driving skills are reflective of one's cognitive, functional and health status. This study suggests that the driving skills assessed in our car handling scenario are associated with cognitive changes over time.

Can Changes in Older Drivers' On-Road Performance Across One year Be Predicted by Changes in their Functional Ability Measures or Self-Reported Driving-Related Comfort, Abilities or Practices?

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This study examined a cohort of older drivers to determine whether changes in their on-road driving performance using the electronic Driver Observation Schedule [eDOS] can be predicted by changes in their functional ability measures or self-reported driving-related comfort, abilities or practices? Two hundred Ozcandrive participants (Male: 71.00%; Median age: 81.00 years) completed several functional ability measures and self-reported driving-related comfort, abilities and practices questionnaires from the Candrive/Ozcandrive annual assessment and two eDOS approximately 12 months apart. Each eDOS commenced from the participant's home and was conducted in their own vehicle on roads familiar to and chosen by them. Observations of participants' driving performance were recorded for intersection negotiation, lane-changing, and merging. Approximately 12 months later, participants repeated the annual assessment and the eDOS. Participants completed significantly fewer driving manoeuvers (intersections, lane changes, merges) during their second eDOS compared to their first (Intersections: $z = -3.59$, $p < 0.01$; Lane changes: $z = -4.20$, $p < 0.01$; Merges: $z = -7.33$, $p < 0.01$). Participants made significantly more driving errors at intersections during their second eDOS compared to their first ($z = -6.81$, $p < 0.001$), however there was no significant change in the proportion of errors for lane changes or merges. A Generalized Linear Model revealed that changes in three factors across the 12 month period were significantly associated with an increase in intersection errors across the first and second eDOS: decreases in Montreal Cognitive Assessment scores ($B = -.16$, $p < 0.05$), increases in Rapid Pace Walk scores ($B = -.22$, $p < 0.05$) and increases in situational driving avoidance scores ($B = .13$, $p < 0.05$). Increases in intersection errors across one year were significantly associated with decreased cognitive and physical performance as well as increased self-reported driving avoidance. Future analyses are planned to explore whether changes in older driver's health or medication use are related to changes in on-road performance.

Changes in Drivers' Readiness for Mobility Transition Over Time: Results from the Candrive Study

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Many older drivers will eventually stop driving. Drivers' increased readiness to transition to non-driving status helps to reduce some of the adverse consequences of driving cessation. Meuser et al. (2011) developed the Assessment of Readiness for Mobility Transition (ARMT) tool as a means to measure attitudinal and emotional preparedness to transition to non-driving. Using data from participants recruited through the Candrive cohort study, we sought to examine changes over time in older drivers' readiness to transition to non-driving. A sub-sample of the Candrive cohort was recruited from 4 Canadian sites (N=95, mean age at baseline = 75 years, SD=4.42). Participants completed the ARMT tool on a yearly basis for three years as part of a larger set of measures. The ARMT tool consists of 24 items with response options ranging from 1 (Strongly Disagree) to 5 (Strongly Agree). Lower ARMT scores indicate greater readiness to transition. Individual items on the ARMT were summed to compute anticipatory anxiety, perceived burden, avoidance, adverse situation, as well as ARMT total score. Little change in drivers' ARMT scores was observed over the 3-year period. The mean change in drivers' ARMT Total score from year 1 to year 3 was M=0.05 (SD=.59). We observed no statistically significant differences in ARMT scores over the three time periods. Based on data collected from a sample of older drivers, ARMT scores were shown to be stable over a three-year period. Subsequent research will involve examining changes in ARMT scores in relation to other driving-related outcomes. The results will be discussed in the context of promoting readiness for mobility transition in advance of driving cessation.

Hand Positioning Behind the Wheel: Naturalistic Observation of Older Drivers from the Candrive Project

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Understanding how drivers are positioned behind the steering wheel is critical, as it has consequences for vehicle control and can ultimately influence driving safety. Hand placement while driving, in particular, may affect a driver's ability to react and respond accordingly to hazards within the roadway environment. Traffic volume, vehicle model, gender, fatigue, and other factors have been linked to hand positioning while driving in the general population. With motorists aged 65 and older set to become the largest demographic of automobile users and given their high risk of crashes, the objective of the current study were to investigate how vehicle type, road environment, traffic density, gender, and health can affect how older drivers position their hands when behind the wheel. Behind-the-wheel behaviour of Candrive participants from the Hamilton site (33 male, 20 female; aged 72-92 M = 78.9 years, SD = 4.95) were video recorded along a 30-45 minute familiar route using the electronic Driving Observation Schedule (eDOS) protocol. Participants were followed in a separate vehicle where maneuvers (e.g., lane changes, merging) and road environment (e.g., traffic volume) were documented. A camera was positioned on the passenger side of the vehicle that captured driver positioning.A hand position [Event] tracking checklist was created to translate each participant's hand positioning during naturalistic driving. Inter-rater reliability analysis of the checklist is underway (as determined by a Kappa statistic) using three independent coders (i.e., 10% of the videos). Frequencies of specific events will be aggregated, from which percentages will be calculated. These data will then be combined with eDOS data to investigate relationships between road environment, traffic condition factors, and health assessment data collected from participants via Candrive. This study outlines a novel approach for developing a tracking mechanism that captures behind-the-wheel behaviour of older drivers in relation to both external demands of the road environment as well as their health.

Poster Presentations

Valuation of Active Blind Spot Detection Systems by Younger and Older Adults

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Older adults have been shown to have trouble checking their blind spot, and crash data have shown that older drivers are more likely than younger drivers to have been merging prior to a crash. Advanced in-vehicle technologies, such as blind spot monitors, have been cited as a possible remedy to help older drivers continue to drive safely, but first they must be adopted by older adults. This study investigated older (aged 65+; N = 49) and younger (ages 18-23; N = 40) adults' valuation of a blind spot monitor and asked if self-reported visual difficulties in daily life and while driving predicted the amount participants were willing to pay for a particular system (BMW's Active Blind Spot Detection System) that was demonstrated using a short video. Large and small anchor values ($250 and $500, respectively) were used as between subjects manipulations to examine the effects of initial valuation, and participants proceeded through a short staircase procedure that offered them either the free installation of the system on their current vehicle or a monetary prize ($25-$950) that changed in value according to their choice in the previous step of the staircase procedure. Willingness to use other advanced driver assistance systems was also analyzed, additionally controlling for prior familiarity of those systems. Results showed that older adults displayed a higher valuation of the Active Blind Spot Detection System in both the large and small anchor value conditions, with greater age being predictive of higher valuation (controlling for income, gender, technology self-efficacy) in the large anchor condition, and a mix of visual factors and lower technology self-efficacy predicting higher valuation in the small anchor condition. Results are discussed in comparison to older adults' willingness to pay for other home-based assistive technologies aimed at improving well-being and independence.

Age-related Differences in Multimodal Information Processing and their Implications for Adaptive Display Design

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In many data-rich, safety-critical environments, such as driving and aviation, operators are gradually faced with numerous concurrent signals and notifications in visual, auditory, and tactile form, also known as multimodal information processing. As a result, the likelihood of an operator having to cope with three or more unrelated signals in separate modalities is extremely high. The goals of this research are to (1) assess performance effects of processing concurrent signals in different modalities and to (2) explore adaptive display techniques to overcome them.

This work focuses on adults aged 65 and older as they are the fastest growing age-group, are known to suffer from sensory deficiencies, and experience difficulties with divided attention. The application domain for this research is driving. The research is expected to add to the knowledge base in multimodal attention and, through informed design, will contribute to increased safety in a wide range of complex domains.

Inferring Alcohol Involvement in Fatal Car Accidents with Ensembled Classifiers

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The Fatality Analysis Reporting System (FARS) provides decades of records of fatal car accidents in the United States. The Michigan Data Science Team (MDST) held a competition in which entrants predicted whether or not a drunk driver was involved in each accident. Over 400,000 fatal accident records were provided. Years 2003-10 were used as training data, and 2011-12 and 2013-14 were used for validation and testing, respectively. Our top-scoring solution used an ensemble of a neural network and gradient boosted decision trees applied to 94 accident-level features. The second and third place teams also employed gradient boosted decision trees in addition to random forest classifiers. The neural network and gradient boosted decision trees alone achieved AUC scores of 0.863 and 0.868, respectively. We ensemble using linear weights to improve the performance to 0.869. The ensemble of the two methods effectively prevents overfitting to validation data by combining the outputs of diverse classifiers. Examining these classifiers reveals that there are complex relationships between certain features (e.g. crash time, accident location, passenger numbers and ages) and the likelihood of alcohol involvement. Other features, such as weather and passenger genders were found to be not as informative.

Evaluating the Impact of the Travel Time Reliability on Elderly Drivers Crash Severity

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Although older drivers (defined as those of age 65 and above) are less involved with speeding, alcohol use as well as night driving, they are more vulnerable to severe crashes. Several studies have evaluated the contributing factors on severity of crashes. However, few studies have established the impact of travel time reliability (TTR) on road safety. In particular, the impact of TTR on senior adults who face several challenges including hearing difficulties, decreasing of the processing skills and cognitive problems in driving is not well established. Therefore, this study focuses on determining possible impacts of TTR on the traffic safety with focus on elderly

drivers. Historical travel speed data from freeway links in the study area were used to calculate TTR metrics that is, planning time index, the buffer index, and the probability of congestion. Four-year information on crashes occurring on these freeway links was acquired. The logit model estimated using the Markov Chain Monte Carlo (MCMC) technique was used to evaluate variables that could be influencing elderly crash severity. Preliminary results of the analysis suggest that TTR is statistically significant in affecting the severity of a crash involving an elderly driver. The result suggests that one unit increase in the probability of congestion reduces the likelihood of the elderly severe crash by nearly 22%. These findings will enhance the understanding of TTR and its impact on the elderly crash severity.

The Impact of Physical Mobility on Vehicle Ingress and Egress by Older Adults

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While most safety-related older driver research focuses on factors contributing to driving patterns, reports also show that older Americans sustain over 37,000 injuries per year when getting into or out of a motor vehicle, 40% of which are due to falls (1). To better understand safety-related user-vehicle interactions, this study examined the vehicle ingress and egress (I/E) movement strategies used by older adults in relation to their physical mobility. Thirty-three older adults participated in the study (mean = 71.99 years (SD = 6.86); 19 females). Standardized trials of vehicle I/E performed with the same vehicle model. Participants also completed a battery of physical mobility tests. A physical mobility index developed based on the tests indicated older drivers with lower scores used I/E strategies that may put them at risk for falls. We hope to use this information to work towards design and education that enable safer user-vehicle interactions during I/E.

Collaborative Industry-wide Research on the Impact of Advanced Vehicle Technologies on Safety-related Driving Outcomes in Young, Middle-aged, and Older drivers: A Scoping Review

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Advanced Vehicle Technologies (AVTs) have the potential to make driving both safer and more dangerous. The rapid growth in the field of AVTs requires researchers and policy makers to stay abreast of the technologies and their influence on driving safety. This study will examine the effectiveness of AVTs on safety behind-the-wheel in younger, middle-aged, and older drivers. A scoping review is planned that will follow the P.I.C.O.S. research framework. White and grey literature will be searched that use NHTSA's AVT levels 0-4. The search for relevant literature is currently underway. We will share our starting point for the strategy as well as the proposed process, including knowledge dissemination and application, will be shared. Working directly with knowledge users through the entire process will ensure our research informs and transforms policy and AVT design. Results will guide future research for Toronto Rehabilitation Institute's state-of-the-art DriverLab facility.

Human Factors Analysis of Transit Dwell Time Performance

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This project examines the efficiency of transit operations and its accommodation of ambulatory and mobility impaired passengers. A systematic task analysis was conducted for a sample of n = 252 bus stops via video recordings from on-board surveillance cameras to document human factors related to transit safety and efficiency. Analysis variables are quantitative and qualitative, including but not limited to bus stop location, fare payment method, and the number of passengers entering or exiting the bus. A model from this data was generated to predict dwell times based on fare payment method of entering passengers. Bus stop dwell time is only partially explained by the fare payment method of entering passengers. Additional variables need to be explored to more accurately model the system. Next steps include analysis of comparing bus stop times to scheduled times, and different passenger entrance and exit combinations.