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FITNESS TO DRIVE IN EARLY STAGE DEMENTIA: AN INSTRUMENTED VEHICLE STUDY

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16. Abstract

Over 25 percent of people age 80 and older suffer from some form of dementia, with Alzheimer's Disease accounting for around 75 percent of all instances. It is estimated that around one-third of people with dementia continue to drive. Compared to the general driving population, drivers with dementia are at an increased risk of unsafe motor vehicle operation. Physicians and other health care professionals are often faced with making recommendations about their patients' fitness to drive, based on driver self-screening, recommendations by family members, and, if available, formal driving assessment. Recent advances in sensor, computer, and telecommunication technologies provide a method for automatically collecting detailed, objective information about a person's driving performance. Providing compelling data on driving performance in naturalistic settings will help those involved with the driving cessation decision plan a timely and appropriate transition toward community mobility options. The study had several specific aims including: demonstrate the feasibility of using in-vehicle data collection to monitor driving actions of individuals with early stage dementia; compare the validity of multiple forms of assessment of driving skills with naturalistic driving in individuals with early stage dementia; and increase understanding of behaviors and issues of drivers with dementia and their families. The study involved recruitment of 10 "triads" consisting of a licensed driver with a diagnosis of early stage dementia, a family member involved in the care of the driver, and a certified driving rehabilitation specialist who assessed the driver. Each driver's vehicle was instrumented with a variety of technologies so that driving behavior could be monitored for 1 month. These driving data were compared to the driving of an older adult sample without dementia. A series of surveys were also conducted to gather subjective assessments of the drivers. The study found: the dementia group drove as safely as the general older adult population sample; had a smaller driver activity space; and got lost more frequently. We found a lack of insight on the part of both drivers and family members when reported driving behaviors were compared to actual driving and that there was poor agreement among the various subjective assessments of the driver. Recommendations are provided for conducting a larger-scale study of the effects of early stage dementia on driving using instrumented vehicle technology.

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Contents

INTRODUCTION

Over 25 percent of people age 80 and older suffer from some form of dementia, with Alzheimer's Disease (AD) accounting for around 75 percent of all instances (Plassman et al., 2007). The number of people age 65 and older will more than double in the next 25 years, with a threefold increase for those age 80 and older (Herbel et al., 2006). Given current treatment, this growth will be accompanied by a commensurate increase in the number of people with dementia, with 10 million US baby boomers developing AD during their lifespan (Alzheimer's Association, 2008). While it might be assumed that individuals with dementia would stop driving after onset of symptoms, it is estimated that around one-third of drivers with dementia continue to drive (Silverstein, 2008). Most drivers are early in the disease process when cognitive deficits are generally mild (Adler & Kuskowski, 2003) and changes to driving performance are minimal. Nonetheless drivers with dementia are one of the groups considered at greatest risk for unsafe driving performance (Langford et al., 2007). Yet, decisions to enforce driving cessation are not straightforward and pose a difficult challenge to family members, licensing authorities, and health care professionals.

Compared to the general driving population, drivers with dementia are at an increased risk of unsafe motor vehicle operation (Man-Son-Hing et al., 2007). Problematic driving behaviors include becoming lost in familiar areas (Silverstein, Flaherty, & Tobin, 2002; Uc et al., 2004), incorrect turning (Uc et al., 2005), impaired signaling (Duchek et al., 2003), decreased comprehension of traffic signs (Carr et al., 1998), and lane deviation (Uc et al., 2005). Crashes, while infrequent, are also of concern for drivers with dementia, who have two-to-five times the crash risk relative to unimpaired older drivers (Charlton et al., 2003). Furthermore, driving skills predictably worsen (Adler et al., 1999) and will ultimately require individuals with dementia to stop driving (Adler et al., 2005).

Driving decisions need to be made not on diagnosis but on an assessment of the dementia's progress and the disease's effects on functional abilities (Duchek et al., 2003; Eby, Molnar, & Kartje, 2009). Unfortunately, there is little consensus on the means to make this assessment. A review of studies that measured driving competency of drivers with dementia found a wide array of different assessment approaches and

even where common protocols were used, there were different conclusions about their usefulness and validity (Reger et al., 2004). Road tests seem essential to answering questions about driving ability; however on-road evaluations by themselves have not been able to fully answer questions of driving competency. Because driving is an overlearned task, standard road tests with step-by-step instructions do not necessarily test the skills or expose errors commonly made by an experienced driver (Odenheimer, 1993). Another approach to assessing driving skills in individuals with dementia involves a driving simulator. Use a simulator, however, can be difficult for drivers with dementia even when given time to adapt to the setting (Cox et al., 1998). Furthermore, individuals with dementia retain abilities that are overlearned and thus, actual driving skills may be better than those assessed under the artificial conditions of a simulator. Neuropsychological tests have frequently been used to predict fitness to drive, often in studies that incorporate on-road or simulator evaluation, although their association with driving impairment and crash risk is at best moderate. Statistically significant associations are often found but their size and variability suggest that no single protocol can confidently indicate for a specific patient the impairment threshold for non-driving (Reger et al., 2004). As a result of current assessment inconsistencies and shortcomings, some drivers with dementia may be remaining on the road longer than is safe while other drivers may be ceasing prematurely. Improved procedures for assessing driving risk are urgently needed (Reger et al., 2004).

Physicians and other health care professionals are often faced with making recommendations about their patients' fitness to drive, based on driver self-screening, recommendations by family members, and, if available, formal driving assessment. Follow-up as the disease progresses occurs at various periodic intervals, ranging from 3 months to a year. The same intervals may be used for all patients without considering variations within stages of the disease or the idiosyncratic rate of disease progression. Yet, no one really understands how the real-life driving performance of an individual changes within the assessment intervals. If the interval is too short, it places an undue burden on the individual and his or her family members. If it is too long, the individual may pose a serious threat to public safety as well as to his or her own safety. In many instances, professionals may recommend geographic or other restrictions with the expectation of the driver's compliance with such recommendations. What is the driver's

experience in following the recommendations? Is he or she getting lost in familiar areas, taking more time to get to and from a familiar location, displaying confusion at intersections, not following road signs, driving at inappropriate speeds, or stopping for no apparent reason in the middle of a roadway?

Recent advances in sensor, computer, and telecommunication technologies provide a method for automatically collecting detailed, objective information about a person's driving performance (e.g., LeBlanc et al., 2006, 2007). This technology, placed unobtrusively in a driver's vehicle, can be used to monitor the driving behavior of individuals diagnosed with early stage dementia. Data from these technologies could also provide an objective look at the natural driving behaviors of early stage dementia patients relative to drivers with no memory impairment, help to guide decisions on how often these drivers need to be assessed, and help to investigate the validity of driving recommendations of clinicians and the assessment of the driver's abilities by family members and the drivers themselves.

The project also took advantage of one large database of naturalistic driving available at UMTRI that included objective driving behaviors of a set of drivers age 60-70 (LeBlanc et al., 2006, 2007). This group served as the comparison group for the present study.

The specific aims of this exploratory study were to: 1) demonstrate the feasibility of using in-vehicle data collection to monitor driving actions of individuals with early stage dementia; 2) compare the validity of multiple forms of assessment of driving skills with naturalistic driving in individuals with early stage dementia; 3); bring greater visibility to deficits in driving performance unique to people with early stage dementia; 4) increase understanding of behaviors and issues of drivers with dementia and their families; and 5) inform decision-makers about appropriate intervals for checking driving competency.

METHODS

Participants

The study was designed around the recruitment of "triads" consisting of a licensed driver with a diagnosis of early stage dementia, a family member involved in the care of the driver, and an occupational therapist (OT), certified as a driving rehabilitation specialist, who had assessed the driver. The original goal of the study was to recruit 24 triads, with the driver in the triad meeting the following criteria: a diagnosis of early stage dementia; having a valid drivers' license; completing and passing a comprehensive driving evaluation (which included clinical and on-road testing); willingness to have their personal vehicle installed with unobtrusive, in-vehicle technology for at least 1 month of driving; willingness to leave their vehicle at UMTRI overnight for the installation to take place; and availability of a vehicle in which the technology could be installed that was used regularly.

In addition, in the early stages of the project, we decided that participants would, by self-report, drive at least 100 miles per week to justify the resources expended to instrument the vehicle. Because of difficulties finding eligible participants, we later relaxed this requirement to 40 miles per week. This threshold was considered to be sufficient to provide meaningful data and at the same time bring in more eligible participants to the study. We also discovered that "early stage dementia" was neither a well defined nor often used diagnosis by physicians and other health professionals. We therefore broadened our criteria for inclusion in the study to include concerns expressed by a health professional about the driver related to *memory loss*.

Our original intent was to recruit participants from the eligible "clients" normally referred to the University of Michigan's (U-M) Drive-Ability program (located within the Occupational Therapy Division, Department of Physical Medicine and Rehabilitation). This program provides comprehensive driver evaluations designed for individuals with physical, visual/perceptual, and/or cognitive impairments. A client was considered eligible for study recruitment only after concerns had been expressed about him or her related to memory loss (by either the physician referring the driver to the Drive-Ability

program for assessment or by the program's OT and the driver was cleared to drive with or without restrictions.

Drivers who were eligible for study recruitment were informed of the study by the OT and asked about their willingness to be contacted by a member of the project team at UMTRI to discuss participation in the study. If they agreed to be contacted, the appropriate contact information was forwarded to the project team by the OT. A member of the project team contacted each driver by telephone, described the study, confirmed eligibility, and obtained information on a family member who could serve as a member of the triad. If a family member was willing to serve as a member of the triad and if the driver consented to participate in the study, an appointment was set up for him or her to come to UMTRI to have the in-vehicle monitoring equipment installed in his or her automobile. A member of the project team also verified that each driver had a valid license. Participants were required to bring the family member serving as a member of their triad to the appointments for installation and removal of the equipment as a condition of study participation. Study participation commenced only after both the driver and family member had signed an informed consent document.

From the time this recruitment strategy was proposed and investigated to the time when participant recruitment began, several issues impacted the effectiveness and timeliness of this process. The most significant issue was a change in Medicare policy resulting in a loss of cost coverage for driving assessment, meaning that older adult Drive-Ability clients had to cover the nearly $500 cost for the assessment out-of-pocket. This led to a dramatic reduction in the number of clients coming to Drive-Ability and, subsequently, the pool of potential participants fitting our criteria. The number of clients eligible to participate was further reduced by several unanticipated developments during the study period including a larger than usual number of clients either failing or refusing to take the on-road test required as part of the Drive-Ability assessment. Therefore, to increase the number of potential participants for our study, we expanded our recruitment strategy in three ways: First, drivers with memory loss were also recruited from the eligible "clients" normally referred to a different driving assessment/rehabilitation center. As with Drive-Ability, this program provides comprehensive driver evaluations designed for individuals with physical, visual/perceptual, and/or cognitive impairments, as well as the

on-road portion of the driving assessment for individuals who have completed the clinical portion elsewhere. Recruitment protocols were the same as for clients recruited from the Drive-Ability Program.

Second, recruitment of study participants was also expanded to include individuals who had memory loss but who had *not* completed a driving assessment (but met other eligibility criteria). This group of potential participants was recruited from the U-M Turner Geriatric Center's specialty clinics, Senior Resource Center, and Silver Club Programs (which sponsor several ongoing memory loss support groups). Written information about the study was provided to representatives at each site including recruitment flyers with the project contact information and scripts for program staff to introduce the study to their clients (including the requirement of passing a driving assessment as a condition of study participation). Clients deemed initially eligible for the study (i.e., clients with some memory loss but still driving) were asked by program staff about their willingness to be contacted by a member of the project team at UMTRI to discuss participation in the study. If they agreed to be contacted, clients' contact information was forwarded to the project team. A member of the project team contacted each driver by telephone, described the study, confirmed initial eligibility, and obtained information for a family member who could serve as a member of the triad. If a family member was willing to serve as a member of the triad and if the driver consented to complete a driving assessment through the Drive-Ability Program as a condition of participation in the study, the driver contacted the Drive-Ability Program Call Center to schedule the assessment. Drivers who successfully completed the assessment were re-contacted by a member of the project team to schedule an appointment for installation of the in-vehicle monitoring equipment. A member of the project team also verified that each driver had a valid license. Participants were required to bring the family member serving as a member of their triad to the appointments for installation and removal of the equipment as a condition of study participation. Drivers who did not pass the driving assessment were re-contacted by a member of the project team and notified that they were not eligible for recruitment into the study. As is the normal practice of the Drive-Ability Program, results of the assessment were reported back to the referring physician regardless of outcome.

Third, we also utilized the U-M Alzheimer's Disease Research Center (ADRC) registry to recruit participants. The registry is comprised of people who have expressed interest in participating in U-M research and who may have been diagnosed with some type of cognitive impairment. The data coordinator for the registry identified people she thought were appropriate for our study (e.g., those with an outcome of "mild memory impairment" from their neuropsychological testing) and forwarded their names to the project team so we could contact them. If they met our preliminary eligibility requirements and were interested in participating, we scheduled them for a driving assessment with the Drive-Ability Program (with costs charged to the project) to confirm their eligibility for the study (by passing the assessment) and invited them to participate. Once recruited into the study, all study protocols for eligible participants applied.

Even with these extraordinary recruitment efforts, only 10 triads could be recruited. The 10 memory loss drivers who participated in this study had a mean age of 71.6 years (SD=8.3), with ages ranging from 63-87 years. Eighty percent of the memory loss group was male. The mean length of time that drivers participated was 37 days (SD=6.8 days), with participation ranging from 29-53 days. Twenty-six subjects from an existing database of naturalistic driving were selected as a comparison group. The mean age for participants in the comparison group was 64.5 years (SD=2.8), with ages ranging from 61-70 years. One-half of the comparison group was male. The mean number of days driving in the comparison group was 25 (SD=0.4), with the number of days ranging from 24-26.

Study Protocols

Eligible drivers who agreed to participate in the study brought their vehicle to UMTRI to have it instrumented with the in vehicle technology. Each driver was accompanied by his or her family member serving as the second member of the triad. Vehicles were installed and returned to drivers the following day. Drivers were asked to drive as they normally would, with the technology in their vehicle, for approximately 1 month. During that time, some data were downloaded in real time to ensure that the system was functioning properly; however, most of the data were not downloaded until the end of the driving period and the technology had been removed from the vehicle. Both drivers and family members returned to UMTRI for removal of the equipment. Approximately 2 weeks after removal of the technology, all members of the triad (driver, family member,

and OT) returned to UMTRI to meet with members of the project team and receive summary information about the driver's experiences during the 1-month driving period.

Each triad provided information to the study team through written questionnaires and additionally, in the case of family members, through telephone interviews. Drivers completed two 30-minute questionnaires about their driving habits, experiences, and competencies. The first was completed while their vehicle was being instrumented with the in vehicle technology. The second was completed immediately after they met with the project team to receive the summary information. Both questionnaires were self-administered, with a member of the project team on hand to give out and collect the questionnaires and answer any questions that came up.

Family members also completed two questionnaires about their impressions of the driving of their family member with memory loss. These questionnaires took about 30 minutes each and were completed at the same time that drivers were completing their questionnaires, but in a different room. In addition, family members were contacted by telephone approximately 2 weeks after the meeting with the project team and asked about any changes in the driving of their family member with memory loss since the meeting.

Finally, the OT who originally assessed the driver with memory loss completed a written questionnaire immediately after participating in each summary session with the driver and his or her family member. The OT was asked to revisit her previous assessment and recommendations and to make any revisions that she deemed appropriate based on the summary information provided in the meeting.

Selection of Behaviors to Monitor

An important component of the study was to determine which driving behaviors to monitor. Those selected represented a combination of behaviors most likely to be affected by early stage dementia and to be measured cost-effectively given the time and budget constraints of the study. The selection process relied on previous and concurrent work by the authors. The process started with a list of behaviors thought to be most critical for safe driving (called critical driving skills) in older adulthood developed

in a previous project for the National Highway Traffic Safety Administration (NHTSA) (Eby, et al., 2008a, 2008b). This work divided critical driving skills into three categories: *strategic* (high-level decisions about trip goals, modes of transit, driving route, driving time, and broader issues); *tactical* (maneuvers made in traffic in response to the driving environment); and *operational* (basic vehicle control behavior such as steering, braking, and scanning). This list of critical driving behaviors was modified to remove skills that could not be measured objectively through in-vehicle technology (such as pre-trip planning) and used as the starting point for discussions among a panel of experts and focus groups with various people involved in assessing older drivers.

Expert Panel

A panel of 15 people with expertise in dementia, traffic safety, older adults, neuropsychology, engineering, and public health was convened in Ann Arbor, MI. The objective of the panel was to obtain feedback on which driving skills the study should attempt to monitor through in-vehicle technology. Prior to the panel, participants completed a worksheet that listed each proposed critical driving skill and asked for the respondent to give his or her opinion on a deficit in that skill might manifest itself in people with early stage dementia. Panel members were also asked to rank each skill on how indicative a deficit in that skill is for early stage dementia. Panel members could also suggest other skills and provide comments. All worksheets were compiled and a summary was provided at the panel. The panel addressed three issues: prioritizing driving skills relative to the study; evaluating the feasibility of measuring these skills through in-vehicle technology; and gathering general feedback on the study.

Focus Groups

Nine focus groups were convened in 2006-2007. The purposes of the focus groups were to: 1) better understand driving behaviors of persons with dementia; 2) identify issues significant to driving decisions; and 3) examine critical components of driving assessment. Three groups of participants were recruited: drivers with dementia, a relative or friend of the driver with dementia, and OTs. Results of these groups were used to inform the development of multimodal assessment study protocols and data collection, including pre/post surveys and telephone follow-up.

After Institutional Review Board approval was obtained, drivers and relatives were recruited through educational programs and support groups conducted by the Houston and Southeast Chapter of the Alzheimer's Association. Driving participants were restricted to those currently licensed with Mini-Mental State Examination (MMSE) scores of 21 or greater and who had a collateral source of information also willing to participate in the study. The collateral group consisted of relatives and friends familiar with the drivers' on-road activities. The health professionals group was restricted to OTs who addressed driving in their practice. These individuals were identified through professional networks familiar to the research team members.

Interested participants were prescreened (drivers/relatives by the Alzheimer's Association Chapter and professionals by the researcher) to ensure they met selection criteria for group membership. A formal invitation was extended to all those who met inclusion criteria. Potential participants were informed of the aims of the project and that their participation was voluntary and confidential. Focus groups were moderated by one of the project investigators or a graduate student. During group sessions, a predetermined list of prompts was used as well as probes to clarify responses to open-ended questions. In separate groups, drivers and relative groups discussed the current driving habits and behaviors of drivers with dementia, plans for continued driving and cessation, and roles and responsibilities of relatives and professionals in driving decision-making. After discussing the purpose of the group, participants were asked to provide written consent and complete a demographic information sheet. Driver and relative groups were conducted at sites identified and provided by the Alzheimer's Association Chapter. The health care professionals were queried about their experiences testing drivers with dementia. They were specifically asked about behaviors frequently observed during an evaluation, components of their testing, recommendations made for continued driving and follow-up. The professionals also provided written consent and a completed demographic information sheet. These groups took place at professional meetings and academic settings identified by the investigator. Each group was audio-taped with the consent of the participants. Groups lasted no longer than 90 minutes. Participants received a small honorarium for their time. Once completed, the group discussions were transcribed verbatim, reviewed and analyzed.

Descriptive statistics were used to characterize the demographic data. Analysis of the overall discussions involved multiple steps. Investigators independently reviewed transcripts of each group separately, categorizing data into codes related to research objectives. Researchers compared and discussed preliminary code categories and patterns. Successive reviews of transcripts led to identification of themes within and across groups.

Forty people participated in 13 focus groups: four groups of drivers, four groups of family members, and five groups of driving professionals. Ten people participated in the driver groups. Participants' mean age was 72.6 (± 7.9) years, 90 percent were male, and 80 percent had a college degree. Driver participants' average experienced memory loss was for 2.6 (±1.7) years. Driver participants drove 5.4 (± 1.3) days per week for 55.6 (±20.6) miles, with one-half reporting driving alone. There were nine participants in the family member groups. Seven of these family members were spouses of the drivers, one was an adult child, and one was a friend. All but one family group member was female, the average age was 65.4 (±11.1) years, seven were college educated (78%), and all were drivers. Twenty-one people participated in the professional focus groups. Participants' mean age was 46.0 (±8.2) years. Seventeen participants were female, with an average length of practice of 17.8 (±8.1) years. Nine had conducted a driving assessment in the past 6 months.

Analysis identified several major themes, some specific to each group category and others common to all. Groups began with discussion about the driving behaviors of individuals with dementia. Although most drivers were experienced, all groups noted a number of red flags or warning signs indicative of declines in driving performance. One of the most frequently reported problem by both drivers and their collateral sources of information was becoming lost in familiar areas. Relatives and professionals also noted poor pre-ignition skills and difficulties with basic vehicle maneuvers (such as inability to maintain appropriate speed and problems merging). Poor insight and judgment was also observed.

Drivers hoped to be able to make their own decisions about driving cessation but several expected that guidance from their family and friends might be necessary. Most collaterals welcomed support and assistance with driving decisions from their physician or another family member. Driving professionals discussed challenges associated with making driving recommendations, such as driver skepticism with assessment results and concerns about adherence to recommendations. The professionals described practicing a variety of approaches to driving assessment. They described an on-road assessment that usually began with an orientation to the vehicle and a course that progressively became more complex and involved observation of the operational and tactical abilities of the drivers. Few OTs saw drivers for more than one assessment (except in cases where it was requested by the physician) although most agreed that intervals for retesting would be 6 to 12 months. The time spent on assessment generally took up to 3 hours.

Based on the expert panel discussion and the focus groups, a list of behaviors was compiled for study consideration. The list was then reviewed by the engineering team to determine which behaviors lent themselves to algorithm development and subsequent instrumentation. The following critical driving skills were ultimately selected for inclusion in the present study:

- Travel patterns
- Wayfinding
- Safety belt use
- Interaction with traffic control devices
- Left turns
- Speed and headway
- Signaling
- Gear errors
- Pedal errors

In Vehicle Technology

A critical element of the study was that drivers with dementia be monitored in their own vehicles rather than in a standardized instrumented vehicle. Thus, each driver's personal vehicle was equipped with a suite of sensors and a data acquisition system (DAS) to provide measurements and observations of the driver's travel patterns, driving performance, and behaviors during the period of testing. This section summarizes the

design of the data system as well as the rationale for the design, and describes how the equipment was installed in and removed from the vehicles.

The final onboard system is depicted in Figure 1. The heart of the system was the DAS main module which included a central processing unit (CPU), data storage media (automotive-grade 80 GB hard disks), power management electronics including a backup battery, and several interfaces (for the sensors, vehicle battery, ignition signal, ethernet for data offloading, and keyboard/monitor interfaces for experimenters). Figure 2 shows the main module mounted in the cargo space of a compact station wagon. The unit measured 3.5 x 8 x 22 inches. The main module was mounted in the trunks of sedans (usually under the package shelf), in the cargo area of SUVs and vans, and behind the seat(s) of pickup trucks. Installation of the main module was done consistently with automotive industry techniques for ensuring the device would remain fixed in the event of a crash.

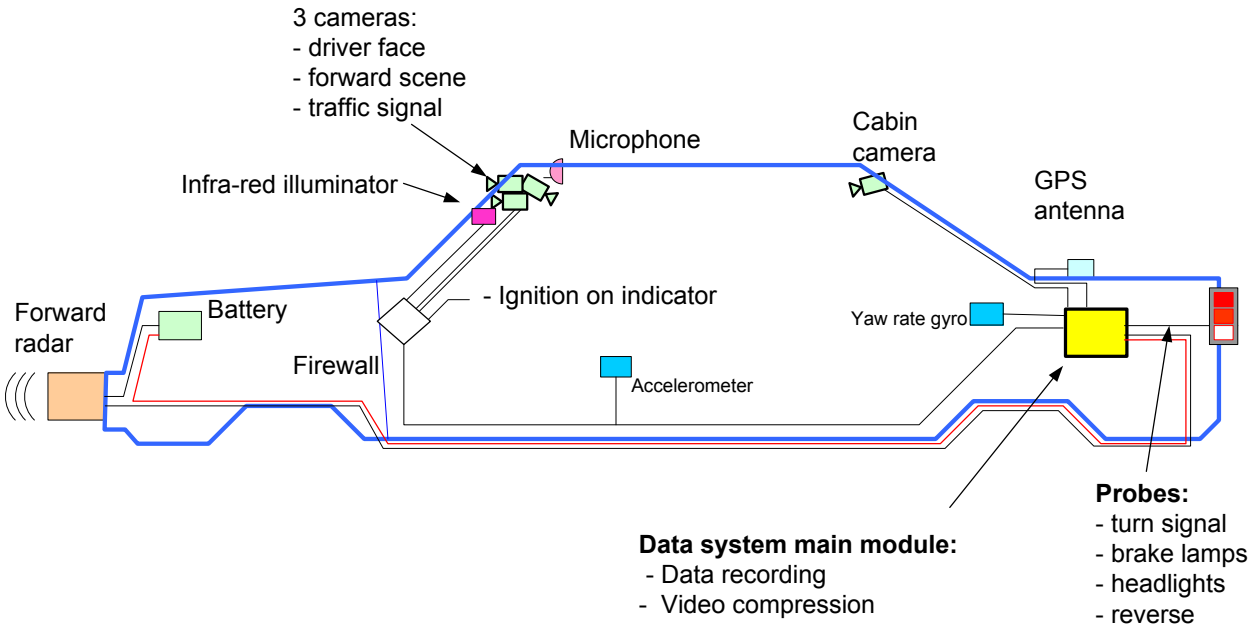

Figure 1: Schematic of the onboard data system

Figure 2: DAS main module in a compact station wagon

Four cameras were installed in the vehicle. Three cameras were mounted behind the rear-view mirror, as shown in Figure 3, and a fourth "cabin" camera was mounted in the rear of the cabin. Sample images for all four cameras are shown in Figure 4. Two forward views were collected: grey-scale images showing the forward scene with a horizontal field of view of approximately 60 deg, and a color image with a horizontal field of view of approximately 20 deg to allow us to see the state of traffic signals during intersection approaches. The forward views were vital to providing the context and driving circumstances of events. A third camera captured the driver's head and shoulders as well as some portions of the exterior near the vehicle on the driver's side and sometimes to the rear of the vehicle (depending on the vehicle model). This allowed the driver to be positively identified, to capture indications of driver attentiveness, and to assess safety belt use. The fourth camera was mounted on the headliner or the rear or side glass to capture a view of the forward portion of the cabin. This provided information about secondary task activities, the presence of front-seat passengers, and the presence of any navigation devices.

Video images were captured continuously at 5 Hz, except for the cabin camera data, which was collected at 1 Hz. The cabin and driver face video collection used infrared illumination of the driver's face and the dashboard and center console area for nighttime information. The video from the four image streams were compressed as individual streams using MPEG-4 compression, providing high quality images at relatively low data volumes.

Figure 1 also shows that a microphone was installed in the cabin, just above the rear-view mirror. Audio data were continuously recorded with a 8 KHz sampling rate. Audio data provided further insight into the context of events which were reviewed by analysts.

An automotive long-range forward radar was used to measure the relative speed and distances to vehicles and other objects in front of the participant's vehicle. This radar was a production unit used in adaptive cruise control systems and was a 77 GHz unit capable of sensing to ranges well over 120 m. The radar was mounted to the center of the vehicle's front bumper and covered with a plastic shroud. Typical installations before and after shroud installation are shown in Figure 5. The forward radar and forward cameras were both aligned to a common frame of reference established with respect to the longitudinal axis of the vehicle.

Figure 3: Three cameras, microphone, and IR illumination module

Figure 4: Sample images from the four cameras

Figure 5: Forward radar: unshrouded (left), shrouded (middle), and cracked shroud with undamaged radar (right).

A two-axis accelerometer was used to measure lateral and longitudinal acceleration. Whenever possible, this was mounted close to the vehicle center of gravity (CG), although on some vehicles (primarily minivans) it was mounted well aft of the CG, although still on the vehicle's centerline. A yaw rate sensor was also installed. This was often mounted along with the main module, although it was located in the trunk below the package shelf. The accelerometer and yaw rate sensor were both aligned with respect to gravity. During installation the participant's vehicle was parked on a flat and level concrete slab and a bubble level was used to align them.

A global positioning system (GPS) antenna was magnet-mounted to the trunk lids of sedans and to the roofs of light trucks, vans, station wagons, and hatchbacks. The GPS was a 4 Hz differential system that used the WAAS satellite correction system for an approximate accuracy of 1 to 5 meters. The GPS served as the basis for knowing the vehicle speed and time of day, as well as the latitude, longitude, and heading.

The brake lamp, reverse lamp, and turn signals were monitored by connecting to the vehicle wiring harness. Accessing these signals often required removing the tail light assemblies, as shown in Figure 6. To leave the vehicle in its original state, the existing connectors were often disassembled and modified with new conductors and fusing so that the vehicle wiring integrity was preserved.

Note that there was no use of ODB-II or proprietary CAN bus data. The SAE standard message set on the ODB-II bus neither adds additional information to the data set described here, nor does it have information with enough resolution to replace the sensors used here. CAN bus data is highly proprietary and it was well beyond the scope of this project to negotiate with the automobile manufacturers for CAN codes for a set of diverse and initially unknown vehicles. Recruitment for the test participant population was so challenging that it was not possible to limit the vehicle makes and models to allow CAN codes to be negotiated for a smaller set of models.

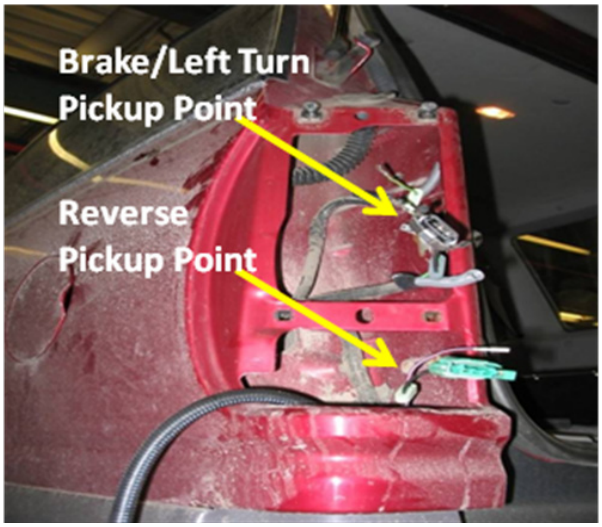

Figure 6: Rear lamp assemblies for observing brake application, reverse gear, and turn signal.

As previously described, drivers participated for about 1 month, with some participating for up to 2 months. The following observations regarding the technology's performance were made:

- No camera or radar failures were noted.
- One video framegrabber failed near the end of a driver's data collection period, and one of the two forward views was lost for several trips.
- One driver's data set had intermittent accelerometer dropouts due to a connector problem.
- On approximately 2 percent of the trips for all vehicles, the GPS did not initialize, so the route and speed data was not collected. These trips were omitted from analyses.
- On some vehicles, ignition noise limited the clarity of recorded audio.

Technology Installation Issues

Because of the difficulties finding drivers who fit our diagnostic criteria for participation and who were willing to participate, we made the decision to not limit vehicle makes or models. As expected, there was considerable vehicle variability in participants' vehicles. Thus, nearly all installation needed to be customized for each vehicle.

Installation, calibration, and removal of the instrumentation from drivers' vehicles represented significant activities for each vehicle. Collectively, these activities took

approximately 55 person-hours per vehicle with a highly experienced team. Our original estimate called for less than one-half of this time for installation per vehicle. This meant the vehicle was at UMTRI for the installation and calibration process for more than 1 full day (but less than 2 days). This time varied by up to 30 percent between vehicles. Removal of the equipment took between 1 and 4 hours. For a "typical" installation, the steps and the approximate fraction of time consumed are listed here:

- Installation, including preparatory work, actual installation, calibrations, and validation (87 percent).
- Release to the subject (2 percent).
- Removal of equipment after the subject's test was complete (11 percent).

Preparation for the installation occurred before the vehicle arrived at UMTRI and was a major activity that accounted for over one-third of the overall installation work. Preparation included several steps, including asking the test participant over the telephone about the vehicle make and model, year, trim level, existence of front license plate brackets (optional in Michigan), and any modifications or special uses of their vehicle that could influence installation (e.g., a need to move large objects). Several hours were required to set up the DAS main module for a new driver, organize and check sensors and wiring harnesses, and consult an online service manual to identify likely interfaces with vehicle systems. Tentative plans for cable routing were developed. Much of the installation and calibration steps were described earlier; it should be noted that every vehicle was unique especially in terms of running wiring harnesses and locating points where ignition or lamp signals could be accessed.

In Vehicle Data Collection

Once participants' vehicles were installed with the technology, they were asked to drive as they normally would for a period of about 1 month. Because of difficulties in participant recruitment early in the project, some drivers participated for up to 2 months, while new participants were being recruited. Participants were contacted after 1 week so that questions could be answered and a check of the technology could be scheduled. The technology was inspected and some data downloaded from the DAS to ensure that the sensors were functional and data were being collected properly. At the end of the

data collection period, participants were contacted to schedule de-installation of the equipment.

Onboard Data Pre-Processing

Upon the return of each study participant's vehicle to UMTRI, sensor data were uploaded from the DAS onboard the vehicle onto servers at UMTRI. The data were then loaded into a relational database, and samples of video, audio, and numerical data were briefly reviewed to find any obvious problems with the instrumentation. A number of automatic calculations and checks were then performed to: ensure that no recorded data were lost during uploading; flag results of automatic checks that suggested data issues; and interpolate, filter, and synchronize various data channels. For example, turn signal raw data were simply the levels of voltage recorded from the turn-lamp to create the blinking turn signal. These changing voltages were coded into a binary form for use by analysts, with "one" indicating that the turn signal was blinking and "zero" indicating that the lamp was not blinking. Another example was that an estimation of yaw rate bias was made using yaw rate values from times when the vehicle came to rest, and that bias estimate was used to correct yaw rate data gathered while the vehicle was moving. Dozens of these basic tasks were performed automatically before further data reduction was done.

The main processing of the data included an integrated series of automatic calculations and analyst reviews of video, audio, and other sensor data. Analyst reviews of over 10,000 events/trips were conducted for this study. The video reviews consisted of:

- Cabin review for each ignition cycle to positively identify the driver and determine whether a passenger was in the vehicle and/or whether a navigation device was visible on the dashboard.
- Safety belt review for each ignition cycle to determine whether the driver wore his or her seat belt. This was done using driver face video, which also showed the driver's shoulders.
- Slowing event review, which was a sampling of all events in which the driver slowed to below 5 mph (8 kph). This was used to review behaviors at stop lights, stop signs, intersections, some unprotected left turns and all other stops (including any mid-block stops).
- Red-light running review, which reviewed sampled instances of drivers passing through a signalized intersection with speeds remaining above 10 mph.
- Wayfinding trips of interest review, which was a detailed review of video, audio, and numerical data to identify trips that may have contained driver errors associated with wayfinding.

Comparison of the data available for the memory loss drivers and the comparison drivers set

As described earlier, the comparison driver data were from a group of 26 drivers from the Road Departure Crash Warning System Field Operational Test (RDCW FOT), which was conducted in 2004-2005 (LeBlanc et al., 2007). Those drivers were recruited from the same southeast Michigan region as those in the memory-loss group, but the comparison driver set was a gender-balanced group between the ages of 60 and 70. The measurements in the RDCW FOT were slightly different from the measurements in the present memory loss study. The data from the comparison driver set do not include video for capturing traffic lights or for determining whether the driver was alone, features added to this study specifically to address dementia-related concerns. Thus, no comparisons can be made for those measures.

Computing measures for statistical analysis

Table 1 summarizes the driving metrics analyzed for this study. This table includes the type of critical driving skill, the metric(s) for assessing that skill, and a description of the metric. This description also notes whether the metric was based on randomly sampled data, because some metrics could not be computed on all data. More detailed descriptions of some of these metrics follow Table 1. Note that many metrics are normalized by an exposure variable, such as distance traveled, trips by that driver, or events of a specific type. The selection of the exposure variable for normalizing a measure was done to allow comparison of measures between drivers with varying participation periods. For example, seat belt use is expressed as the fraction of travel distance traversed while belted. Also, red-light running is expressed as the fraction of signalized encounters.

Travel patterns

Travel pattern measures depended primarily on GPS measurements that included location, time of day, speed, heading, and GPS quality indicators. The fraction of distance traveled alone and/or with a navigation device depended as well on review of brief driver-face video clips by an analyst.

Table 1: Description of the driving skills and metrics investigated in the study		
Driving Skill	**Metric**	**Description**
Travel patterns	Trips per day	Trip was defined as ignition-on to ignition-off.
	Miles driven per day	Determined with GPS data.
	Number of unique destinations per week	Unique destinations divided by the number of weeks in the testing period.
	Percent miles driven on freeways	Miles traveled on freeways divided by all miles traveled
	Percent miles driven within 5 miles of home	Miles traveled while within 5 miles of the driver's residence divided by all miles traveled by that driver.
	Percent miles driven within 10 miles of home	Miles traveled while within 10 miles of the driver's residence divided by all miles traveled by that driver.
	Percent miles driven during daylight	Percentage of all miles traveled in daylight, as defined by civil twilight.
	Percent miles driven during rush hour	Percentage of all miles traveled during weekday rush hours (6.30 to 9 am, 4 to 6.30 pm).
	Percent miles driven alone [memory loss drivers only]	Percentage of all miles traveled that were traveled with no passengers in the vehicle as determined by review of cabin video.
Wayfinding	Percent miles driven with a navigation device [Memory loss drivers only]	Percentage of all miles traveled with a navigation device present as determined by review of cabin video.
	Number of wayfinding trips of interest	Number of trips that were determined to be wayfinding trips of interest.
	Percent wayfinding trips of interest	Percentage of all trips that were wayfinding trips of interest.
	Number of likely lost trips	Number of trips that were judged to involve the driver getting lost.
Safety belt use	Percent distance belted	Percentage of all miles traveled that occurred on trips where the driver was deemed to be belted, based on face video analysis.
Headway	Percent miles driven with short headway	Percentage of following time spent tailgating another driver (see text for description).
Speed	Percent miles driven 10 mph slower than surrounding traffic	Time with a preceding vehicle traveling 10 mph faster than the participant's vehicle, divided by the total time that a preceding vehicle was present.
Interaction with traffic control devices	Percent stops that were inappropriate	Percentage of all sampled slowing/stopped events that involved actions by the participant that were unsafe given the particular

Table 1: Description of the driving skills and metrics investigated in the study		
		circumstances of that event.
	Percent inappropriate actions at stop signs	Percentage of all sampled stop sign-related slowing/stopping events that involved actions by the test subject that were unsafe given the particular circumstances of the event.
	Percent red-light running	Percentage of analyst-reviewed signal encounters with minimum speeds of 10 mph or more in which the driver entered the intersection while the light had been red for at least 1.5 sec upon entering the intersection.
Left turns	Percent inappropriate left turns	Percentage of analyst-reviewed left turns across paths that involved maneuvers by the participant that were unsafe for the circumstances of that event.
Signaling	Percent turn signal use for turns	The fraction of sampled turns associated with the driver's use of the turn signal.
Gear errors	Number of wrong gear events per week	Wrong-gear or backing events divided by number of weeks in the testing period.
Pedal errors	Number of pedal errors per week	Unintended forward accelerations that were observed at low speeds, divided by number of weeks in the testing period.

Wayfinding trips of interest/likely lost trips

Wayfinding trips of interest were defined as trips over 1/8 mile for which either:

- The route from the starting point to the end point deviated significantly from a direct route for a reason that could not be determined or confidently assumed by review of the data; or
- The trip itself was part of a sequence of trips that included navigation that was significantly indirect.

If the latter reason applied, only one trip was counted as a wayfinding trip of interest. Likewise, a single trip that had more than one instance of probable wayfinding errors was counted only once.

Wayfinding trips of interest were identified by first running an initial automatic filter to identify trips that needed to be reviewed by an analyst. Next, a sequence of steps was completed by the analyst to either understand the purpose of the driver's travel behavior or retain the trip as a wayfinding trip of interest. Note that the comparison set of drivers

for these analyses represented a randomly-selected subset of the full set of comparison drivers, due to project resource limitations.

The filter that determined whether a trip was reviewed employed a comparison of the actual trip distance (D) with the computed distance for a trip from the start to end points of the trip (CD), using a navigation software package (Microsoft MapPoint). The trip was considered for review if it was at least 0.75 miles long, and if C/(CD) > 1.4 or C – CD > 1.5 miles. This filter was developed by reviewing a large sample of trips for nine of the memory loss drivers and finding a filter that captured 90 percent of the wayfinding trips of interest, while requiring a relatively limited review of the trips.

For trips satisfying the first filter, the navigation software package presented a map showing both the actual and the software-calculated routes. In many cases, the analyst could understand the difference between the actual and the computed routes immediately (e.g., perhaps the driver took an alternate route avoiding freeways, or perhaps the driver was taking a child to school without stopping the vehicle on a route observed earlier in the review). For other trips, however, the analyst reviewed video of the trip, and possibly other trips, to determine if there was evidence that the inefficient routing discovered through the navigation software had a reasonable explanation. These trips often involved ferrying passengers, going through drive-through restaurants, banks, or car washes, picking up newspapers from coin-operated machines, wandering through wooded parks or cemeteries, taking alternate routes, and so on. High confidence was required to conclude that these were the actual purposes for the trips. For instance, meandering through wooded parks for one participant was judged as not being a wayfinding problem because it was a regular activity on trips with the participant's spouse and both occupants could be seen pointing at objects and slowing down to look at certain sites. All remaining trips were classified as "wayfinding trips of interest;" that is, trips in which, by our judgment, there were wayfinding problems, such as getting lost or forgetting a destination once a trip had started.

The wayfinding data analyses have some limitations. For a small minority of the drivers' trips, it was a challenge to determine with confidence the purpose of the trip. Without knowing the trip purpose, it was often difficult to distinguish whether a trip was along an

intended route, with a purpose unknown to the analyst, or whether it was truly a trip with wayfinding problems. Another important point is that nearly all drivers made wrong turns that were identified by the driver and corrected. These were not counted in the wayfinding analyses.

Following distance

This metric was the fraction of "car-following time" spent with short headway times relative to a vehicle ahead. Car-following time was defined as the time spent when the participant's vehicle was traveling at least 25 mph with a forward vehicle present at a headway time of no more than 3.5 sec and with a relative speed within 5 mph. (Note that headway time was the distance to the vehicle ahead divided by the speed of the participant's vehicle.) The metric was the percentage of car-following time during which the time headway was less than 0.7 sec. This time headway threshold is generally recognized as tailgating.

Speed

This metric was intended to identify drivers who traveled much slower than surrounding traffic. The measure was the fraction of time that the forward radar detected that same-direction vehicles were traveling more than 10 mph faster than the participant's vehicle. The metric was normalized by the total time during which same-direction traffic was sensed by the radar.

Red-light running

Red-light running was studied by analysts reviewing a sample of events in which the participant drove through a signalized intersection with a minimum speed of 10 mph or more. This review was done only for the memory loss drivers because data for the comparison driver set did not include a wide angle view of the forward scene that would have allowed us to determine the state of the traffic signal. For memory loss participants, signalized intersections were identified using a map database provided by the Southeast Michigan Council of Governments (SEMCOG) which covers a seven-county region. Traffic signal encounters were found automatically using the GPS data and the map database, and a short clip of video was cued for the reviewer to code the maneuver, the traffic signal state, and any indication of inappropriate behavior by the participant. The sampling led to about 60 reviewed events per driver, selected randomly.

Wrong gear errors

Wrong gear errors were determined in part by an analyst's review of video and data. This metric was defined as events that were close in time to the driver being in the reverse gear, which involved any observations of gear confusion (using the wrong gear), backing into existing traffic, bumping into an object, or other instances of risky or unintentional behavior. All events in which there was a change in backing acceleration (jerk) of at least 10 m/s^2 per second were reviewed. The intention was to capture events that could include impacts as well as firm braking.

Pedal errors

This metric was defined as unintended forward accelerations. Searches for unintended accelerations involved reviewing all events in the memory loss driver set that satisfied at least one of two sets of criteria. The first criteria set was to find events with a substantial forward acceleration that began at a low speed (less than 5 mph). There were several unique events for which the forward acceleration exceeded a threshold (A) for at least a given period of time (DT), where:

(A, DT) = (2 m/s^2, 4 sec) or (3 m/s^2, 1 sec) or (4 m/s^2, 0.3 sec).

None of these events appeared to involve any risk or lack of driver intention to increase speed. Many of these were simply hard accelerations at intersections, in parking lots, or pulling into traffic. Thus, a secondary search was done for events in which the final vehicle speed 10 sec after the acceleration began was less than 5 mph, based on the assumption that an unintended acceleration would be followed within this time period by a recovery by the driver, and the car would be slowed. No unintended acceleration events were identified; the remaining events flagged by this analysis included drivers crossing divided roads, maneuvering in traffic signal queues, and pulling onto a road near queues.

Data Analysis

Data were entered into an excel spreadsheet and checked for errors in preparation for analysis. Data were analyzed using the SAS Statistical Software package. Univariate descriptive statistics were generated for both the memory loss group and the comparison group. As part of this process, data for each group were plotted to assess

normality and determine the most appropriate statistical tests for comparing the groups. Because several of the variables were not normally distributed and our sample sizes were small, we used a nonparametric test, the Wilcoxon Signed Rank Test, rather than a t-test to compare group means for each of the variables of interest (see Cody & Smith, 1997). Nonparametric methods generally have the additional advantage of being resistant to outliers and other extreme values.

We used a one-tailed test for each of the group mean comparisons between the memory loss group and comparison group, given that we had reasonable expectations that the memory loss group would not only differ from the comparison group along the various driving measures, but that these differences could be expected to be in one direction or the other (more or less) depending on the variable of interest.

RESULTS

As described previously, this study had three specific aims: compare the objective driving measures in the present study to similar measures obtained from previous studies on older drivers; compare the validity of multiple forms of assessment of skills with naturalistic, objective driving in individuals with dementia; and determine changes in assessment after each member of the triad was exposed to the objective driving data. Separate analyses were conducted to address each of these aims.

Compare the objective driving measures in the present study to similar measures obtained from previous studies on older drivers

This aim was addressed by comparing the driving performance data obtained through the in-vehicle technology in the present study to similar data from a comparison group of older adults without memory loss. The number of participants (N), mean score, confidence interval, and probability level of the Wilcoxon Signed Rank Sum test (p-value) for each variable investigated in the study can be found in Table 2. Note that some variables could not be investigated in the comparison group sample, either because the data were not available or the project budget and timeline did not allow for us to investigate the variable. In addition, for two variables, 17 comparison subjects were randomly selected from the 26 for analysis, as these variables required labor-intensive analysis of video. P-values shown in bold indicate that there was a statistically significant difference ($p<.05$) between the memory loss group and the comparison group.

As shown in Table 2, several variables did not differ significantly between the groups. Both groups drove a large majority of the time during daylight hours and about 15 percent of the time during rush hour. Both groups used turn signals slightly less than 80 percent of the time and both groups had little travel that involved inappropriate stopping. We found that no driver in either group ran a stop sign or made an inappropriate left turn. In addition, there were few cases in both groups in which the participant used the wrong gear.

Table 2: The number of participants (N), mean score, confidence interval (±), and probability level of the Wilcoxon Signed Rank Sum test (p-value) for each variable investigated in the study by group			
	Memory Loss	**Older Adult Comparison**	
Metric	**Mean (N=10)**	**Mean (N=26; *N=17)**	**p-value**
Trips per day	3.0 ± 0.9	4.3 ± 0.7	**0.0200**
Miles driven per day	15.3 ± 7.3	35.7 ± 6.1	**0.0001**
Number of unique destinations per week	6.4 ± 2.2	12.8 ± 2.2	**0.0001**
Percent miles driven on freeway	20.6 ± 14.8	32.9 ± 6.8	**0.0394**
Percent miles driven within 5 miles of home	64.1 ± 15.7	43.0 ± 6.5	**0.0025**
Percent miles driven within 10 miles of home	81.3 ± 16.5	60.3 ± 8.3	**0.0030**
Percent miles driven during daylight hours	88.9 ± 8.0	86.2 ± 6.1	0.3434
Percent miles driven during rush hour	14.8 ± 7.2	16.6 ± 4.7	0.2683
Percent miles driven alone	45.2 ± 23.9	unavailable	N/A
Percent miles driven with a navigation device	0.0 ± 0.0	unavailable	N/A
Number of wayfinding trips of interest	0.9 ± 0.6	2.4 ± 0.9*	**0.0141**
Percent wayfinding trips of interest	0.9 ± 0.6	2.8 ± 1.5*	**0.0259**
Number of likely lost trips	0.2 ± 0.2	0.0 ± 0.0*	0.0714
Percent distance belted	96.5 ± 5.0	98.8 ± 2.3	**0.0036**
Percent miles driven with short headway	3.1 ± 2.4	6.1 ± 3.4	0.1354
Percent miles driven 10 mph or more slower than surrounding traffic	4.7 ± 1.9	1.8 ± 0.5	**0.0002**
Percent stops that were inappropriate	0.1 ± 0.1	0.1 ± 0.1	0.6359
Percent inappropriate actions at stop signs	0.0 ± 0.0	0.0 ± 0.0	N/A
Percent turn signal use for turns	76.5 ± 14.2	79.4 ± 8.0	0.3092
Percent inappropriate left turns	0.0 ± 0.0	0.0 ± 0.0	N/A
Percent red-light running	0.1 ± 0.1	unavailable	N/A
Number of wrong gear error events per week	0.0 ± 0.0	0.0 ± 0.0	0.5159
Number of pedal error confusion events	0.0 ± 0.0	unavailable	N/A

Several driving behaviors differed significantly between the two groups. The memory-loss group took significantly fewer trips per day, drove fewer miles per day, traveled less often on the freeway, drove to about one-half as many unique destinations per week, and traveled significantly more miles within both 5 and 10 miles from home. Thus, in general, driving among the memory loss group exhibited a much smaller and more limited driving space than the comparison group.

There were only a few differences in driving behavior related to safety. When compared to the comparison group, the memory loss group was more than twice as likely to travel at least 10 mph slower than surrounding traffic and was one-half as likely to travel with a close headway (tailgate), although this latter result was not a statistically significant difference. The memory loss group also was slightly less likely to use a safety belt, with both groups exhibiting high rates of use.

Surprisingly, an examination of wayfinding between the groups showed that wayfinding trips of interest were more common, both by number and percent, for the older adult comparison group. There were, however, more trips in which the driver got lost for the memory-loss group, but this difference was not significant.

Among the driving behavior metrics that we could only investigate within the memory loss group, we found that slightly less than one-half of the time drivers drove alone, no driver used a navigation device, there were few incidents of red-light running, and no pedal confusion was found.

Compare the validity of multiple forms of assessment of skills with naturalistic, objective driving in persons with dementia

Also of interest in this study was determining how well drivers and their family members reported on behaviors of the driver. We addressed this issue by comparing responses in Survey 1 of the driver and family member, on questions related to the memory-loss drivers' driving habits and experiences with related objective driving performance measures derived from the in-vehicle monitoring equipment. In some cases, more than one survey question was related to a specific behavior, such as wayfinding. In these cases we analyzed each question separately, and by a new variable that combined the

responses from each question. Spearman correlations were calculated. The results can be found in Table 3.

Table 3: Spearman correlations comparing driver and family member self-reported behaviors (subjective) with actual behaviors (objective) on drivers with memory loss (correlations shown in bold are significant at the .05 probability level).

Behavior (objective/subjective)	Memory Loss Driver	Family Member
Miles driven per week/Miles driven typical week	**-0.64**	-0.11
Days driven per week/Days driven per week	0.56	0.60
Percent miles driven on freeway/How often expressway avoided	-0.46	**-0.83**
Percent miles driven within 10 miles of home/How often avoid nonlocal areas	-0.19	0.56
Percent miles driven within 10 miles of home/How often avoid unfamiliar areas	0.12	0.46
Percent miles driven within 10 miles of home/How often avoid unfamiliar OR nonlocal areas	0.08	0.56
Number of wayfinding trips of interest/How often took longer to get somewhere than expected	0.54	0.13
Number of wayfinding trips of interest/How often got lost	0.61	0.12
Number of wayfinding trips of interest/How often took longer to get somewhere than expected OR got lost	**0.75**	0.04
Percent miles driven with short headway/How often difficulty maintaining proper distance from car ahead	0.17	0.63
Number of likely lost trips/How often got lost	0.23	-0.28
Percent inappropriate actions at stop signs/How often ran a stop sign	NA*	NA*
Percent inappropriate left turns/How often avoid left turns	NA*	NA*
Number of pedal error confusion events/How often confuse gas and brake pedals	NA*	NA*
Percent miles driven during daylight hours/How often avoid night driving	0.43	**0.80**
Percent miles driven during rush hour/How often avoid rush hour	0.14	-0.26
Percent miles driven alone/How often avoid driving alone	0.00	**-0.77**
Percent distance belted/How often forget to use seat belt	**0.62**	**-0.68**

* Correlations cannot be calculated on these variables because there was no variance in the objective data (i.e., no occurrences were found for any driver).

As can be seen in Table 3, there was generally poor agreement between the driver's judgments of his or her behaviors and what we found when behaviors were measured objectively. A similar conclusion can be drawn about the judgments of the family members about their memory loss driver. In addition, for 2 of the 7 correlations that were statistically significant (miles driven per week and belt use), the correlations were in the opposite direction; that is, the judgments were systematically incorrect. For example, the drivers who drove few miles per week reported high miles driven per week and those who drove high miles per week reported low miles driven per week. As described earlier, we found that no participant ran a stop sign, made an inappropriate left turn, or had a pedal confusion event. The subjective (survey) data on these situations also showed that both the memory loss drivers and their family members reported few occurrences. Even though we could not calculate a statistic, there was good agreement between subjective and objective measures on these three behaviors.

Compliance with the OT Recommended Restrictions

Also of interest in this study was an assessment of the degree to which drivers with memory loss complied with the driving restrictions placed on them by the OT after the comprehensive assessment. We addressed this issue by analyzing the objective data to determine the frequency with which drivers complied. Six of the 10 memory loss drivers had no restrictions placed on their driving. Two of the drivers were told to restrict driving at night. The objective data showed that neither of these drivers drove at night during the study period. Two drivers were told to restrict freeway driving. Neither of these drivers drove at all on freeways during the study period. Three drivers were told to restrict driving to familiar/overlearned areas. During the study period, these drivers had 100%, 97%, and 94% of their travel within 10 miles of home. Thus, although there were few restrictions placed on drivers, those with restrictions appeared to follow them.

Determine changes in assessment after each member of the triad was exposed to the objective driving data

As described previously, the members of the triad completed surveys at various time points during participation in the study. The driver and family member completed a survey just prior to the driver's vehicle being instrumented with the technology (Survey

1). All three completed a survey approximately 2 weeks after the technology was taken out of the vehicle and immediately after receiving feedback on the objective driving data collected during the 1 month of driving (Survey 2). The family member completed a third survey by telephone interview about 1 month after the second survey (Survey 3). Complete univariate results of these surveys are presented in Appendix A. Each survey included a series of questions related to how the respondent judged the driving habits and abilities of the driver with memory loss. This aim was addressed by analyzing changes in these assessments over time and among the various groups. Results are grouped into three general categories: driving ability ratings; self restriction ratings; and driving behaviors associated with early stage dementia. We complete this section with a presentation of the unique survey results from the OT.

Driver ability ratings

How do you rate [yourself/your family member] as a driver?

One of the study objectives was to compare the driver's self assessment of driving ability with the assessments by the family member and the OT. Participants rated the driver's skill on a scale of "poor" (1), "fair" (2), "good" (3), "very good" (4), or "excellent" (5). Table 4 presents case level responses by drivers, family members, and the OT at the various survey time periods. Table 5 shows statistical comparisons among the various members of the triads. Both Spearman correlations and Wilcoxon Signed Ranks tests are presented and scores that are bold are significant at the 0.05 probability level.

Table 4: Case Level Responses by Drivers, Family Members, and the OT at the Various Survey Time Periods

	Driver		Family Member			OT
Triad	**Survey 1**	**Survey 2**	**Survey 1**	**Survey 2**	**Survey 3**	**Survey 2**
1	very good	very good	good	fair	fair	good
2	good	very good	good	good	very good	good
3	good	good	good	good	very good	fair
4	excellent	very good	excellent	very good	excellent	very good
5	very good	very good	excellent	very good	good	very good
6	excellent	excellent	excellent	excellent	excellent	excellent
7	very good	good	good	very good	very good	good
8	very good	very good	very good	very good	very good	very good
9	very good	good	very good	good	very good	very good
10	very good	good	excellent	very good	very good	good

Table 5: Comparison of Memory Loss Driver's Driving Ability Assessments Among Drivers (D), Family Members (FM), and the OT		
	Spearman Correlation	**Wilcoxon signed ranks test Z- score**
Survey 1: D/FM	**.707**	**-2.640**
Survey 2: D/FM	.326	-0.378
D Survey 1/OT Survey 2	**.763**	**-2.879**
D Survey 2/OT Survey 2	.611	-1.000
FM Survey 1/OT Survey 2	**.706**	-1.890
FM Survey 2/OT Survey 2	.608	-0.447
FM Survey 3/OT Survey 2	.595	-1.667

The correlation between driver and family member ratings of drivers' driving was significant for Survey 1 but not Survey 2. Although drivers, on average, rated their driving higher at Survey 1 (mean= 4.00) than did family members (mean=3.00), driver and family member ratings were in the same direction. Both driver and family member Survey 1 driver ratings were significantly correlated with the OT driver ratings. Overall, however, driver ratings were higher than OT ratings. All other comparisons were not significantly different.

Wilcoxon signed ranks tests were used to test for changes in driver ratings between Survey 1 and Survey 2 for both drivers and family members. Drivers rated their driving significantly lower at Survey 2 (Z = -2.74, p = .006). Family members rated drivers' driving ability lower after Survey 2 as well, but this was not significant (Z = -1.63, p = .102). Curiously, analysis of Survey 3 data showed that family members rated drivers' driving ability more positively at 2-weeks following Survey 2 than they had immediately after Survey 2 (Z = -2.00, p = .046) such that there was no significant difference between family members' Survey 1 driver ratings and their ratings given in Survey 3 (Z = .00, p = 1.000).

Driver Self-Restriction Ratings

The driver and family member surveys also asked for ratings on how frequently the memory loss driver avoided specific situations (self-restrictions) by asking: How often do you (your family member) try to avoid driving in the following situations (never [0]; rarely [1]; sometimes [2], and usually [3])? Table 6 shows how respondents answered this question for a number of situations during Survey 1. We also developed a self-restriction scale as a measure of overall self-restrictions. This scale was unweighted

and consisted of a simple count of restrictions with a range of possible scores from 0 to 30. Table 7 shows statistical comparisons between the drivers and family members on reports of how frequently the various situations were avoided by the memory loss driver. Note that scores shown in bold are significant at the 0.05 probability level and no correlation could be calculated for traveling with child passengers because all memory loss drivers indicated that they never avoided this situation.

Table 6: Mean and Standard Deviation (SD) of Frequency of the Driver Avoiding Certain Driving Situations as Reported by Memory Loss Drivers and Family Members

	Memory Loss Driver			Family Member		
Situation	**N**	**Mean**	**SD**	**N**	**Mean**	**SD**
Unfamiliar areas	10	0.70	0.82	9	2.00	1.22
At night	10	1.00	1.05	9	1.67	1.41
In bad weather	10	1.60	0.84	9	1.67	1.22
High glare times	10	0.80	0.79	8	1.00	1.10
Making left turns	10	0.40	0.70	8	0.75	1.16
In high traffic/rush hour	10	0.40	0.52	9	1.33	1.22
On the expressway	10	0.50	1.08	9	1.11	1.45
With child passengers	10	0.10	0.32	8	0.62	1.19
Alone	10	0.40	0.84	10	1.00	1.33
Non-local areas	10	0.30	0.48	9	1.89	1.27
Total self-restrictions scale	10	6.20	4.29	10	11.6	9.31

Table 7: Statistical Comparisons Between Drivers and Family Members on Reports of How Frequently Various Driving Situations are Avoided by the Memory-Loss Driver

Situation	N	Spearman Correlation	Wilcoxon signed ranks test Z score
Unfamiliar areas	9	.438	**-2.232**
At night	9	**.687**	-1.518
In bad weather	9	.518	-0.333
High glare times	8	.466	-.0707
Making left turns	8	.289	-1.300
In high traffic/rush hour	9	.134	-1.807
On the expressway	9	**.689**	-1.633
With child passengers	8	N/A	-1.342
Alone	9	.000	-1.300
Non-local areas	9	.289	**-2.271**
Total self-restriction score	10	**.677***	**-2.094**

In general, drivers reported few self-restrictions and family members reported more restrictions for the memory loss driver than were reported by the drivers. Driver and family member self-restriction ratings were significantly correlated for only two items (driving at night and on the expressway). We also found that the measure of overall restrictions was significantly correlated between drivers and family members as well. Family members reported that drivers restricted driving in unfamiliar and non-local areas significantly more often than memory loss drivers reported.

Family members reported that drivers *sometimes* restricted their driving in unfamiliar areas, at night, in bad weather, and in non-local areas, while drivers reported *sometimes* restricting driving only in bad weather. Based on median ratings, neither drivers nor family members reported that drivers restricted making left turns, driving on the expressway, driving with child passengers, or driving alone.

Both drivers and family members offered similar ratings on the extent to which they limited driving at night and on the expressway. There was a trend toward agreement on limiting driving in unfamiliar areas and bad weather as well. Family member and driver reports of driver self-restrictions significantly differed for driving in unfamiliar and non-local areas, with family members reporting more restrictions that they thought the driver was making than drivers reported.

Occurrence of driving behaviors potentially associated with dementia

Drivers and family members were asked a series of questions about how often the memory loss driver experienced a variety of situations in the past year (never [0], rarely [1], often [2], very often [3], or don't know [DK]). The same questions were asked in both Survey 1 and Survey 2. Table 8 shows the individual responses to these questions for each driver and his or her family member. Within each table cell, the response on top is for Survey 1 and the bottom response is for Survey 2.

Table 8: Individual Responses to the Questions About the Frequency of Occurrence of Specific Driving Problems in the Past Year								
Triad #	**Confused pedals**		**Took longer to get somewhere**		**Became confused at intersection or exit**		**Got lost**	
	Driver	**FM**	**Driver**	**FM**	**Driver**	**FM**	**Driver**	**FM**
1	Never Never	Never DK	Never Rarely	Sometimes Sometimes	Rarely Rarely	DK Sometimes	Rarely Never	Sometimes DK
2	Never Never	DK DK	Sometimes Never	Sometimes Frequently	Rarely Never	DK DK	Never Never	DK DK
3	Never Never	Never Never	Sometimes Skipped	Sometimes Sometimes	Sometimes DK	Sometimes Sometimes	DK Sometimes	Frequently Sometimes
4	Never Never	Never Never	Rarely Sometimes	Never Never	Rarely Sometimes	Never Never	Sometimes Rarely	Never Never
5	Never Never	Never Never	Rarely Rarely	Never Never	Rarely Rarely	Never Never	Rarely Never	Never Rarely
6	Never Never	Never DK	Never Rarely	Rarely Rarely	Never Never	Never Never	Never Rarely	Rarely Never
7	Never Never	Never Never	Never Never	Rarely Sometimes	Rarely Rarely	Rarely Rarely	Never Never	Rarely Rarely
8	Never Never	Never Never	Sometimes Sometimes	Never Never	Rarely Rarely	DK Never	Rarely Never	Never Never
9	Never Never	Never Never	Rarely Never	Never Rarely	Never Never	DK Never	Never Rarely	Rarely Rarely
10	Never Never	Never Never	Rarely Never	Never Never	Very often Rarely	Never Never	Never Never	Rarely Rarely

The ratings in Table 8 were analyzed using Spearman correlations and Wilcoxon Rank tests to determine the level of agreement between the drivers' and family members' responses. Because "never" was most often selected as a response to these questions, data were recoded into binary form such that "never" was coded zero and any occurrence was coded one. Table 9 shows the mean, standard deviations (SD), and statistical scores for drivers and family members. Note that scores shown in bold are significant at the 0.05 probability level.

Table 9: Comparison of Driver and Family Member Ratings of Driving Behaviors Potentially Associated with Dementia by Survey.						
	Driver		Family Member		Spearman Correlation	Wilcoxon Signed Rank Test
Driving Behavior	N	Mean (SD)	N	Mean (SD)		
	Survey 1					
Confused the brake and gas pedals	10	.00 (.00)	9	.00 (.00)	1.000	0.000
Took longer to get somewhere	10	.70 (.48)	10	.50 (.53)	**-.655***	-0.707
Became confused at an intersection/exit	10	.80 (.42)	6	.33 (.52)	.316	-1.732
Got lost	9	.44 (.53)	9	.67 (.50)	**-.775***	-.378
	Survey 2					
Confused the brake and gas pedals	10	.00 (.00)	8	.00 (.00)	1.000	0.000
Took longer to get somewhere	9	.56 (.53)	10	.60 (.52)	-.350	0.000
Became confused at an intersection/exit	9	.67 (.50)	9	.33 (.50)	.333	**-2.000***
Got lost	10	.40 (.52)	8	.62 (.52)	-.258	-.447

There were no reports of confusing gas and brake pedal. At the Survey 1 time period, there was substantial disagreement among drivers and family members regarding how often drivers took longer than expected to get to destinations and how often drivers got lost (significant negative correlation). The extent of disagreement was somewhat less after participation in the study at the Survey 2 time period, although the correlation coefficients were still negative.

Based on Wilcoxon Signed Rank tests of differences, there were no significant differences between driver and family memory ratings of dementia-related behaviors at Survey 1. At the Survey 2 time period, however, drivers were significantly more likely to report being confused at intersections than family members reported them to be.

Survey Results for the OT

The OT completed a survey following the debriefing summary of the objective data gleaned from the month-long instrumentation (Survey 2). The main purpose of the OT

questionnaire was to assess what changes, if any, the OT would have made in her recommendations to the driver regarding driving status.

The OT was first asked for background information about the evaluation of the 10 drivers. Most drivers (8) were referred to the evaluation by their physician. One was a self-referral. A family member or friend was noted as a secondary referral for three of the drivers. None of the drivers had been through a specialized driving assessment in the past, prior to the assessment required for participation in the current study.

After hearing the results of the instrumentation, the OT was asked, *how often should the driver be re-tested by a driving evaluator?* The responses for the 10 drivers were:

2 Every 3 months
3 Every 6 months
4 Once a year
1 *If any changes occur*

The OT was then asked to offer an opinion on whose advice the driver would accept regarding recommendations on changes to driving habits. Table 10 illustrates that after self, law enforcement was considered the major influence for following through on recommendations.

Table 10: Advice Driver Would Likely Follow Regarding Recommended Changes in Driving

Source	Not at all likely	Somewhat likely	Very likely	Definitely
Self			1	9
Spouse		3	5	1
Adult children		5	5	
Sibling		6	3	
Friend	1	7	2	
Other family member	1	7	2	
Physician		2	6	2
Eye doctor		1		2
Dept. of Motor Vehicles		4	6	
Law enforcement			3	7
Religious leader		1	2	3
Counselor/therapist		3	4	2
Driving evaluator		4	5	1
OT if different from above		5	4	1

DISCUSSION AND CONCLUSION

This report describes a feasibility study using custom in-vehicle technology to objectively measure driving behaviors of people with early stage dementia and to compare these behaviors with a general population sample of older drivers among similarly measured behaviors. The study also served as a feasibility study to gain insights into the issues of recruiting and retaining subjects with early stage dementia, installing technology in drivers' personal vehicles, and processing/analyzing the data generated from the various on-board sensors.

The study found that there were several differences in driving behaviors between the memory loss participants and the comparison sample of older drivers. One finding from the study was that the memory loss group drove as safely (and perhaps more safely) than the general older adult population sample. Few safety-related behavioral errors were found for either group. The memory loss group tailgated less often and drove slower than surrounding traffic more often. On the other hand, the memory loss group used safety belts less often. Given that several studies have shown that individuals with early stage dementia drive less well than controls, as measured on-the-road, in simulators, and from family/caregiver report (Man-Son-Hing, Marshall, Molnar, & Wilson, 2007), it might seem surprising that we did not discover more safety problems in our memory loss group. One possible explanation for this finding is related to how participants were recruited. Prior to enrolling in the study, all memory loss participants were required to complete and pass a comprehensive driving evaluation that included an assessment of on-road driving performance. Such a process is currently the gold standard for determining fitness-to-drive. Dementia, however, is a progressive disease and it might be thought that even though participants had been judged to be safe to drive initially, some would experience cognitive declines that would result in declines in driving ability. In the present study, all participant data were collected within 3 months of the initial assessment. The time between successful completion of the assessment and the start of data collection averaged less than 1 month and the longest time a participant was in the study was 2 months. The recommended reassessment period for all of the memory loss participants in our study was at least 6 months. It is possible

that if the project had a longer data collection period (e.g., 6 months), we would have found greater driving safety problems in the later months of data collection. Anecdotally, in our study, one participant's family member reported during the telephone follow-up that she had noticed such significant declines in driving in the weeks following data collection that they were planning to end the participant's driving in the following weeks. Thus, this finding argues for a much longer data collection period for studying the effects of early stage dementia on driving. The data collection period should be at least 6 months.

The study also found that the driving activity space was significantly smaller for the memory loss group than for the older adult population sample. Participants in the memory loss group drove shorter distances, drove to fewer destinations, restricted driving to daytime, and avoided freeways. A restriction in driving space for people with various medical conditions, including cognitive impairment, has been found previously using self reported measures such as diaries and interviews (Barber-Gateau & Fabrigoule, 1997; May, Nayak, & Isaacs, 1985; Marottoli, et al., 1997; Stalvey, Owsley, Sloane, & Ball, 1999). The present study is the first to show, using objective measures of driving, that drivers with memory loss restrict their driving space.

This study also investigated the wayfinding behaviors of both driver groups. We hypothesized that drivers in the memory loss group would be more likely to have wayfinding difficulties than the older driver population sample, because "wandering behavior" is common in people with dementia (see e.g., Silverstein, Flaherty, & Tobin, 2002). We found a low incidence of wayfinding problems in both groups. However, trips during which the participant was likely lost (based on our judgment) were only found for the memory loss group, providing support for our hypothesis.

We encountered several difficulties, however, in assessing wayfinding problems in this study. As discussed previously, there was no algorithmic method for finding trips for which wayfinding problems were present. Instead, we relied on heuristics to identify potential trips with wayfinding problems. These potentially problematic trips were then analyzed individually in a labor intensive process that required viewing of trip video and listening to audio recordings of conversations within the vehicle. This analysis was

largely subjective. For example, one memory loss driver took two trips about 1 hour apart. On both trips, the driver traveled different short routes in his neighborhood and returned home without stopping anywhere. Analysis of the video did not reveal any obvious purpose for either trip. We concluded that the driver was not lost, but rather forgot his destinations once he began each trip. Thus, the wayfinding results reported here should be considered exploratory in nature. It is possible that our heuristics missed trips in which wayfinding problems were present and that our subjective conclusions were incorrect in some instances. Further investigation into wayfinding problems, particularly getting lost, among drivers with memory loss is warranted.

The study also investigated the validity of two assessments of the memory loss drivers' skills—from the perspective of the family member and the memory loss driver him\herself. Validity was assessed by comparing self-reported behaviors with similar behaviors measured objectively using the in-vehicle technology. We found a surprising lack of insight on the part of the family member and the memory loss drivers. For most behaviors that we could analyze, there was poor agreement between what family member and drivers reported and what we found in the objective data. In some cases, we found significant negative correlations, indicating that there were systematic errors in reporting. For example, the memory drivers who drove few miles per week reported driving many miles and those who actually drove many miles per week, reported that they drove only a few miles per week. These data highlight the limitations of self-reported driving data, at least for this population of individuals with memory loss.

The study design also allowed us to examine the degree to which memory loss drivers followed the driving restrictions recommended by the OT, through an analysis of the objective driving data. Although, few drivers had restrictions placed on them, those that did followed the restrictions very closely.

The study also examined the degree of agreement between the members of the triad at various points in time (at the various surveys). In terms of rating the memory loss drivers' driving ability, drivers tended to rate their skills more favorably than the family member or the OT. After exposure to the objective driving data, both family members and the drivers themselves rated driving ability less favorably. This result suggests that

the presentation of actual driving behavior over the month influenced subjective ratings of driving abilities. Similar analyses were conducted for questions on how frequently the memory loss driver tried to avoid certain driving situations and the frequency of driving problems. We found that drivers reported very infrequent avoidance of most situations and that family members reported significantly more avoidance. In general, there was poor correlation between these two groups on assessments of avoidance in most situations. Similar results were found for self-reported driving behaviors. These results, along with the results showing a poor correlation among self-reported driving behaviors and actual driving behaviors, indicate that self-reports of driving from both the memory loss driver and family members have little value, at least in this population of drivers.

The study provides valuable information about recruiting and retaining participants with early stage dementia. Our original inclusion criteria for recruitment were fairly strict and specific. They included: having a diagnosis of early stage dementia by a physician; having been assessed by the U-M Drive-Ability Program and considered safe to drive prior to any contact by the study team for recruitment; and having a valid driver license. It became clear early on that a formal diagnosis of early stage dementia was often not included in patients' medical records even when they were exhibiting symptoms of such dementia. Instead, patients were more likely to be described as suffering from memory loss or memory impairment. This was certainly the case for patients referred to the Drive-Ability Program by a physician. Therefore, we expanded our recruitment criteria to include a diagnosis of memory loss or memory impairment; otherwise we would have had virtually no study participants who met the inclusion criteria. Our original decision to recruit only from the pool of clients who had successfully completed a comprehensive assessment through the Drive-Ability Program was based on wanting a consistent referral and assessment process for potential participants. In addition, we had an established relationship with the Drive-Ability Program, having worked with them on other projects, and we had received early assurances from program staff that our recruitment goals were attainable. Unfortunately, the program experienced an unanticipated and substantial decline in the pool of eligible clients during our study period for a variety of reasons outside of the program's control. To enroll sufficient numbers of study participants, we had to expand our recruitment pool to other comprehensive assessment programs in the area, as well as U-M clinics serving clients

with memory loss who had not undergone a comprehensive driving assessment. For this latter group, we required that they be referred to the Drive-Ability Program by their physician and successfully complete the assessment (for which we paid) before they could be enrolled in the study.

Successful retention of participants throughout the full course of the study depended to a great degree on the effectiveness of the interactions between project staff and participants. Interactions with participants occurred at several points during the study including enrollment of participants in the study, home visits prior to technology installation in some cases to assess vehicle issues, actual technology installation, monitoring during the study period to make sure the technology was functioning appropriately, and technology de-installation. In addition, several project team members were often involved in a particular interaction. Project team members had to be particularly sensitive to concerns by participants about privacy and confidentiality issues, as well as the susceptibility of some participants to become confused about project timetables and requirements. Having a family member accompany the driver to the technology installation and de-installation helped overcome some of these challenges. In addition, a single research assistant coordinated all contact with participants to provide stability throughout the study. She was also available to provide some backup transportation during the technology installation so that participants were not stranded without their car for too long.

The challenges associated with participant recruitment and retention resulted in our gaining several insights about how other studies of this type could be enhanced. First, we recognize that adults with early stage dementia represent a special population that often requires more careful attention to communication and interaction. It is important to have project team members who are sensitive to the needs of this population, can build trust with individual participants, and can effectively manage the logistics of scheduling activities, particularly for those who may easily become confused. Flexibility is paramount when working with this population.

As a first study of its kind, one of the greatest challenges we faced was installing the in-vehicle technology in drivers' personal vehicles. As described previously, custom

engineering was needed for nearly all subjects in the study to effectively install the technology without damaging the vehicle. With an average of 55 skilled person hours required for each participant just for technology installation/de-installation, a large proportion of the project's labor was devoted to this task. Despite this challenge, we still think that among this population of drivers it is important to measure objective behaviors while drivers are using a vehicle that is familiar to them rather than having them drive an instrumented experimental vehicle that is unfamiliar. This study showed that future work of this type will need to ensure that adequate engineering resources are included in the project.

We found that the custom technology we utilized in the project was very successful and dependable, resulting in full-time video collection of video, audio, and several data channels for more than 5,000 miles of driving in all seasons with the population of the 10 memory loss drivers. The technology installed onboard the vehicles was generally appropriate for this type of study and is likely to serve well for any future studies on drivers with cognitive impairment, perhaps with a few adjustments. Adding a rear view camera would help with understanding backing events as well as capturing more of the driving context. The forward radar could be a shorter-range sensor (24 GHz instead of 77 GHz), which could be smaller, less expensive, and slightly easier to install. The use of two cameras to view the forward scene was found to be very useful. The long-range color camera was capable of collecting traffic signal state at long ranges (using a human reviewer), and the wide-angle grey-level camera was useful for intersection analyses. The unique use in this project of separately compressing the individual video streams reduced data volume by up to 30 percent without loss of information, relative to more common schemes of compressing a composite of several images.

The results of this study did not identify straightforward and substantial savings for future studies. GPS and video are required for almost every analysis reported here. Once any video is required, the onboard DAS must have substantial storage and processing capabilities, and hence non-trivial packaging and mounting requirements as well as power and ignition signals. The remaining sensors (lamps, vehicle motion, and radar) are necessary to observe driver control and potential risks. The marginal costs of

the other sensors used in this study were about 30 percent more for installation and 10 percent more in system costs, so that stripping down the system is not advisable.

This study also provides insights into processing the sensor data into metrics of driving skills. We discovered during analysis that GPS alone is insufficient to study wayfinding issues. The simple notion that drivers will travel direct paths between successive destinations is not necessarily true. Indeed, trips with indirect routes occur much more often than do trips with wayfinding errors. Furthermore, a key step in understanding wayfinding issues is to determine the intended destinations themselves. Destinations are not obvious from GPS data, and often become obvious only through video analysis, including knowledge of when passengers are in or out of the vehicle. Thus, having knowledge of the nature of destinations or stopping points (e.g., a shopping center, drive-through bank, child's school with a passenger entering the vehicle) would be beneficial. In this study, wayfinding was investigated using map databases and video was used, as well as a buildup of information over time about specific driver's patterns. In the short term, this may remain the best non-intrusive technique until map databases with much more specific information are available, such as the information provided in a Geographic Information System (GIS). We found that audio was very useful for understanding wayfinding, as occasionally the trip objectives would change as a passenger asked to go somewhere, and thus the path taken had a sharp change in direction that only audio could provide insight into.

The study had several limitations that should be considered when interpreting the results. First, the experimental participants necessarily represent a convenience sample of drivers who were willing to have their driving monitored and who had a family member available to serve as the second member of the triad. As such, the behaviors of these drivers may not be representative of the population of drivers with memory loss. In addition, our comparison group of drivers was also a convenience sample of people aged 60 to 70 years. These drivers may not be representative of this population. Second, the drivers in the comparison group were not screened for memory loss. Because these participants responded independently to recruitment advertisements, completed questionnaires, and responded appropriately with research staff for the study in which they were recruited, it is unlikely that any had memory loss, but some may

have. Third, even though we ended up using "memory loss concerns expressed by a health professional" as the diagnostic inclusion criterion, there was likely great variability in the level of memory loss among our participants.

One conclusion from this project is that a much larger sample of drivers who drive for a longer period of time is needed to make definitive conclusions about the driving behaviors of people with early stage dementia and/or memory loss. Based on the issues we addressed in this project we provide the following recommendations for a large scale, longitudinal study of driving among individuals with early stage dementia.

- Study participation should commence with a comprehensive driving assessment to ensure that participants have been cleared to drive by a health professional.
- Drivers should participate for at least 6 months and preferably for 1 year. Analysis should look at changes in driving behaviors over time within participants.
- A quantitative measure of early stage dementia or memory loss should be used in the study. This measure might be the result of a single test or the results of a battery of tests, but should be able to classify participants on their level of cognitive impairment.
- Because of the difficulties encountered with participant recruitment, a large scale study should utilize multiple participant recruitment sites and possibly multiple data collection sites. Such an expansion will need to done after ensuring that the local databases needed for analysis, such as a database of traffic control device locations, are available.
- Participants' own vehicles should be instrumented. This will mean that a large portion of the effort and budget will need to be devoted to the engineering aspects of the project.
- A large scale study should utilize a means to more easily identify trip purposes. One possibility is to construct a GIS database that contains business, recreation areas, schools, churches, and other locations linked to GPS coordinates; another strategy would be for the driver or family member to keep a diary or log in trip destinations or perhaps enter that information through a voice command upon entering the vehicle.
- Finally, the study should expand upon the methods used for identifying wayfinding errors. Significant resources were expended in the present study to identify wayfinding problems and such an effort would be intractable for a large scale study.

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APPENDIX A: UNIVARIATE RESULTS OF SURVEYS

Driving

How many days per week do [you/your family member] typically drive?

	Driver		Family Member		
Days per week	**Survey 1 % (N)**	**Survey 2 % (N)**	**Survey 1 % (N)**	**Survey 2 % (N)**	**Survey 3 % (N)**
1	-	-	-	-	-
2	10% (1)	-	-	-	-
3	10% (1)	-	10% (1)	10% (1)	30% (3)
4	-	-	20% (2)	20% (2)	-
5	30% (3)	30% (3)	50% (5)	30% (3)	50% (5)
6	10% (1)	40% (4)	-	20% (2)	10% (1)
7	40% (4)	30% (3)	20% (2)	10% (1)	10% (1)
Don't know	-	-	-	10% (1)	-

About how many miles do [you/your family member] drive in a typical week?

	Driver		Family Member		
Miles per week	**Survey 1 % (N)**	**Survey 2 % (N)**	**Survey 1 % (N)**	**Survey 2 % (N)**	**Survey 3 % (N)**
10 or less	20% (2)	-	10% (1)	-	10% (1)
11-30	20% (2)	10% (1)	10% (1)	40% (4)	30% (3)
31-50	40% (4)	60% (6)	50% (5)	10% (1)	30% (3)
51-100	20% (2)	30% (3)	10% (1)	10% (1)	20% (2)
More than 100	-	-	-	10% (1)	10% (1)
Don't Know	-	-	20% (2)	30% (3)	-

How often do [you/your family member] take drives that are greater than 30 miles round trip?

	Driver		Family Member		
Frequency	**Survey 1 % (N)**	**Survey 2 % (N)**	**Survey 1 % (N)**	**Survey 2 % (N)**	**Survey 3 % (N)**
Usually	-	10% (1)	-	10% (1)	10% (1)
Sometimes	70% (7)	50% (5)	50% (5)	30% (3)	40% (4)
Rarely	30% (3)	30% (3)	40% (4)	20% (2)	10% (1)
Never	-	10% (1)	10% (1)	30% (3)	40% (4)
Don't Know	-	-	-	10% (1)	-

Would you say that most of [your/your family member's] trips are mainly in:

	Driver		Family Member		
Area	**Survey 1 % (N)**	**Survey 2 % (N)**	**Survey 1 % (N)**	**Survey 2 % (N)**	**Survey 3 % (N)**
Urban	20% (2)	20% (2)	10% (1)	40% (4)	40% (4)
Suburban	50% (5)	40% (4)	40% (4)	40% (4)	50% (5)
Rural	10% (1)	20% (2)	10% (1)	20% (2)	10% (1)
A mixture*	20% (2)	20% (2)	40% (4)	-	-
Don't Know	-	-	-	-	-

* Not included as option on Family Member surveys; if 2 options were checked, mixture was coded.

Compared to five years ago, would you say that the amount of driving [you/your family member] do has:

	Driver	Family Member
Amount	**Survey 1 % (N)**	**Survey 1 % (N)**
Decreased	70% (7)	90% (9)
Same	20% (2)	-
Increased	10% (1)	10% (1)
Don't Know	-	-

How often do [you/your family member] plan routes before going out to drive?

	Driver	Family Member
Frequency	**Survey 1 % (N)**	**Survey 1 % (N)**
Usually	60% (6)	60% (6)
Sometimes	20% (2)	30% (3)
Rarely	20% (2)	10% (1)
Never	-	-
Don't Know	-	-

How often do [you/your family member] pass up opportunities to go shopping, visit friends, or go on outings because of concerns about driving?

	Driver	Family Member
Frequency	**Survey 1 % (N)**	**Survey 1 % (N)**
Usually	-	40% (4)
Sometimes	-	30% (3)
Rarely	20% (2)	20% (2)
Never	80% (8)	10% (1)

Don't Know	-	-

In the past three months, have you [your family member]: (check all that apply)

	Driver	Family Member
Transport Mode	**Survey 1 % (N)**	**Survey 1 % (N)**
Been a passenger in a car driven by a relative or friend	90% (9)	90% (9)
Used public transportation	-	10% (1)
Ridden in a senior van or volunteer driver's vehicle	10% (1)	-
Taken a taxi	-	10% (1)
Walked to a destination	40% (4)	20% (2)
Ridden a bicycle	20% (2)	10% (1)
Used another form of transportation to local destination	-	-
Don't Know	-	-

If for some reason [you/your family member] could not drive either now or in the future, how would [you/your family member] get around: (check all that apply)

	Driver	Family Member
Transport Mode	**Survey 1 % (N)**	**Survey 1 % (N)**
Ride with a relative or friend in his or her car	90% (9)	100% (10)
Use public transportation	40% (4)	-
Ride in a senior van or volunteer driver's vehicle	60% (6)	40% (4)
Take a taxi	40% (4)	10% (1)
Walk to a destination	40% (4)	20% (2)
Ride a bicycle	30% (3)	20% (2)
Use another form of transportation	-	10% (1)
Don't Know	-	-

Some drivers feel they need a passenger to assist them with navigation while driving. How often do [you/your family member] drive with a passenger who assists in this way?

	Driver	Family Member
Frequency	**Survey 1 % (N)**	**Survey 1 % (N)**
Usually	20% (2)	20% (2)
Sometimes	10% (1)	40% (4)
Rarely	50% (5)	20% (2)
Never	20% (2)	20% (2)
Don't Know	-	-

How often are you a passenger while your family member is driving?

	Family Member		
Frequency	**Survey 1 % (N)**	**Survey 2 % (N)**	**Survey 3 % (N)**
Usually	40% (4)	60% (6)	50% (5)
Sometimes	30% (3)	20% (2)	30% (3)
Rarely	20% (2)	10% (1)	10% (1)
Never	10% (1)	10% (1)	10% (1)
Don't Know	-	-	-

Overall, how would you rate [your/your family member's] driving ability compared to (5 years ago [Survey 1]; 1 month ago [Survey 2]; before study [Survey 3]):

	Driver		Family Member		
Rating	**Survey 1 % (N)**	**Survey 2 % (N)**	**Survey 1 % (N)**	**Survey 2 % (N)**	**Survey 3 % (N)**
Better	-	10% (1)		-	10% (1)
Same	90% (9)	90% (9)	70% (7)	90% (9)	80% (8)
Not as good	10% (1)	-	30% (3)	-	10% (1)
Don't Know	-	-	-	10% (1)	-

How often do [you/your family member] try to avoid driving in unfamiliar areas?

	Driver	Family Member
Frequency	**Survey 1 % (N)**	**Survey 1 % (N)**
Usually	-	40% (4)
Sometimes	20% (2)	30% (3)
Rarely	30% (3)	-
Never	50% (5)	20% (2)
Don't Know	-	10% (1)

How often do [you/your family member] try to avoid driving at night?

	Driver	Family Member
Frequency	**Survey 1 % (N)**	**Survey 1 % (N)**
Usually	10% (1)	40% (4)
Sometimes	20% (2)	10% (1)
Rarely	30% (3)	10% (1)
Never	40% (4)	30% (3)
Don't Know	-	10% (1)

How often do [you/your family member] try to avoid driving in bad weather?

	Driver	Family Member
Frequency	**Survey 1 % (N)**	**Survey 1 % (N)**
Usually	10% (1)	30% (3)
Sometimes	50% (1)	20% (2)
Rarely	30% (3)	20% (2)
Never	10% (1)	20% (2)
Don't Know	-	10% (1)

How often do [you/your family member] try to avoid driving during high glare times (dawn/dusk)?

	Driver	Family Member
Frequency	**Survey 1 % (N)**	**Survey 1 % (N)**
Usually	-	10% (1)
Sometimes	20% (2)	10% (1)
Rarely	40% (4)	30% (3)
Never	40% (4)	30% (3)
Don't Know	-	20% (2)

How often do [you/your family member] try to avoid making left turns?

	Driver	Family Member
Frequency	**Survey 1 % (N)**	**Survey 1 % (N)**
Usually	-	10% (1)
Sometimes	10% (1)	10% (1)
Rarely	20% (2)	10% (1)
Never	70% (7)	50% (5)
Don't Know	-	20% (2)

How often do [you/your family member] try to avoid during high traffic times or rush hour?

	Driver	Family Member
Frequency	**Survey 1 % (N)**	**Survey 1 % (N)**
Usually	-	20% (2)
Sometimes	-	20% (2)
Rarely	40% (4)	20% (2)
Never	60% (6)	30% (3)
Don't Know	-	10% (1)

How often do [you/your family member] try to avoid driving on the expressway?

	Driver	Family Member
Frequency	**Survey 1 % (N)**	**Survey 1 % (N)**
Usually	10% (1)	30% (3)
Sometimes	10% (1)	-
Rarely	-	10% (1)
Never	80% (8)	50% (5)
Don't Know	-	10% (1)

How often do [you/your family member] try to avoid driving with child passengers?

	Driver	Family Member
Frequency	**Survey 1 % (N)**	**Survey 1 % (N)**
Usually	-	10% (1)
Sometimes	-	10% (1)
Rarely	10% (1)	-
Never	90% (9)	60% (6)
Don't Know	-	20% (2)

How often do [you/your family member] try to avoid driving alone?

	Driver	Family Member
Frequency	**Survey 1 % (N)**	**Survey 1 % (N)**
Usually	-	20% (2)
Sometimes	20% (2)	20% (2)
Rarely	-	-
Never	80% (8)	60% (6)
Don't Know	-	-

How often do [you/your family member] try to avoid driving in non-local areas?

	Driver	Family Member
Frequency	**Survey 1 % (N)**	**Survey 1 % (N)**
Usually	-	40% (4)
Sometimes	-	20% (2)
Rarely	30% (3)	10% (1)
Never	70% (7)	20% (2)
Don't Know	-	10% (1)

Whose advice would [you/your family member/this driver] likely follow regarding making changes in driving? Self

	Driver	Family Member	Occupational Therapist
Likelihood	**Survey 1 % (N)**	**Survey 1 % (N)**	**Survey 1 % (N)**
Not at all	-	-	-
Somewhat	20% (2)	20% (2)	-
Very	30% (3)	60% (6)	10% (1)
Definitely	50% (5)	20% (2)	90% (9)
Don't Know/NA	-	-	-

Whose advice would [you/your family member] likely follow regarding making changes in driving? Spouse/Partner

	Driver	Family Member	Occupational Therapist
Likelihood	**Survey 1 % (N)**	**Survey 1 % (N)**	**Survey 1 % (N)**
Not at all	-	-	-
Somewhat	20% (2)	50% (5)	30% (3)
Very	50% (5)	30% (3)	50% (5)
Definitely	20% (2)	-	10% (1)
Don't Know/NA	10% (1)	20% (2)	10% (1)

Whose advice would [you/your family member] likely follow regarding making changes in driving? Adult Child

	Driver	Family Member	Occupational Therapist
Likelihood	**Survey 1 % (N)**	**Survey 1 % (N)**	**Survey 1 % (N)**
Not at all	20% (2)	10% (1)	-
Somewhat	40% (4)	70% (7)	50% (5)
Very	30% (3)	10% (1)	50% (5)
Definitely	10% (1)	10% (1)	-
Don't Know/NA	-	-	-

Whose advice would [you/your family member] likely follow regarding making changes in driving? Sibling

	Driver	Family Member	Occupational Therapist
Likelihood	**Survey 1 % (N)**	**Survey 1 % (N)**	**Survey 1 % (N)**
Not at all	70% (7)	50% (5)	-
Somewhat	10% (1)	40% (4)	60% (6)
Very	10% (1)	-	30% (3)
Definitely	10% (1)	10% (1)	-
Don't Know/NA	-	-	10% (1)

Whose advice would [you/your family member] likely follow regarding making changes in driving? Friend

	Driver	Family Member	Occupational Therapist
Likelihood	**Survey 1 % (N)**	**Survey 1 % (N)**	**Survey 1 % (N)**
Not at all	30% (3)	20% (2)	10% (1)
Somewhat	40% (4)	50% (5)	70% (7)
Very	20% (2)	20% (2)	20% (2)
Definitely	10% (1)	10% (1)	-
Don't Know/NA	-	-	-

Whose advice would [you/your family member] likely follow regarding making changes in driving? Other family member

	Driver	Family Member	Occupational Therapist
Likelihood	**Survey 1 % (N)**	**Survey 1 % (N)**	**Survey 1 % (N)**
Not at all	30% (3)	-	10% (1)
Somewhat	40% (4)	70% (7)	70% (7)
Very	20% (2)	20% (2)	20% (2)
Definitely	10% (1)	10% (1)	-
Don't Know/NA	-	-	-

Whose advice would [you/your family member] likely follow regarding making changes in driving? Physician

	Driver	Family Member	Occupational Therapist
Likelihood	**Survey 1 % (N)**	**Survey 1 % (N)**	**Survey 1 % (N)**
Not at all	10% (1)	-	-
Somewhat	10% (1)	10% (1)	20% (2)
Very	20% (2)	60% (6)	60% (6)
Definitely	60% (6)	30% (3)	20% (2)
Don't Know/NA	-	-	-

Whose advice would [you/your family member] likely follow regarding making changes in driving? Eye doctor

	Driver	Family Member	Occupational Therapist
Likelihood	**Survey 1 % (N)**	**Survey 1 % (N)**	**Survey 1 % (N)**
Not at all	-	-	-
Somewhat	20% (2)	20% (2)	10% (1)
Very	20% (2)	50% (5)	60% (6)
Definitely	60% (6)	30% (3)	20% (2)
Don't Know/NA	-	-	10% (1)

Whose advice would [you/your family member] likely follow regarding making changes in driving? Dept./Registry of Motor Vehicles

	Driver	Family Member	Occupational Therapist
Likelihood	**Survey 1 % (N)**	**Survey 1 % (N)**	**Survey 1 % (N)**
Not at all	-	-	-
Somewhat	10% (1)	-	-
Very	30% (3)	30% (3)	40% (4)
Definitely	60% (6)	70% (7)	60% (6)
Don't Know/NA	-	-	-

Whose advice would [you/your family member] likely follow regarding making changes in driving? Police officer

	Driver	Family Member	Occupational Therapist
Likelihood	**Survey 1 % (N)**	**Survey 1 % (N)**	**Survey 1 % (N)**
Not at all	-	-	-
Somewhat	10% (1)	-	-
Very	20% (2)	40% (4)	30% (3)
Definitely	70% (7)	60% (6)	70% (7)
Don't Know/NA	-	-	-

Whose advice would [you/your family member] likely follow regarding making changes in driving? Judge

	Driver	Family Member	Occupational Therapist
Likelihood	**Survey 1 % (N)**	**Survey 1 % (N)**	**Survey 1 % (N)**
Not at all	-	-	-
Somewhat	20% (2)	-	-
Very	10% (1)	30% (3)	30% (3)
Definitely	70% (7)	70% (7)	70% (7)
Don't Know/NA	-	-	-

Whose advice would [you/your family member] likely follow regarding making changes in driving? Religious leader

	Driver	Family Member	Occupational Therapist
Likelihood	**Survey 1 % (N)**	**Survey 1 % (N)**	**Survey 1 % (N)**
Not at all	40% (4)	30% (3)	-
Somewhat	40% (4)	40% (4)	10% (1)
Very	10% (1)	-	20% (2)
Definitely	10% (1)	30% (3)	30% (3)
Don't Know/NA	-	-	40% (4)

Whose advice would [you/your family member] likely follow regarding making changes in driving? Counselor/psychotherapist

	Driver	Family Member	Occupational Therapist
Likelihood	**Survey 1 % (N)**	**Survey 1 % (N)**	**Survey 1 % (N)**
Not at all	30% (3)	-	-
Somewhat	20% (2)	40% (4)	30% (3)
Very	20% (2)	30% (3)	40% (4)
Definitely	30% (3)	30% (3)	20% (2)
Don't Know/NA	-	-	10% (1)

Whose advice would [you/your family member] likely follow regarding making changes in driving? Professional driving evaluator

	Driver	Family Member	Occupational Therapist
Likelihood	**Survey 1 % (N)**	**Survey 1 % (N)**	**Survey 1 % (N)**
Not at all	-	-	-
Somewhat	10% (1)	30% (3)	40% (4)
Very	30% (3)	20% (2)	50% (5)
Definitely	60% (6)	50% (5)	10% (1)
Don't Know/NA	-	-	-

How often do you think [your/your family member's] driving skills should be re-tested by a professional driving evaluator?

	Driver	Family Member			Occupational Therapist
Frequency	**Survey 1 % (N)**	**Survey 1 % (N)**	**Survey 2 % (N)**	**Survey 3 % (N)**	**Survey 1 % (N)**
Never	10% (1)	-	-	-	-
Every 3 months	-	-	10% (1)	10% (1)	20% (2)
Every 6 months	10% (1)	10% (1)	-	-	30% (3)
Every 9 months	-	-	-	10% (1)	-
Once a year	50% (5)	40% (4)	60% (6)	50% (5)	40% (4)
Once every 3 years	10% (1)	-	-	10% (1)	-
Upon license renewal	20% (2)	30% (3)	20% (2)	10% (1)	-
Other *	-	20% (2)	10% (1)	10% (1)	10% (1)
Don't Know	-	-	-	-	-

* Notes indicated retesting if noticeable decline in cognition or driving

Have you had a conversation with your family member about when the time comes that it is no longer safe for [you/your family member] to continue driving?

	Driver	Family Member
Response	**Survey 1 % (N)**	**Survey 1 % (N)**
Yes	40% (4)	40% (4)
No	60% (6)	60% (6)
NA	-	-

How many accidents has [you/your family member] had in the past 2 years?

	Driver	Family Member
Number	**Survey 1 % (N)**	**Survey 1 % (N)**
None	100% (10)	90% (9)
One	-	-
Two	-	10% (1)
More than two	-	-
Don't know	-	-

How often have [you/your family member] forgotten to fasten seatbelt in the past (year [Survey 1]; month [Survey 2]; since study end [Survey 3])

	Driver		Family Member		
Frequency	**Survey 1 % (N)**	**Survey 2 % (N)**	**Survey 1 % (N)**	**Survey 2 % (N)**	**Survey 3 % (N)**
Very often	-	-	-	-	-
Sometimes	-	-	10% (1)	10% (1)	-
Rarely	20% (2)	30% (3)	20% (2)	10% (1)	10% (1)
Never	80% (8)	70% (7)	60% (6)	60% (6)	80% (8)
Don't Know	-	-	10% (1)	20% (2)	10% (1)

How often have [you/your family member] forgotten to check mirrors for traffic in the past (year [Survey 1]; month [Survey 2]; since study end [Survey 3])

	Driver		Family Member		
Frequency	**Survey 1 % (N)**	**Survey 2 % (N)**	**Survey 1 % (N)**	**Survey 2 % (N)**	**Survey 3 % (N)**
Very often	20% (2)	-	-	-	-
Sometimes	-	10% (1)	-	-	-
Rarely	40% (4)	30% (3)	30% (3)	10% (1)	10% (1)
Never	40% (4)	60% (6)	60% (6)	60% (6)	80% (8)
Don't Know	-	-	10% (1)	30% (3)	10% (1)

How often have [you/your family member] forgotten to shut the car door in the past (year [Survey 1]; month [Survey 2]; since study end [Survey 3])

	Driver		Family Member		
Frequency	**Survey 1 % (N)**	**Survey 2 % (N)**	**Survey 1 % (N)**	**Survey 2 % (N)**	**Survey 3 % (N)**
Very often	-	-	-	-	-
Sometimes	-	-	-	-	-
Rarely	10% (1)	-	10% (1)	-	-
Never	90% (9)	100% (10)	80% (8)	80% (8)	90% (9)
Don't Know	-	-	10% (1)	20% (2)	10% (1)

How often have [you/your family member] had difficulty inserting the ignition key in the past (year [Survey 1]; month [Survey 2]; since study end [Survey 3])

	Driver		Family Member		
Frequency	**Survey 1 % (N)**	**Survey 2 % (N)**	**Survey 1 % (N)**	**Survey 2 % (N)**	**Survey 3 % (N)**
Very often	-	-	-	-	-
Sometimes	-	-	10% (1)	-	-
Rarely	10% (1)	10% (1)	10% (1)	10% (1)	
Never	90% (9)	90% (9)	70% (7)	70% (7)	90% (9)
Don't Know	-	-	10% (1)	20% (2)	10% (1)

How often have [you/your family member] had difficulty using the windshield wipers in the past (year [Survey 1]; month [Survey 2]; since study end [Survey 3])

	Driver		Family Member		
Frequency	**Survey 1 % (N)**	**Survey 2 % (N)**	**Survey 1 % (N)**	**Survey 2 % (N)**	**Survey 3 % (N)**
Very often	-	-	-	-	-
Sometimes	-	-	-	-	-
Rarely	10% (1)	-	10% (1)	-	-
Never	90% (9)	100% (10)	80% (8)	70% (7)	90% (9)
Don't Know	-	-	10% (1)	30% (3)	10% (1)

How often have [you/your family member] confused the brake and gas pedals in the past (year [Survey 1]; month [Survey 2]; since study end [Survey 3])

	Driver		Family Member		
Frequency	**Survey 1 % (N)**	**Survey 2 % (N)**	**Survey 1 % (N)**	**Survey 2 % (N)**	**Survey 3 % (N)**
Very often	-	-	-	-	-
Sometimes	-	-	-	-	-
Rarely	-	-	-	-	-
Never	100% (10)	100% (10)	90% (9)	70% (7)	90% (9)
Don't Know	-	-	10% (1)	30% (3)	10% (1)

How often were [you/your family member] unable to put the car into gear in the past (year [Survey 1]; month [Survey 2]; since study end [Survey 3])

	Driver		Family Member		
Frequency	**Survey 1 % (N)**	**Survey 2 % (N)**	**Survey 1 % (N)**	**Survey 2 % (N)**	**Survey 3 % (N)**
Very often	-	-	-	-	-
Sometimes	-	-	-	-	-
Rarely	10% (1)	-	-	10% (1)	-
Never	90% (9)	100% (10)	90% (9)	70% (7)	90% (9)
Don't Know	-	-	10% (1)	20% (2)	10% (1)

How often have [you/your family member] lost car in the parking lot in the past (year [Survey 1]; month [Survey 2]; since study end [Survey 3])

	Driver		Family Member		
Frequency	**Survey 1 % (N)**	**Survey 2 % (N)**	**Survey 1 % (N)**	**Survey 2 % (N)**	**Survey 3 % (N)**
Very often	-	-	-	-	-
Sometimes	-	20% (2)	10% (1)	10% (1)	-
Rarely	60% (6)	20% (2)	20% (2)	10% (1)	30% (3)
Never	40% (4)	60% (6)	50% (5)	40% (4)	60% (6)
Don't Know	-	-	20% (2)	40% (4)	10% (1)

How often have [you/your family member] relative/friend expressed concerns about your driving or won't ride you in the past (year [Survey 1]; month [Survey 2]; since study end [Survey 3])

	Driver		Family Member		
Frequency	**Survey 1 % (N)**	**Survey 2 % (N)**	**Survey 1 % (N)**	**Survey 2 % (N)**	**Survey 3 % (N)**
Very often	-	-	-	10% (1)	-
Sometimes	10% (1)	-	30% (3)	-	-
Rarely	20% (2)	20% (2)	20% (2)	-	-
Never	70% (7)	80% (8)	50% (5)	70% (7)	90% (9)
Don't Know	-	-	-	20% (2)	10% (1)

How often have [you/your family member] had a close call or a near crash in the past (year [Survey 1]; month [Survey 2]; since study end [Survey 3])

	Driver		Family Member		
Frequency	**Survey 1 % (N)**	**Survey 2 % (N)**	**Survey 1 % (N)**	**Survey 2 % (N)**	**Survey 3 % (N)**
Very often	-	-	-	-	-
Sometimes	-	-	10% (1)	-	-
Rarely	30% (3)	10% (1)	20% (2)	10% (1)	
Never	70% (7)	90% (9)	50% (5)	60% (6)	90% (9)
Don't Know	-	-	20% (2)	30% (3)	10% (1)

How often have [you/your family member] had difficulty merging or changing lanes in the past (year [Survey 1]; month [Survey 2]; since study end [Survey 3])

	Driver		Family Member		
Frequency	**Survey 1 % (N)**	**Survey 2 % (N)**	**Survey 1 % (N)**	**Survey 2 % (N)**	**Survey 3 % (N)**
Very often	-	-	-	-	-
Sometimes	10% (1)	-	-	-	-
Rarely	10% (1)	10% (1)	30% (3)	10% (1)	10% (1)
Never	80% (8)	90% (9)	50% (5)	60% (6)	80% (8)
Don't Know	-	-	20% (2)	30% (3)	10% (1)

How often have [you/your family member] had difficulty judging when to brake in the past (year [Survey 1]; month [Survey 2]; since study end [Survey 3])

	Driver		Family Member		
Frequency	**Survey 1 % (N)**	**Survey 2 % (N)**	**Survey 1 % (N)**	**Survey 2 % (N)**	**Survey 3 % (N)**
Very often	-	-	-	-	-
Sometimes	-	-	-	-	-
Rarely	20% (2)	30% (3)	30% (3)	10% (1)	10% (1)
Never	80% (8)	70% (7)	40% (4)	60% (6)	80% (8)
Don't Know	-	-	30% (3)	30% (3)	10% (1)

How often have [you/your family member] taken longer to get somewhere in the past (year [Survey 1]; month [Survey 2]; since study end [Survey 3])

	Driver		Family Member		
Frequency	**Survey 1 % (N)**	**Survey 2 % (N)**	**Survey 1 % (N)**	**Survey 2 % (N)**	**Survey 3 % (N)**
Very often	-	-	-	10% (1)	-
Sometimes	30% (3)	20% (2)	30% (3)	30% (3)	10% (1)
Rarely	40% (4)	30% (3)	20% (2)	20% (2)	30% (3)
Never	30% (3)	40% (4)	50% (5)	40% (4)	30% (3)
Don't Know/NA	-	10% (1)	-	-	30% (3)

How often have [you/your family member] become confused at an intersection or exit in the past (year [Survey 1]; month [Survey 2]; since study end [Survey 3])

	Driver		Family Member		
Frequency	**Survey 1 % (N)**	**Survey 2 % (N)**	**Survey 1 % (N)**	**Survey 2 % (N)**	**Survey 3 % (N)**
Very often	10% (1)	-	-	-	-
Sometimes	10% (1)	10% (1)	10% (1)	20% (2)	10% (1)
Rarely	60% (6)	50% (5)	10% (1)	10% (1)	20% (2)
Never	20% (2)	30% (3)	40% (4)	60% (6)	50% (5)
Don't Know/NA	-	10% (1)	40% (4)	10% (1)	20% (2)

How often have [you/your family member] run a stop sign in the past (year [Survey 1]; month [Survey 2]; since study end [Survey 3])

	Driver		Family Member		
Frequency	**Survey 1 % (N)**	**Survey 2 % (N)**	**Survey 1 % (N)**	**Survey 2 % (N)**	**Survey 3 % (N)**
Very often	-	-	-	-	-
Sometimes	-	-	-	-	-
Rarely	30% (3)	10% (1)	30% (3)	10% (1)	-
Never	70% (7)	90% (9)	50% (5)	70% (7)	80% (8)
Don't Know/NA	-	-	20% (2)	20% (2)	20% (2)

How often have [you/your family member] ran a red light or stopped at a green light in the past (year [Survey 1]; month [Survey 2]; since study end [Survey 3])

	Driver		Family Member		
Frequency	**Survey 1 % (N)**	**Survey 2 % (N)**	**Survey 1 % (N)**	**Survey 2 % (N)**	**Survey 3 % (N)**
Very often	-	-	-	-	-
Sometimes	-	-	-	-	-
Rarely	20% (2)	10% (1)	-	10% (1)	-
Never	80% (8)	90% (9)	80% (8)	80% (8)	80% (8)
Don't Know/NA	-	-	20% (2)	10% (1)	20% (2)

How often have [you/your family member] gotten lost in the past (year [Survey 1]; month [Survey 2]; since study end [Survey 3])

	Driver		Family Member		
Frequency	**Survey 1 % (N)**	**Survey 2 % (N)**	**Survey 1 % (N)**	**Survey 2 % (N)**	**Survey 3 % (N)**
Very often	-	-	10% (1)	-	-
Sometimes	10% (1)	10% (1)	10% (1)	10% (1)	-
Rarely	30% (3)	30% (3)	40% (4)	40% (4)	10% (1)
Never	50% (5)	60% (6)	30% (3)	30% (3)	60% (6)
Don't Know/NA	10% (1)	-	10% (1)	20% (2)	30% (3)

How often have [you/your family member] bumped into an object while backing up in the past (year [Survey 1]; month [Survey 2]; since study end [Survey 3])

	Driver		Family Member		
Frequency	**Survey 1 % (N)**	**Survey 2 % (N)**	**Survey 1 % (N)**	**Survey 2 % (N)**	**Survey 3 % (N)**
Very often	-	-	-	-	-
Sometimes	10% (1)	10% (1)	-	-	-
Rarely	30% (3)	10% (1)	10% (1)	10% (1)	10% (1)
Never	60% (6)	80% (8)	50% (5)	70% (7)	70% (7)
Don't Know/NA	-	-	40% (4)	20% (2)	20% (2)

How often have [you/your family member] had difficulty maintaining distance from the vehicle ahead in the past (year [Survey 1]; month [Survey 2]; since study end [Survey 3])

	Driver		Family Member		
Frequency	**Survey 1 % (N)**	**Survey 2 % (N)**	**Survey 1 % (N)**	**Survey 2 % (N)**	**Survey 3 % (N)**
Very often	-	-	-	-	-
Sometimes	-	-	-	-	-
Rarely	20% (2)	30% (3)	20% (2)	20% (2)	-
Never	80% (8)	70% (7)	60% (6)	60% (6)	80% (8)
Don't Know/NA	-	-	20% (2)	20% (2)	20% (2)

How often have [you/your family member] other drivers honked at you in the past (year [Survey 1]; month [Survey 2]; since study end [Survey 3])

	Driver		Family Member		
Frequency	**Survey 1 % (N)**	**Survey 2 % (N)**	**Survey 1 % (N)**	**Survey 2 % (N)**	**Survey 3 % (N)**
Very often	-	-	-	-	-
Sometimes	10% (1)	10% (1)	10% (1)	-	-
Rarely	30% (3)	20% (2)	10% (1)	10% (1)	10% (1)
Never	60% (6)	70% (7)	50% (5)	60% (6)	60% (6)
Don't Know/NA	-	-	30% (3)	30% (3)	30% (3)

How often were [you/your family member] stopped by police and given a ticket or warning in the past (year [Survey 1]; month [Survey 2]; since study end [Survey 3])

	Driver		Family Member		
Frequency	**Survey 1 % (N)**	**Survey 2 % (N)**	**Survey 1 % (N)**	**Survey 2 % (N)**	**Survey 3 % (N)**
Very often	-	-	-	-	-
Sometimes	-	-	10% (1)	-	-
Rarely	30% (3)	10% (1)	10% (1)	-	-
Never	70% (7)	90% (9)	70% (7)	90% (9)	80% (8)
Don't Know/NA	-	-	10% (1)	10% (1)	20% (2)

How often have [you/your family member] had difficulty reading traffic and street signs in the past (year [Survey 1]; month [Survey 2]; since study end [Survey 3])

	Driver		Family Member		
Frequency	**Survey 1 % (N)**	**Survey 2 % (N)**	**Survey 1 % (N)**	**Survey 2 % (N)**	**Survey 3 % (N)**
Very often	-	-	-	-	-
Sometimes	-	10% (1)	-	-	-
Rarely	40% (4)	20% (2)	10% (1)	10% (1)	10% (1)
Never	60% (6)	70% (7)	70% (7)	70% (7)	70% (7)
Don't Know/NA	-	-	20% (2)	20% (2)	20% (2)

How often have [you/your family member] had difficulty crossing an intersection or turning onto a busy road in the past (year [Survey 1]; month [Survey 2]; since study end [Survey 3])

	Driver		Family Member		
Frequency	**Survey 1 % (N)**	**Survey 2 % (N)**	**Survey 1 % (N)**	**Survey 2 % (N)**	**Survey 3 % (N)**
Very often	-	-	-	-	-
Sometimes	-	-	-	-	-
Rarely	10% (1)	30% (3)	10% (1)	10% (1)	-
Never	90% (9)	70% (7)	70% (7)	60% (6)	80% (8)
Don't Know/NA	-	-	20% (2)	30% (3)	20% (2)

How often have you observed while a passenger your family member driving and slowing inappropriately at an intersection without a traffic signal in the past (year [Survey 1]; month [Survey 2]; few weeks [survey 3])?

	Family Member		
Frequency	**Survey 1 % (N)**	**Survey 2 % (N)**	**Survey 3 % (N)**
Frequently	-	-	-
Sometimes	10% (1)	20% (2)	-
Rarely	10% (1)	20% (2)	-
Never	60% (6)	40% (4)	90% (9)
Don't Know/NA	20% (2)	20% (2)	10% (1)

How often have you observed while a passenger your family member driving and slowing inappropriately at a green light in the past (year [Survey 1]; month [Survey 2]; few weeks [survey 3])?

	Family Member		
Frequency	**Survey 1 % (N)**	**Survey 2 % (N)**	**Survey 3 % (N)**
Frequently	-	-	-
Sometimes	-	-	-
Rarely	20% (2)	10% (1)	10% (1)
Never	60% (6)	70% (7)	80% (8)
Don't Know/NA	20% (2)	20% (2)	10% (1)

How often have you observed while a passenger your family member driving and passing a vehicle with oncoming traffic or a risky sight distance in the past (year [Survey 1]; month [Survey 2]; few weeks [survey 3])?

	Family Member		
Frequency	**Survey 1 % (N)**	**Survey 2 % (N)**	**Survey 3 % (N)**
Frequently	-	-	-
Sometimes	-	-	-
Rarely	10% (1)	-	-
Never	70% (7)	80% (8)	90% (9)
Don't Know/NA	20% (2)	20% (2)	10% (1)

How often have you observed while a passenger your family member driving and lingering at a light, stop sign, or intersection in the past (year [Survey 1]; month [Survey 2]; few weeks [survey 3])?

	Family Member		
Frequency	**Survey 1 % (N)**	**Survey 2 % (N)**	**Survey 3 % (N)**
Frequently	-	-	-
Sometimes	10% (1)	-	-
Rarely	40% (4)	20% (2)	20% (2)
Never	30% (3)	60% (6)	70% (7)
Don't Know/NA	20% (2)	20% (2)	10% (1)

How often have you observed while a passenger your family member driving and them driving much faster or slower than surrounding traffic in the past (year [Survey 1]; month [Survey 2]; few weeks [survey 3])?

	Family Member		
Frequency	**Survey 1 % (N)**	**Survey 2 % (N)**	**Survey 3 % (N)**
Frequently	-	-	-
Sometimes	50% (5)	20% (2)	10% (1)
Rarely	20% (2)	30% (3)	20% (2)
Never	20% (2)	40% (4)	60% (6)
Don't Know/NA	10% (1)	10% (1)	10% (1)

How often have you observed while a passenger your family member driving and failing to use turn signal for lane change/turn in the past (year [Survey 1]; month [Survey 2]; few weeks [survey 3])?

	Family Member		
Frequency	**Survey 1 % (N)**	**Survey 2 % (N)**	**Survey 3 % (N)**
Frequently	-	-	-
Sometimes	30% (3)	50% (5)	10% (1)
Rarely	20% (2)	10% (1)	30% (3)
Never	40% (4)	30% (3)	50% (5)
Don't Know/NA	10% (1)	10% (1)	10% (1)

How often have you observed while a passenger your family member driving and braking suddenly or hard inappropriately in the past (year [Survey 1]; month [Survey 2]; few weeks [survey 3])?

	Family Member		
Frequency	**Survey 1 % (N)**	**Survey 2 % (N)**	**Survey 3 % (N)**
Frequently	-	-	-
Sometimes	10% (1)	10% (1)	-
Rarely	30% (3)	10% (1)	10% (1)
Never	50% (5)	70% (7)	80% (8)
Don't Know/NA	10% (1)	10% (1)	10% (1)

How often have you observed while a passenger your family member driving and ignoring a pedestrian or bicyclist in the past (year [Survey 1]; month [Survey 2]; few weeks [survey 3])?

	Family Member		
Frequency	**Survey 1 % (N)**	**Survey 2 % (N)**	**Survey 3 % (N)**
Frequently	-	-	-
Sometimes	-	-	-
Rarely	-	-	-
Never	90% (9)	90% (9)	90% (9)
Don't Know/NA	10% (1)	10% (1)	10% (1)

How often have you observed while a passenger your family member driving and having a problem turning right in the past (year [Survey 1]; month [Survey 2]; few weeks [survey 3])?

	Family Member		
Frequency	**Survey 1 % (N)**	**Survey 2 % (N)**	**Survey 3 % (N)**
Frequently	-	-	-
Sometimes	-	-	-
Rarely	10% (1)	-	-
Never	80% (8)	80% (8)	90% (9)
Don't Know/NA	10% (1)	20% (2)	10% (1)

How often have you observed while a passenger your family member driving and having a problem turning left in the past (year [Survey 1]; month [Survey 2]; few weeks [survey 3])?

	Family Member		
Frequency	**Survey 1 % (N)**	**Survey 2 % (N)**	**Survey 3 % (N)**
Frequently	-	-	-
Sometimes	-	-	-
Rarely	10% (1)	-	-
Never	80% (8)	80% (8)	90% (9)
Don't Know/NA	10% (1)	20% (2)	10% (1)

How often have you observed while a passenger your family member driving and backing up with turning his or head in the past (year [Survey 1]; month [Survey 2]; few weeks [survey 3])?

	Family Member		
Frequency	**Survey 1 % (N)**	**Survey 2 % (N)**	**Survey 3 % (N)**
Frequently	-	-	10% (1)
Sometimes	-	-	-
Rarely	20% (2)	30% (3)	30% (3)
Never	60% (6)	50% (5)	40% (4)
Don't Know/NA	20% (2)	20% (2)	10% (1)

How often have you observed while a passenger your family member driving and having difficulty multitasking in the past (year [Survey 1]; month [Survey 2]; few weeks [survey 3])?

	Family Member		
Frequency	**Survey 1 % (N)**	**Survey 2 % (N)**	**Survey 3 % (N)**
Frequently	-	-	10% (1)
Sometimes	30% (3)	30% (3)	20% (2)
Rarely	30% (3)	10% (1)	10% (1)
Never	30% (3)	50% (5)	50% (5)
Don't Know/NA	10% (1)	10% (1)	10% (1)

How do you rate [yourself/your family member] as a driver.

	Driver		Family Member			Occupational Therapist
Rating	**Survey 1 % (N)**	**Survey 2 % (N)**	**Survey 1 % (N)**	**Survey 2 % (N)**	**Survey 3 % (N)**	**Survey 1 % (N)**
Excellent	20% (2)	-	-	-	-	-
Very Good	60% (6)	10% (1)	40% (4)	10% (1)	20% (2)	10% (1)
Good	20% (2)	50% (5)	20% (2)	50% (5)	70% (7)	40% (4)
Fair	-	40% (4)	40% (4)	30% (3)	-	40% (4)
Poor	-	-	-	10% (1)	10% (1)	10% (1)
Don't Know	-	-	-	-	-	-

Study Protocols/vehicle Instrumentation/Driving Summary

Your family member is eligible to participate in this study because he or she has been evaluated as safe to drive. How strongly do you agree with that assessment?

	Family Member
Agreement	**Survey 1 % (N)**
Strongly Agree	60% (6)
Agree	20% (2)
Neither agree nor disagree	10% (1)
Disagree	10% (1)
Strongly Disagree	-

Overall, how did you feel about having the equipment installed in [your/your family member's] car during this past month to measure your driving behavior?

	Driver	Family Member
Sentiment	**Survey 2 % (N)**	**Survey 2 % (N)**
I thought it was an excellent idea	60% (6)	90% (9)
I thought it was a very good idea	30% (3)	10% (1)
I thought it was a good idea	10% (1)	-
It bothered me somewhat	-	-
It bothered me a great deal	-	-

You were just given a summary of [your/your family member's] driving performance in the past month. How much do you agree with the information that was shared with you?

	Driver	Family Member
Agreement	**Survey 2 % (N)**	**Survey 2 % (N)**
Strongly agree	50% (5)	70% (7)
Agree	50% (5)	30% (3)
Neither agree nor disagree	-	-
Disagree	-	-
Strongly disagree	-	-

How helpful was the summary of your family member's driving performance during this past month?

	Family Member
Helpfulness	**Survey 2 % (N)**
Very helpful	70% (7)
Helpful	20% (2)
Somewhat helpful	10% (1)
Not very helpful	-
Not at all helpful	-

Given the information that was recently provided to you about [you/your family member's] driving, how concerned are you about [you/your family member's] ability to drive safely?

	Driver	Family Member
Concern	**Survey 2 % (N)**	**Survey 2 % (N)**
Very concerned	-	10% (1)
Concerned	10% (1)	10% (1)
Somewhat concerned	20% (2)	10% (1)
Not very concerned	30% (3)	60% (6)
Not at all concerned	40% (4)	10% (1)

How likely is it that your family member] will follow the recommendations provided?

	Family Member
Likelihood	**Survey 2 % (N)**
Very likely	40% (4)
Likely	30% (3)
Somewhat likely	20% (2)
Not very likely	-
Not at all likely	10% (1)
Don't know	-

How likely were you to accept the recommendations of the driving evaluator that were given to you right after your driving assessment?

	Driver
Likelihood	**Survey 2 % (N)**
Very likely	70% (7)
Likely	20% (2)
Somewhat likely	10% (1)
Not very likely	-
Not at all likely	-

How likely are you to follow the driving evaluator's recommendations now that you have also been given feedback on your driving while the monitoring equipment was in your car?

	Driver
Likelihood	**Survey 2 % (N)**
Very likely	70% (7)
Likely	30% (3)
Somewhat likely	-
Not very likely	-
Not at all likely	-

Have you changed your mind in any way as to when it may no longer be safe for [you/your family member] to drive?

	Driver	Family Member	
Answer	**Survey 2 % (N)**	**Survey 2 % (N)**	**Survey 3 % (N)**
No	90% (9)	90% (9)	100% (10)
yes	10% (1)	10% (1)	-

What are your current plans related to driving? (Driver Survey 2)
What do you think your family member will do as result of the information received from the driving assessment and monitoring? (Family Member Survey 2)
What has your family member done as a result of the information received from the driving assessment and monitoring? (Family Member Survey 3)

	Driver	Family Member	
Plans	**Survey 2 % (N)**	**Survey 2 % (N)**	**Survey 3 % (N)**
Continue(d) driving as before participation in this study	90% (9)	40% (4)	60% (6)
Continue(d) driving with some modifications	10% (1)	40% (4)	30% (3)
Stop driving within the next year	-	-	NA
Stop(ped) driving immediately	-	-	-
Other	NA	NA	10% (1) *
Don't know	-	20% (2)	-

* Drove as before the study for 2 weeks, then stopped driving.

Do [you/your family member] plan to return to a driving evaluator for another driving evaluation?

	Driver	Family Member
Answer	**Survey 2 % (N)**	**Survey 3 % (N)**
No	50% (5)	50% (5)
Yes	50% (5)	10% (10
Don't know	-	40% (4)

To what extent has your family member followed the recommendations of the driving evaluator?

	Family Member
Compliance	**Survey 3 % (N)**
Followed all of the recommendations	30% (3)
Followed most of the recommendations	20% (2)
Followed about half of the recommendations	-
Followed a few of the recommendations	-
Followed none of the recommendations	-
Don't know	10% (1)
NA (Evaluator made no recommendations other than "Drive as before.")	40% (4)

Health and Physical Condition

How would you rate [your/your family member's] vision for driving during the day?

	Driver	Family Member
Rating	**Survey 1 % (N)**	**Survey 1 % (N)**
Excellent	80% (8)	50% (5)
Good	20% (2)	50% (5)
Fair	-	-
Poor	-	-
Don't Know	-	-

How would you rate [your/your family member's] vision for driving at night?

	Driver	Family Member
Rating	**Survey 1 % (N)**	**Survey 1 % (N)**
Excellent	40% (4)	30% (3)
Good	50% (5)	20% (2)
Fair	10% (1)	40% (4)
Poor	-	10% (1)
Don't Know	-	-

How would you rate [your/your family member's] speed of decision making while driving?

	Driver	Family Member
Rating	**Survey 1 % (N)**	**Survey 1 % (N)**
Excellent	60% (6)	60% (6)
Good	40% (4)	30% (3)
Fair	-	10% (1)
Poor	-	-
Don't Know	-	-

How would you rate [your/your family member's] upper body strength and flexibility for driving?

	Driver	Family Member
Rating	**Survey 1 % (N)**	**Survey 1 % (N)**
Excellent	70% (7)	50% (5)
Good	20% (2)	50% (5)
Fair	10% (1)	-
Poor	-	-
Don't Know	-	-

How would you rate [your/your family member's] lower body strength and flexibility for driving?

	Driver	Family Member
Rating	**Survey 1 % (N)**	**Survey 1 % (N)**
Excellent	70% (7)	50% (5)
Good	20% (2)	40% (4)
Fair	10% (1)	10% (1)
Poor	-	-
Don't Know	-	-

How would you rate [your/your family member's] ability to walk ½ mile without help?

	Driver	Family Member
Rating	**Survey 1 % (N)**	**Survey 1 % (N)**
Excellent	-	40% (4)
Good	-	30% (3)
Fair	20% (2)	10% (1)
Poor	80% (8)	20% (2)
Don't Know	-	-

How would you rate [your/your family member's] ability to climb two flights of stairs without help?

	Driver	Family Member
Rating	**Survey 1 % (N)**	**Survey 1 % (N)**
Excellent	70% (7)	50% (5)
Good	20% (2)	30% (3)
Fair	10% (1)	20% (2)
Poor	-	-
Don't Know	-	-

How would you rate [your/your family member's] general physical fitness?

	Driver	Family Member
Rating	**Survey 1 % (N)**	**Survey 1 % (N)**
Excellent	30% (3)	30% (3)
Good	50% (5)	30% (3)
Fair	20% (2)	20% (2)
Poor	-	20% (2)
Don't Know	-	-

How many medications do [you/your family member] take regularly?

	Driver	Family Member
Number	**Survey 1 % (N)**	**Survey 1 % (N)**
None	10% (1)	10% (1)
1-5	50% (5)	60% (6)
6-10	30% (3)	20% (2)
11-15	-	10% (1)
16-20	10% (1)	-
More than 20	-	-
Don't Know	-	-

Do [you/your family member] have any of the following conditions?

Condition	Driver Survey 1 % (N)			Family Member Survey 1 % (N)		
	Yes	**No**	**Unsure**	**Yes**	**No**	**Unsure**
Glaucoma	10% (1)	80% (8)	10% (1)	20% (2)	70% (7)	10% (1)
Macular Degeneration	-	80% (8)	20% (2)	10% (1)	70% (7)	20% (2)
Heart disease	-	80% (8)	20% (2)	30% (3)	70% (7)	-
Diabetes	20% (2)	80% (8)	-	20% (2)	80% (8)	-
Memory loss	80% (8)	10% (1)	10% (1)	100% (10)	-	-
Arthritis	40% (4)	60% (6)	-	50% (5)	50% (5)	-
Parkinson's disease	-	100% (10)	-	-	100% (10)	-
Sleep disorders	40% (4)	60% (6)	-	30% (3)	60% (6)	10% (1)
Seizure disorder/syncope	-	100% (10)	-		100% (10)	-
Problem with blood pressure	30% (3)	70% (7)	-	40% (4)	50% (5)	10% (1)
Other	40% (4)	40% (4)	20% (2)	70% (7)	20% (2)	10% (1)

Thinking back over the past six months, how frequently would you say your family member has experienced or had problems with the following situations?

Situation	Family Member Survey 1 % (N)			
	Not at all	**Sometimes**	**Frequently**	**Don't know**
Repeating or asking the same thing over and over	10% (1)	50% (5)	40% (4)	-
Forgetting appointments, family occasions, or holidays	20% (2)	50% (5)	30% (3)	-
Writing checks, paying bills, balancing the checkbook	40% (4)	20% (2)	20% (2)	20% (2)
Shopping independently for clothes or groceries	40% (4)	20% (2)	20% (2)	20% (2)
Taking medications according to directions	40% (4)	60% (6)	-	-
Getting lost while walking or driving in familiar places	70% (7)	30% (3)	-	-
Making decisions that arise in everyday living	30% (3)	60% (6)	10% (1)	-

In the past month, has there been any change in your physical or mental health?

	Driver	Family Member	
Answer	**Survey 2 % (N)**	**Survey 2 % (N)**	**Survey 3 % (N)**
Yes	10% (1)	40% (4)	-
No	90% (9)	60% (6)	100% (10)