U.S. Department
of Transportation
National Highway
Traffic Safety
Administration

DOT HS 812 577 January 2019

Mild Cognitive Impairment and Driving Performance

Disclaimer

Suggested APA Format Citation:

Staplin, L., Lococo, K., Mastromatto, T., Gish, K. W., Golembiewski, G., & Sifrit, K. J. (2019, January). *Mild cognitive impairment and driving performance* (Report No. DOT HS 812 577). Washington, DC: National Highway Traffic Safety Administration.

Technical Report Documentation Page

1. Report No. DOT HS 812 577	**2. Government Accession No.**	**3. Recipient's Catalog No.**
1. Title and Subtitle Mild Cognitive Impairment and Driving Performance		**5. Report Date** January 2019 **6. Performing Organization Code**
7. Authors Loren Staplin,* Kathy Lococo,*Tia Mastromatto,* Kenneth W. Gish,* Gary Golembiewski,† and Kathy J. Sifrit‡		**8. Performing Organization Report No.**
9. **Performing Organization Names and Addresses** *TransAnalytics, LLC 336 West Broad Street Quakertown, PA 18951 † Leidos, Inc. 11951 Freedom Drive Reston, VA 20190		**10. Work Unit No. (TRAIS)** **11. Contract or Grant No.** DTNH22-09-D-00135L, Task Order No. 09
12. Sponsoring Agency Name and Address ‡Office of Behavioral Safety Research National Highway Traffic Safety Administration 1200 New Jersey Avenue, SE Washington, DC 20590		**13. Type of Report and Period Covered** Final Report **14. Sponsoring Agency Code**
15. Supplementary Notes Dr. Kathy Sifrit was the NHTSA Task Order Manager on this project.		

16. Abstract

The objective of this project was to explore differences in driving performance and exposure between participants with mild cognitive impairment (MCI) – operationally defined through recognized clinical methods – and a comparison group of drivers of comparable age who did not meet those criteria. MCI refers to an intermediary, symptomatic state between age-appropriate cognitive decline and dementia. An initial literature review revealed a lack of clear boundaries between these cognitive status categories, which led researchers to consider continuous measures of cognitive impairment to predict road test performance and exposure. Thirty-eight participants were recruited. Clinical measures, administered by a certified driver rehabilitation specialist (CDRS), included the trail-making and maze tests, plus the Montreal Cognitive Assessment (MoCA). The Functional Activities Questionnaire (FAQ) was used to obtain participants' self-reports indicating cognitive status. A CDRS also administered the road tests in two study locations (in and near Roanoke and Richmond, Virginia). Exposure data were recorded with GPS loggers and cameras installed in participants' own vehicles for approximately one month. Regression models identified MoCA scores, and to a lesser extent Maze Test scores, as significant predictors of road test results, particularly with respect to tactical driving tasks. There were no significant regression models for analyses of exposure measures. Analysis of impairment status (not impaired, MCI, or moderate cognitive impairment) using only the MoCA classifications showed that those classified as unimpaired received significantly fewer points off on the on-road assessment than those classified as MCI, and this difference increased when comparing the unimpaired to those with any level of impairment. While the evidence was mixed regarding the extent to which MCI drivers appropriately self-restrict their exposure, MoCA appears to be a practical tool for occupational therapist generalists to use in identifying referrals for a comprehensive driving evaluation.

17. Key Words age, older, driver, performance, exposure, cognitive, impairment		**18. Distribution Statement** Document is available to the public from the National Technical Information Service, www.ntis.gov.	
19. Security Classif. (of this report) Unclassified	**20. Security Classif. (of this page)** Unclassified	**21. No. of Pages** 72	**22. Price**

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

Acknowledgements

The efforts of John H. Vaughter, CDRS, and Janet T. Stohler, OTR/L, CDRS, were key to the completion of this study. These professionals reached out to organizations in their communities to solicit research participants and performed the clinical and on-road assessments that generated the data of primary interest for the planned analyses. Sandra Bell, in the office of Ms. Stohler, also provided essential support in completing informed consent procedures and other administrative responsibilities.

The instrumentation of participants' vehicles with the exposure data collection system used in this research was accomplished through the work of Patrick Spratt, who installed and removed the systems from the private vehicles of consenting participants and performed system troubleshooting when necessary, often traveling great distances so participants could meet these requirements of research participation in the convenience of their own homes.

Table of Contents

List of Tables

List of Figures

List of Acronyms and Abbreviations

AD	Alzheimer's disease
ADL	Activities of Daily Living
BTW	Behind the Wheel
CDRS	Certified Driver Rehabilitation Specialist
DMV	Department of Motor Vehicles
DOT	Department of Transportation
DRS	Driver Rehabilitation Specialist
GPS	Global Positioning System
IADL	Instrumental Activities of Daily Living
IRB	Institutional Review Board
MCI	Mild Cognitive Impairment
NCI	Non-Cognitively Impaired
NHTSA	National Highway Traffic Safety Administration
OT	Occupational Therapist
RA	Research Assistant

Executive Summary

With the aim of exploring differences in performance and exposure between older drivers who are cognitively intact and those with mild cognitive impairment (MCI), researchers conducted a literature search encompassing the definition, operationalization, and domains of cognition affected, as well as measures used to diagnose this condition. The review focused on studies addressing the impact of MCI on driving safety and performance published in 2003 and later. While an underlying premise in the research design was that clinicians could apply widely-accepted criteria for diagnosing MCI, distinct from higher levels of cognitive impairment, the results of the literature review called this assumption into question. Evidence in the form of neuropsychological testing is necessary, but not sufficient, to define MCI. Perceptions of changes in cognition by the affected person or those close to them, coupled with greater difficulty performing instrumental activities of daily living, also factor into a diagnosis of MCI.

Two consulting certified driver rehabilitation specialists (CDRS) in Richmond, and Roanoke, Virginia, recruited study participants under OMB Control Number 2127-0712. In each area, one CDRS solicited participants through presentations in community settings such as health fairs and continuing care retirement centers (CCRCs) while also receiving referrals from physicians and other health care professionals. Participants also included drivers who had been advised by the Virginia DMV that they must complete CDRS driving evaluations as a condition of continued licensure. Participants took part in a clinical assessment and received comprehensive driving evaluations by a CDRS. When participants completed the evaluations, they were offered additional compensation for allowing their driving exposure to be monitored for a month via a miniature camera and GPS logger installed in their personal vehicles. Thirty-eight participants 62 to 88 years old completed the clinical and on-road assessments. Of these, 31 consented to participate in the exposure data collection, and 29 completed it.

The clinical measures used to assess cognitive status included the Montreal Cognitive Assessment battery (MoCA), the Trail-making Test Parts A and B, the Maze Test, and the Functional Abilities Questionnaire. The MoCA targets multiple domains including memory, attention, visuospatial ability, and verbal fluency. The Trail-making Test, however, is more specialized towards visual search and divided attention, and the Maze Test targets visuospatial ability and planning/executive function. The Functional Abilities Questionnaire seeks to identify difficulties in performing 10 instrumental activities of daily living (IADL) through self-reports, or reports of knowledgeable others such as family members. The clinical assessment also measured vision and general mobility to rule out deficits in these functional abilities as potential confounds. The on-road assessments took place on test routes designed by the CDRS in the cities where each was based and included single- and multiple-lane roadways in residential and commercial areas as well as limited freeway driving. Each test route included a range of situations and maneuvers deemed risky for drivers with MCI. The CDRS scored performance on a wide range of operational, tactical, and strategic driving tasks.

MoCA showed the strongest association between measures of cognitive status and road test performance, particularly with respect to the tactical and total road test scores. Lower (poorer) scores on the MoCA were associated with larger point deductions (poorer scores) on the road test. Time-to-complete the Maze Test and Trails B showed moderate correlations with points off for tactical tasks (Maze Test), strategic tasks (Trails B) and total road test scores. All measures of cognitive status showed weak to no association with road test performance at the operational level; this was not unexpected, as these are overlearned basic vehicle operating and control skills that would not necessarily degrade with mild cognitive impairment.

The relationships between measures of cognitive status and exposure were weak to moderate, and only 3 of the 45 tested correlations were statistically significant at the 0.05-level. None of the clinical measures accounted for more than 12% of the variance in total number of trips, total driving hours, or total miles driven.

Multiple regression analyses of the relationships between the measures of cognitive status and the on-road driving assessment scores, and between the cognitive measures and driving exposure, were equivocal. Only two of the four driving assessment models, and none of the nine driving exposure models, were statistically significant overall. Together, the cognitive variables accounted for a significant amount the variance with R-squared values of 43% and 44% for Tactical and Total road test scores, respectively, with the MoCA score (and to a lesser extent, the time-to-complete the Maze Test) explaining the most variance.

The overall superiority of MoCA scores in predicting assessment outcomes warranted inferential tests of the significance of differences between groups classified using this measurement tool. Most notably, those classified as cognitively unimpaired received significantly fewer points off on the on-road assessment than those classified with mild cognitive impairment; and this difference increased when comparing the unimpaired to those with any level of impairment.

This research increased our understanding of how and to what extent mild cognitive impairment influences safe driving performance and underscored the utility of a rapid cognitive screening instrument common among clinicians. The relationship between cognitive status and exposure, however, is less clear.

Introduction

Background and Understanding of the Problem

Driving provides independent mobility that improves older adults' access to the goods and services they need and enhances their ability to participate in community and family activities that support quality of life. According to Herbel, Rosenbloom, Stutts, and Welch (2006), the number of people 65 and older will more than double in the next 25 years, with a threefold increase for those 80 and older. As older adults comprise an increasing proportion of the driving population, there is reason for concern about the consequences of early stage dementia, MCI, and driver performance and safety because these conditions become markedly more prevalent with advancing age. The Alzheimer's Association (2015) reported that 11% of Americans 65 and older, 14% of those 71 and older, and 32% of those 85 and older had Alzheimer's disease. Research suggests that on average 10% to 20% of people age 65 and older have MCI. Incidence rates in the Unites States average 5% to 10% per year in community settings and 10% to 15% per year in clinical settings (Petersen, 2011). Research has established that drivers with dementia are at a greater risk for crashes compared to cognitively normal adults, but little research has been done regarding the effects of mild cognitive impairment on driving performance (Carr & Ott, 2010). Because one-third or more of drivers with dementia continue to drive (Silverstein, 2008), it is important to better understand the effects of MCI and early dementia on driving performance.

MCI refers to an intermediary, symptomatic state between age-appropriate cognitive decline and dementia. While definitive clinical measures and operationalization of the condition have yet to be established in formal guidelines such as the *Diagnostic and Statistical Manual of Mental Disorders*, it is generally agreed that the clinical presentation of MCI must involve the following criteria (Albert et al., 2011; Petersen, 2004; Winblad et al., 2004).

1) *Subjective complaint or concern* regarding cognitive decline or impairment, as compared to an individual's previous state of cognitive functioning. This complaint usually, but not always, refers to memory loss and may come from people themselves or from a close informant.
2) *Objective evidence* of impairment in one or more cognitive domains beyond the level of what is to be expected for normative aging. This objective evidence is generally obtained through clinical evaluation and/or neuropsychological testing.
3) *Relatively normal performance of functional activities of daily living* or ADLs (personal hygiene, feeding oneself, etc.), although people with MCI may experience more minor difficulties than they are used to in performing complex tasks (instrumental activities of daily living or IADLs) such as paying bills, cooking, and driving.
4) *Does not meet criteria for a dementia syndrome*. Cognitive impairments are insignificant enough as to not warrant the diagnosis of dementia (i.e., do not interfere with social or occupational functions).

A variety of problem driving behaviors have been associated with the onset of dementia, including signaling errors (Duchek, Carr, Hunt, Roe, Xiong, Shah, & Morros, 2003), turning errors (Uc, Rizzo, Anderson, Shi, & Dawson, 2005), failing to comprehend traffic signs (Carr, LaBarge, Dunnigan, & Storandt, 1998), lane-keeping errors (Uc et al., 2005), and becoming lost in familiar areas (Silverstein et al., 2002). Eby et al. (2009) found that a sample of 10 drivers with early stage dementia did *not* demonstrate more unsafe behaviors than a comparison group of healthy older drivers based on data reduced from an in-vehicle video system installed in participants' own cars. However, the early stage dementia group drove fewer miles and drove to fewer unique destinations compared to drivers without dementia, and they were significantly more likely to exhibit wayfinding problems, operationalized in terms of an analyst's determination that the driver got lost or "seemed to forget a destination after starting a trip." The present study of driving performance by drivers with MCI and healthy older drivers expands upon the study by Eby et al. by recruiting more participants to increase the sample sizes, sampling MCI and healthy comparison group drivers contemporaneously, using a CDRS to score driver performance, and instrumenting participants' vehicles with off-the-shelf equipment that could be quickly installed by a research assistant to verify driver identification and record travel patterns.

To support the agency's mission of reducing vehicle-related crashes and preventing injuries, NHTSA provides guidance to State driver licensing agencies, as well as to physicians, CDRSs, and other health caregivers who advise older adults about when to transition from or to cease driving. The findings of this study support efforts to develop reliable evidence-based guidance regarding the relationship between age-related cognitive declines, including those associated with MCI, and the ability to drive safely. The improved understanding of changes in driving behaviors associated with MCI also will help physicians, driver rehabilitation specialists, and others who provide guidance to older adults regarding driving safety to know when to recommend driving cessation. Finally, study findings will help clinicians to identify and intervene when a client with dementia begins to exhibit potentially risky driving behaviors.

Project Objective

The objective of this project was to document differences in driving performance and exposure between participants with MCI – operationally defined through recognized clinical methods – and a comparison group of drivers of comparable age who did not meet those criteria. Three sets of measures addressed the research questions in this project:

(1) Clinical measures of participants' cognitive function that the technical literature indicated may be used to discriminate MCI patients from age-normal controls plus sensory measures and measures of general mobility (to rule out other potential sources of performance differences).

(2) Driving performance data collected by the CDRS in a passenger vehicle instrumented with a dual-braking system during an on-road drive in traffic.

(3) Participants' driving exposure measured by an in-vehicle data acquisition system installed in participants' own vehicles for approximately one month.

The researchers performed analyses using all three sets of measures (clinical, driving performance, and exposure) to determine the extent to which limitations demonstrated in the clinic were related to driving performance and exposure (e.g., in terms of total miles traveled or trip distance from home).

More specifically, analyses of driving performance evaluation scores addressed the following research questions about differences among drivers in vehicle control and safe maneuvering through traffic as a function of their clinical scores:

- Did drivers differ in the extent to which they monitored surrounding traffic to maintain awareness of traffic conditions and potential hazards through scanning and use of mirrors?
- Were there differences among drivers in responses to traffic control signals, responses to other drivers, use of turn signals, and/or in positioning of the vehicle when stopping at intersections?
- Did drivers differ in ability to maintain speed and lane position, choose appropriate gaps when merging or turning across traffic, and accelerate and decelerate smoothly?
- Were there differences among drivers in their ability to coordinate steering and pedal movements required in performing sharp turns, backing and parking?

Analyses of the exposure data answered the following research questions about where, when, and how much participants drove as a function of their clinical scores:

- Did drivers differ in the overall distance and time spent driving, the (average) number of trips per day, or trip distribution in terms of their distance from a participant's home?
- Were some study participants more likely to drive on high-speed and/or limited access roadways?
- Were there differences in the time of day that participants drove (e.g., day versus night)?

Finally, analyses of the driving performance *and* exposure data were used to address the research question:

- Were drivers with poorer driving skills more likely to limit their overall driving (time and/or miles) or avoid potentially difficult conditions such as night or rush hour driving?

To meet the project's objective, the researchers began with a literature review to determine whether similar studies had been conducted within the past 10 years and to consider relevant findings in developing the current study. The researchers then designed a quasi-experimental driving performance and exposure study and received approval from the Office of Management and Budget to begin data collection (OMB Control No. 2127-0712). The CDRSs recruited 38 study participants, including 19 drivers 60 and older who fit a medical profile consistent with the current definition of mild or moderate cognitive impairment, and 19 of similar age who were cognitively intact to participate in the study. The following sections of this report describe the literature review methods and results, followed by the driving performance study methods and results.

Literature Review

Methods

The researchers searched for articles in the TRID, PsycINFO, and Ageline databases and performed Internet searches in Google Scholar, NIH, PubMed (which includes MedLine), and Science Direct. A broad search encompassing the definition, operationalization, domains of cognitive impairment, and diagnostic measures for MCI captured the potential impact of these subjects on the design of the current study. As MCI is a relatively novel concept, no date-range limitations were imposed. Table 1 displays the search terms and strategy used for the search.

Table 1. *Literature Review Search Strategy*

mild cognitive impairment OR MCI
AND
driv* OR defin* OR detect* OR eval* OR deficit* OR screen* OR *test

The second, more refined search specifically focused on studies published between 2003 and 2013 that described the relationship between MCI and driving performance.

Results

The researchers acquired 120 full-text reports as candidates for the literature review. One hundred of these reports contained information pertinent to this review. General findings were that those with MCI performed statistically better than people with dementia on tests of functional activity, had a greater awareness of their cognitive deficits, and could accurately self-report their driving ability (Okonkwo et al., 2008). Those with MCI tended to self-regulate their driving behaviors according to their perceived abilities by driving less than older adults with normal cognitive function and avoiding more difficult driving situations like making left-hand turns (Johnson, Frank, Pond, & Stocks, 2013; Kowalski et al., 2012; O'Connor, Edwards, Wadley, & Crowe, 2010; O'Connor, Edwards, & Bannon, 2013). Research also suggested that this population was not opposed to restricting driving behaviors based on their abilities, particularly when such advice came from a well-respected source like their primary care provider or when impairment was documented objectively through on-road driving evaluations (Johnson, Frank, Pond, & Stocks, 2013; Kowalski et al., 2012).

The research surrounding mild cognitive impairment and driving performance was limited to six studies, with considerable variation in the condition's operationalization, inclusion of subtypes, and sample sizes. For example, three conducted on-road driving assessments, and three evaluated driving performance using a simulator. Though the operationalization of MCI varied throughout these studies, each identified MCI explicitly and differentiated it from mild dementia and normal cognitive function.

Wadley et al. (2009) compared the on-road driving performance of 46 patients with MCI to 59 cognitively normal controls. A CDRS evaluated driving performance in terms of right turns, left turns, lane control, gap judgments, steering steadiness, speed maintenance, and a global rating of driving performance. Ratings ranged from 5 (optimal) to 1 (evaluator took control of car). Mean scores for the seven skills ranged from 4.80 to 4.93 for MCI patients, and from 4.82 to 4.97 for controls, indicating that many participants in both groups received ratings at or near the ceiling. Analyses then focused on the proportion of MCI versus control participants whose scores were less than optimal (scores of 1 to 4) on each driving skill. The researchers found that participants with MCI were significantly more likely to receive less-than-optimal ratings on left-hand turns, lane control, and for the global driving score. Although performance was slightly impaired in the MCI sample, it was not impaired to the degree that these drivers were deemed unsafe by the authors, as mean ratings in both groups fell close to the highest rating available on the scale used. Notably, however, most suboptimal scores for both the MCI group and the control group were documented for left-hand turns and steadiness of steering.

Patomella, Johansson, & Kottorp (2010) sought to determine the internal scale validity and reliability of the Performance Analysis of Driving Ability (P-Drive) on-road driving assessment tool for estimating the on-road driving performance of people with neurological disorders in Sweden. Participants in this validation study were drivers who held a current driver's license but were referred to an occupational therapist for an on-road driving assessment. The sample included 128 people who had had a stroke (mean age=67), 34 diagnosed with dementia (mean age=73), and 43 diagnosed with MCI (mean age=73). The researchers found that participants with MCI and dementia had relatively more difficulty with *finding the way* than did those who had had a stroke, but *giving right-of-way*, *keeping distance*, and *heeding regulation signs* were less difficult for those with MCI compared to those with a stroke history.

Snellgrove (2005) studied two groups of older drivers: 23 diagnosed with MCI and 92 diagnosed with early dementia. The on-road driving assessment included a 45-minute in-traffic road test along a pre-determined route, and a South Australia (SA) license examiner scored the driver using the SA licensing authority criteria. Driving skills assessed included maintaining speed, obeying traffic signs, signaling, turning, yielding right of way, changing lanes, anticipating and reacting to traffic conditions, negotiating intersections, and parallel parking. For this study, failure was set as a score of below 70% (as opposed to the SA licensing criteria of below 85%) to avoid failing drivers for committing errors considered "bad habits" of experienced, competent drivers (e.g., failure to signal for 5 seconds prior to changing lanes or turning). Failure according to the study's criteria thus implied that a driver was not fit to drive. Significantly more participants with MCI passed the driving assessment (52%) than did the mild dementia participants (24%) ($p< .01$), but still nearly half of the MCI participants failed the study's on-road driving assessment (48%). Verbal feedback provided by the assessor indicated that driving faults (among both groups) were related to poor scanning and observation of other vehicles on the road or parked on the curb, poor scanning and observation of road signs and signals, an inability to monitor and control vehicle speed (both high and low), poor positioning of the car on the road and when parked, confusion with pedals and with gear selection (both manual and automatic), and lack of anticipatory or defensive driving. According to the author, faults occurred more often when driving tasks became more complex and when traffic was heavier.

Devlin, McGillivray, Charlton, Lowndes, & Etienne (2012) investigated the braking patterns of 14 drivers with mild cognitive impairment (mean age=77; 9 males, 5 females) when approaching intersections, as compared to 14 age- and gender-matched controls (mean age=77; 9 males, 5 females) using a portable driving simulator. The driving scenario consisted of a number of intersection maneuvers that included two stop signs, two traffic light-controlled intersections with critical light changes, and two uncontrolled intersections. For the critical light changes, the traffic lights were programmed to change from green to amber when a driver was 4.5 seconds away from the intersection, and the two uncontrolled intersections had no stop signs or traffic lights to indicate right of way. While there were no statistically significant group differences found in terms of driving performance measures, some trends did emerge. According to the researchers, drivers with MCI were less likely than controls to stop at stop-sign controlled intersections and critical light change intersections, yet the control group demonstrated a greater number of right foot hesitations than did the MCI group. The authors speculate that perhaps foot hesitations were associated with advanced age, but it is unclear whether these hesitations were due to cognitive decline or were a strategic maneuver to allow more time for processing necessary decision-making information.

Frittelli et al. (2009) assessed the simulated driving performance of people with mild Alzheimer's disease (AD) (n=20), MCI (n=20), and healthy age-matched controls (n=19). The STISIM driving simulator driving scenario included a car moving on a two-lane urban and extra-urban road, about 6 km long, with good light and visibility conditions. Events along the designated route included traffic lights, trucks and cars occupying the oncoming lane or preceding the test car, intersections, and pedestrian crossings. Outcome measures of the simulation drive included: (1) the length of run, defined as the time spent in completion of the posted driving test; (2) the number of infractions (speed limit violations, failure to stop at pedestrian crossings); (3) the number of stops at traffic lights; (4) the mean time to collision, i.e. the time to contact the preceding vehicle if the test car kept moving under constant velocity; and (5) the number of off-road events, defined as the center of the car's hood crossed the lateral border of the road. Results showed only limited impairment of driving performance for the MCI group when compared to controls with a statistically significant difference just for mean time to collision. No significant differences were found in reaction time latencies between the MCI and control group or on any other measure. Overall, impaired driving performance was detected in the mild AD group when compared to the MCI and control groups; drivers with mild AD performed significantly worse on length of run, mean time to collision, and number of off-road events. Simple visual reaction times were significantly longer in those with mild AD compared to those with MCI and to the healthy controls.

Kawano et al. (2012) compared the simulated driving performance of adults with amnestic MCI (aMCI) to both older and younger adults with normal cognition. Driving simulator skills tested included road-tracking, car-following, and harsh-braking. The aMCI group demonstrated significantly poorer performance than the normal young adult (NYA) group on the car-following and road-tracking tasks, but they only performed significantly poorer than the normal older adult (NOA) group on the car-following task. There were no significant group differences on the harsh-braking task. The researchers found a significant positive correlation in the older group (NOA and aMCI) between the car-following task and Trail-Making Part B (TMT-B) such that TMT-B scores significantly predicted performance on this task after adjusting for the severity level of amnesia. While this study only included amnestic MCI participants, the correlation between performance on the car-following task and TMT-B score suggests that mild impairments in visual attention and executive function, independent of memory impairment, may be a valid predictor of crash risk among people with MCI. Therefore, these findings could potentially be generalized to other types of MCI besides isolated amnestic (single domain). Also, in this study aMCI participants were compared to both age-matched healthy controls and younger healthy controls, which may provide insight into the type of age-related cognitive declines that affect driving performance and how they differ from MCI-related impairment.

Findings from both the focused and expanded search informed the design and conduct of the present study. As discussed below, these findings related to how MCI was defined/operationalized in the current project; what instruments were used to classify drivers as normal aging, MCI or early dementia (Alzheimer's); and what safety relevant measures of driving performance were most likely to yield significant differences.

The expanded literature review provided evidence of clear advantages to using a combination of standardized cognitive tests and a questionnaire designed to reveal changes in a person's functional activities (i.e., compared to an earlier baseline) to operationalize MCI. The research team focused on selecting a cognitive test (or tests) that demonstrated adequate sensitivity and specificity for identifying MCI that was practical to administer. An emphasis on executive[1] tasks was desirable, as deficits in these domains were expected to account for the greatest variance in driving performance and safety. The researchers selected the MoCA. The choice among functional activity questionnaires was more arbitrary, but the research team opted to focus upon IADLs as these activities are usually minimally impaired in those with MCI but more impaired in people with dementia – an important discrimination in this research. Regarding a self-report versus informant-report protocol, not all potential study participants could be expected to have an informant capable of providing accurate information about their activities. Given this concern and research cited in the review indicating that those with MCI can and do accurately report changes in their functional performance, researchers selected a self-report protocol.

Finally, the literature review suggested that driving performance measures are subject to ceiling effects because the impairments among people with MCI are often subtle, particularly for an overlearned behavior such as driving. At the same time, the limited driving performance research related to drivers with MCI pointed to tasks involving gap judgment or time-to-collision estimates, in particular car-following behavior, as more sensitive to detecting differences relative to normal (age-matched) controls. Driving tasks that rely upon executive function (e.g., attention switching, decision-making) and are likely to impact performance and safety—i.e., not only orientation and navigation—were a focus of the dependent measures in the on-road assessments.

[1] Executive function describes a variety of loosely related higher-order cognitive processes like initiation, planning, hypothesis generation, cognitive flexibility, decision-making, regulation, judgment, feedback utilization, and self-perception that are necessary for effective and appropriate behavior (Daigneault, Joly, & Frigon, 2002).

Driving Performance Study Methods

Participant Recruitment and Screening

The study team sought to recruit 30 participants age 60 and older who fit a medical profile consistent with the current definition of MCI and 30 of similar age who were cognitively intact, with males and females equally represented in both groups. The CDRSs recruited study participants in the State of Virginia using several approaches.

Both CDRSs on the study team were approved as evaluators by the Virginia Department of Motor Vehicles' (DMV). Appropriate clients for study recruitment were those whom the DMV referred for a CDRS evaluation as part of the DMV medical review procedure due to concerns about possible cognitive impairment. Such clients had undergone an examination by their treating physicians or nurse practitioner, and based on the examination, the healthcare practitioner provided specific responses on the DMV Medical Report Form (see Figure 1):

- "Based on this examination, is the patient medically capable of operating a motor vehicle?"
  ANSWER: Yes.
- "Based on this examination, patient needs the following:"
  ANSWER: A driver evaluation with a certified independent driver rehabilitation specialist (CDRS).
- "Based on this examination, the patient's driving ability is likely to be impaired by limitations in the following areas:"
  ANSWER: Problem Solving and Decision Making OR Cognitive Function.

The participating CDRSs also sought to recruit participants through presentations at community events (e.g., health fairs targeting older residents), to professionals serving the senior population (e.g., Southwestern Virginia Aging Council, Agencies on Aging in Virginia and the District of Columbia), to rehabilitation networking groups, at continuing care retirement communities, and to religious and civic groups in their communities. They also posted research flyers in central areas of local churches and in church newsletter bulletins in the areas surrounding Vinton and Richmond. The study was highlighted in an article published in the "Timeless Magazine" (a quarterly insert in the Roanoke Times newspaper) in the fall of 2016. The CDRSs also sought referrals from physicians' practices in their respective communities.

To recruit the comparison sample of older participants (those without evidence of cognitive impairment) the CDRSs asked the MCI study enrollees to suggest a friend or neighbor of similar age as a potential study participant. The CDRSs also recruited participants in the comparison sample at the same community events and organizations as noted above. When addressing professionals who served the senior population, the CDRSs emphasized considering their own parents as potential study participants in addition to the seniors they served.

Customer Medical Report

MED 2 (08/25/2010)
Page 8

(MUST BE COMPLETED BY PHYSICIAN OR NURSE PRACTITIONER)

NAME (Last) (First) (MI) (Suffix)	BIRTH DATE (mm/dd/yyyy)	CUSTOMER NUMBER or SSN

PART F - GENERAL RECOMMENDATIONS

FIRST MEDICAL PROVIDER

Is the patient's condition(s) stable? ☐ YES ☐ NO If No, explain.

Is the patient compliant with treatment? ☐ YES ☐ NO If No, explain:

Does the patient experience side effects of medications, which are likely to impair driving ability? ☐ YES ☐ NO If Yes, explain:

Based on this examination, is the patient medically capable of:
- safely operating a motor vehicle? ☐ YES ☐ NO and/or
- operating a commercial motor vehicle includes tractor trailers, passenger buses, tank vehicles, school buses for 16 or more occupants (including the driver), or vehicles carrying hazardous materials? ☐ YES ☐ NO

Based on this examination, patient needs the following: (check each appropriate item)

☐ to be retested by DMV on ☐ Knowledge ☐ Road ☐ Both
☐ an adaptive device/equipment required to safely operate a motor vehicle.
☐ a driver evaluation (with a certified independent driver rehabilitation specialist CDRS).
☐ a prosthetic/orthotic device to operate a motor vehicle

For clarification on any of the above, contact Medical Review Services at 804 367-6203.

Based on this examination, the patient's driving ability is likely to be impaired by limitations in the following areas: (check each appropriate item)

Judgment and Insight
☐ Problem Solving and Decision Making ☐ Cognitive Function
☐ Emotional or Behavioral Stability ☐ Reaction Time

Sensorimotor Function
☐ Strength and Endurance ☐ Maneuvering Skills
☐ Range of Motion ☐ Use of Arm(s) and/or Leg(s)

ADDITIONAL RECOMMENDED RESTRICTIONS	MEDICATIONS
PHYSICIAN/NURSE PRACTITIONER NAME (print)	MEDICAL SPECIALTY

MEDICAL LICENSE NUMBER	EXPIRATION DATE (mm/dd/yyyy)	ISSUING STATE	TELEPHONE NUMBER ( )	FAX NUMBER ( )

PHYSICIAN/NURSE PRACTITIONER SIGNATURE	DATE (mm/dd/yyyy)

If you have questions or need more information to complete this page, call Medical Review Services (804) 367- 6203.

Figure 1. Virginia DMV Medical Examination Report.

When drivers referred by the VA DMV contacted a CDRS to make an appointment for their evaluation, the CDRS apprised them of the study opportunity and provided an information packet including consent materials to those who were interested. The consent materials stated that the study would pay for their CDRS evaluation[2] if they chose to enroll as a participant, and participants would receive a $100 gift card for allowing his/her own car to be instrumented to obtain exposure data.

Participants recruited through organizations other than the DMV were provided with the CDRSs' contact information for a pre-screening telephone interview. The eligibility criteria are listed below:

- 60 or older at the time of data collection
- Licensed to drive

[2] The value of the evaluation by the CDRS was approximately $400, which would be an out-of-pocket expense for a driver with MCI who was referred by the DMV for evaluation of qualifications for driving. The driving evaluation was provided free of charge to all participants, paid for by the study sponsor, NHTSA.

- Drove at least three trips per week
- Did not have adaptive equipment installed in the vehicle (e.g., hand controls)
- Had no medical condition of such severity as to interfere with safe driving
- Had not had a medical professional recommend driving cessation
- Intended to be in the data collection area during the data collection interval (e.g., did not plan an extended trip during the naturalistic data collection interval)

If the candidate met inclusion criteria, the driver made an appointment to read and sign the consent form (30 minutes), undergo an in-clinic assessment including a prescribed set of functional screening measures (1 hour), and undergo a driving evaluation (1 hour). At the end of the evaluation, the CDRS advised the study participant that a member of the research team would contact them to schedule an appointment for vehicle instrumentation.

In-Clinic Assessment

In addition to clinical measures they collect for a standard driving evaluation, the CDRSs assessed each participant's functional domains of vision (acuity and contrast sensitivity) and general mobility (rapid pace walk) to control for potential sources of driving performance and exposure differences across groups. The CDRSs also assessed various cognitive domains to discriminate MCI patients from those without cognitive impairment and those whose impairment has progressed beyond MCI. Finally, the CDRS administered a self-reported functional activities questionnaire to assist in identifying MCI patients. These measures are described in more detail below.

Vision: Visual acuity. The CDRS assessed visual acuity using an Early Treatment Diabetic Retinopathy Study (ETDRS) 2000 Series eye chart test, placed 3 m (10 ft) from the test participant. This chart measured 24.5 by 25.5 inches and contained 14 rows of 5 Sloan letters each. The size of the optotypes on each row progressed geometrically up or down the chart by 0.1 log units. The top row corresponded to an acuity of 20/200 (LogMar 1.0) and the bottom row to 20/10 (LogMar -0.3). The CDRS instructed the participant to state the letters on each row from left to right, beginning with the top row. The CDRS stopped the test when the participant could not accurately read at least 3 of the 5 letters presented on a row. The acuity was recorded as the last row where they could read all 5 letters accurately, minus 0.02 log units for every letter that was correctly identified beyond the last row where all 5 letters were correctly identified. For example, if the patient read all of the letters correctly on the 20/30 row and then 3 letters correctly on the 20/25 row, the Log Score was calculated as follows:

20/30 Row = 0.20
3 letters X 0.02 log/letter = – 0.06
ETDRS Acuity Log Score = 0.14

Vision: Contrast sensitivity. The CDRS assessed contrast sensitivity using a MARS Contrast Sensitivity test chart set 20 inches from the participant. The MARS Letter Contract Sensitivity Test (Mars Perceptrix Corporation, 2003) is a 9- by 14-inch chart with 48 letters (6 letters in each of 8 rows). The contrast of each letter, reading from left to right and continuing on successive lines, decreases by a constant factor of 0.04 log units. The test developers state that normal values of log CS are approximately 1.8 in children and young adults, and about 1.68 for older adults (over age 60). They also state that when both eyes have equal CS, binocular CS is typically 0.15 log units higher.

The CDRS instructed the participant to read each letter across each row, and then continue to the next row. The score was the contrast of the final correct letter the participant identified before making two consecutive errors (minus 0.04 for each previous incorrect letter). The CDRS encouraged participants to guess, even when they thought the letters were too faint to see accurately. The CDRS recorded the contrast sensitivity score, which the research team later converted to log scores to summarize performance.

General mobility: Rapid pace walk. The CDRS measured participants' general mobility using the Rapid Pace Walk test. A 10-foot distance was pre-marked on the floor. The participant walked the 10-foot distance, turned at the end, and walked back to the start position. The total walking distance was 20 ft. The CDRS stated, "*I want you to start at this mark, walk to the other mark, turn around, and walk back here as quickly as you can*." (Demonstrate) "*If you use a cane or walker, you may use it if you feel more comfortable. I am going to time you. Go as fast as you feel safe and comfortable*." "*Ready, begin*." The CDRS started timing when the participant picked up his or her first foot, and stopped timing when the last foot crossed the finish line. The CDRS recorded the total time to traverse the 10-ft path up and back with a stopwatch. Staplin, Gish, and Wagner (2003) found that drivers who could not complete this measure in less than 9 seconds were at a significantly increased risk of crash involvement.

Cognitive function: Montreal Cognitive Assessment. The MoCA is a rapid cognitive screening instrument that is divided into several domains: short term memory; visuospatial; executive; attention; concentration; and working memory, language, and orientation. These categories include many subtests that are frequently used in neuro-psychological batteries like the Trail Making Test-B, copy of the cube, the clock drawing test, digit span forward and backward, etc. The MoCA screen has been shown to be most accurate when considering the overall score rather than isolated individual scores on each subtest (Freitas, Simoes, Maroco, Alves, & Santana, 2012; Moafmashhadi & Koski, 2013). The MoCA's success relative to the MMSE and other measures for detecting MCI may reflect its inclusion of executive function measures. Researchers have found that executive function shows the highest discriminative capacity between MCI and comparison groups without cognitive impairment, as those with MCI generally score lower on such tests than do those without cognitive impairment (Ahmed, de Jager, & Wilcock, 2012). It has also been suggested that the MoCA's increased sensitivity over the MMSE may be due not only to the inclusion of executive tasks, but because it has more complex short-term memory, language, attention, concentration, working memory, and visuospatial tasks as well. The MOCA and scoring instructions are presented in Appendix A. The maximum score is 30; a score of 26 or higher is considered "normal." The test developers provide the following ranges to grade severity: scores of 18 to 25 may be considered *mild* cognitive impairment, 10 to 17 *moderate* cognitive impairment, and less than 10 *severe* cognitive impairment. Researchers validating the MoCA for screening MCI and AD suggest an optimal cut-off of below 22 for MCI and below 17 for AD (Freitas, Simões, Alves, and Santana, 2013).

Cognitive function: Trail-Making Test (Parts A and B) and the Maze Test (Maze 1 and Maze 2). These tests are established measures of cognitive function and have also been validated as significant predictors of crashes among older drivers (Staplin, Gish, & Wagner, 2003; Roy & Molnar, 2013; Staplin, Gish, Lococo, Joyce, & Sifrit, 2003). Roy and Molnar

(2013) found a positive association between Trails B performance and fitness to drive in 32 of 47 studies, with support from 7 studies for 3 minutes (180 seconds) as the cutpoint, and three other studies recommending shorter cutpoints ranging from 90 to 147 seconds. Staplin, Lococo, Gish, and Decina found that older drivers who required 100 seconds or more to complete Trails B were 3.5 times more likely to have been crash-involved as a contributing driver 1 year retrospectively and 2 years prospectively. Staplin, Gish, Lococo, Joyce, and Sifrit (2013) found that the odds of being involved in a crash within 18 months after testing were 3.55 times higher for older drivers who required 19.1 seconds or longer to complete Maze 1, and 2.54 times higher for older drivers who required 31.2 seconds or longer to complete Maze 2. The odds of being crash-involved were 4.58 times higher for drivers who required 42.2 seconds or longer to complete both mazes.

As noted in the literature review, there is no clear consensus about where the cutpoints should be placed to discriminate persons without cognitive impairment from persons with MCI (and persons with MCI from persons with early dementia). Therefore, acknowledging that (1) there is no tool or combination of tools at present that define sharp boundaries between the non-cognitively impaired and MCI populations of interest, and (2) that drivers recruited into this study were likely to differ along a continuum for each instrument used to measure cognitive function, the research team elected a regression model approach versus a between-groups study design. Multiple regression allows the strength of association between each clinical measure included in the study and the criterion measures of driving performance and exposure to be determined. For those predictors (clinical measures) that are significantly related to each criterion measure, their respective weights (coefficients) provide further evidence of their relative contributions in the regression model. This approach also alleviated a potential problem of requiring the participating CDRS evaluators to apply subjective, 'expert judgment' to assign drivers to non-cognitively impaired versus MCI groups when their clinical scores made such assignments ambiguous.

Cognitive function: Functional Activities Questionnaire. Since a change in functional status is widely accepted as an important criterion in diagnosing MCI, and because cognitive scores often overlap when early MCI cases perform in the normal range and late MCI cases perform in the mild dementia range (Trzepacz, Hochstetler, Wang, Walker & Saykin, 2015), the CDRSs administered the 10-item Functional Activities Questionnaire (FAQ) (Pfeffer, Kurosaki, Harrah, Chance, & Filos, 1982). This questionnaire is presented in Appendix B. As noted earlier, research has indicated that those with MCI can accurately report changes in their functional performance. For these reasons, a self-report protocol was considered appropriate for the present study. Teng, Becker, Woo, Knopman, Cummings, and Po (2010) found that scores of 6 and higher distinguished AD from MCI with high sensitivity, specificity, and classification accuracy.

On-Road Evaluation

Following the in-clinic assessment, the CDRS evaluated each study participant's on-road driving performance. For participants who lived far from the CDRS's office location (Richmond and Roanoke, Virginia, respectively), the test route began and ended at (or close to) the participant's home. Otherwise, common test routes in the cities where each CDRS was based were used. Each test route included a range of situations and maneuvers deemed risky for drivers with MCI based on the technical literature, on anecdotal reports, and on the professional judgment of the CDRS.

The evaluation lasted approximately one hour. Specific driving situations included:

- residential areas with curves and non-90 degree intersections;
- multiple lane roadways with moderate to heavy traffic;
- limited access highways with a speed limit of at least 55 mph;
- instances where the participant must complete multiple lane changes across traffic quickly, to make a planned maneuver; and
- unprotected left turns.

The driving skills and behaviors the CDRS observed and scored during the on-road evaluation included:

- maintaining speed and lane position;
- hazardous driving behaviors (e.g., running stop signs or cutting off other drivers);
- driving substantially over or under the posted speed;
- slowing or stopping at inappropriate times or locations;
- accelerating and braking smoothly;
- signaling turns;
- turning into the proper lane;
- managing lane changes and merges, including checking blind spots;
- gap selection when turning across traffic; and
- intersection navigation and performance at other decision points.

The CDRS used a scoring protocol that provided for finer gradations in behavior than a simple ‘pass/fail’ outcome to increase variation and alleviate a restriction of range in the evaluation data. These behaviors were grouped within subsets of driving skills labeled *operational*, *tactical*, and *strategic* by the developer of the protocol (see Figure 2). While labeling skill sets in this way proved useful for later analyses, readers should be aware that the present use of these terms is not entirely consistent with the larger body of technical literature in this area (cf. Michon, 1985).

CDRS BTW TEST Name:________________________________ Number: _______

Operational Skills	Tally	Total
Independent access to vehicle (1)..		
Negotiation of driver door (1)		
Adjusts seat (3).............................		
Adjusts wheel (3).........................		
Adjusts mirrors (3)		
Fastens seat belt (3).......................		
Ignition Control (3)..........................		
Proper gear selection (3)................		
Brake control (3)............................		
Accelerator control (3)		
Steering (5)....................................		
Identify speedometer (5)............ .		
Signal ability (5)............................		
Dashboard controls (5)..................		
Wiper/Cruise controls (5)............		
Parking brake engagement (5)......		
Points off		

Strategic Skills	Tally	Total
Correct and safe decisions		
Residential (5)..........................		
City (5)......................................		
Limited access hwy (5)............		
Route planning(5)..........................		
Route logically sequenced(5)........		
Remembers and executes the route in the preplanned order(5)		
Maintains appropriate conversation(5)		
Knowledge of rules of the road (5)		
Decisions in advance of maneuvers(5)............................		
Separates hazards (5)		
Observes cues from other road users (5).......................................		
Anticipates(5)................................		
Attention – "looked but didn't see" (5)....................................		
Processing speed(5).......................		
Followed directions (5)..................		
Points Off		

SCORING: TOTAL POINTS OFF= (A – 0-24; pass with no restrictions), (B – 25-49; pass with recommendations), (C – 50-75; marginal with restrictions; marginal with training), (D – 76-99; Fail), (F – 100 up; Fail)

A vertical mark beside an item indicates points off (tally). The point value of each item is in parenthesis. Each item may have several vertical marks beside it representing the errors that were committed more than one time. Multiply the number of vertical marks times the point value in parenthesis to get the Points Off for that item (total).

100 or more Total Points Off is a failure.

TOTAL ROAD POINTS ...._____________ **Score:** _____________

Tactical Skills	Tally	Total
Visual Skills:		
Scans environment (10)...............		
Use of mirrors (5)..........................		
Blind spot checks (5)......................		
Awareness of signage(5)..........		
Checks speedometer(5)........... ...		
Vehicle Position:		
Lane maintenance (5)....................		
Drives in proper lane (5)............ ..		
Follow distance/Lateral Cushion (5)...		
Stopping position (5)......................		
Response to other traffic (5)........		
Intersections/Turns *(Right)*		
Check Traffic (5)................................		
Proper Lane (5)...............................		
Speed (3)...		
Safe gap selection/yield (10).....		
Complete stop (10)......................		
Runs red light (100).......................		
Intersections/Turns *(Left)*		
Check traffic (5)............................		
ProperlLane (5)................................		
Speed (3)...		
Safe gap selection/yield (10).....		
Complete stop (10)......................		
Runs red light (100)......................		
Lane changes:		
Check traffic (5)............................		
Position (3)....................................		
Speed (3)...		
Lane (5)...		
Safe gap selection/yield (10).....		
Merges on/off limited access hwy		
Judgment of space (5)...............		
Signaling(5)....................................		
Speed regulation(5)......................		
Visual scanning/Blind spot (5)....		
Vehicle Handling:		
Judge and regulate speed (5).......		
Smooth steering(5)		
Smooth accelerator(5)		
Smooth braking(5)		
Appropriate use of signals (5)........		
Response to traffic signal (5)........		
Parking : Approach (3)........................		
Position (3)..........................		
Speed (3)..............................		
Backing: Check Traffic (5)......................		
Position (3).............................		
Speed (3).................................		
Safe/yield (10)...................		
3-pt turn around (5).........................		
Points Off		

Figure 2. Road Test Scoring Metric.

Driving Exposure Vehicle Instrumentation

After completing the on-road performance evaluation, a research team member contacted each participant to schedule an appointment for installing exposure data collection equipment in his or her vehicle at the participant's residence or at any convenient public meeting place. The equipment included a GPS data logger, a miniature camera, motion sensors, a power management circuit to turn the system on and off, and a battery to power the system (see Figure 3). Depending upon what kind of vehicle the participant drove, the technician installed the GPS unit under the dashboard, under the passenger seat, on the rear deck under the rear window, or in the trunk. The technician installed the camera along the edge of the windshield, either near the dashboard or the roof, or near the inside rearview mirror, depending upon what was most practical with the make and model of car. Equipment installation took approximately 30 minutes, did not damage the participant's car in any way, and did not interfere with his or her ability to operate the car. The camera unit recorded and stored video of the interior of the participant's car at 1 frame per second to confirm that the study participant was the driver. The researchers analyzed only the trips where the participant (as opposed to, for example, a family member) was the driver.

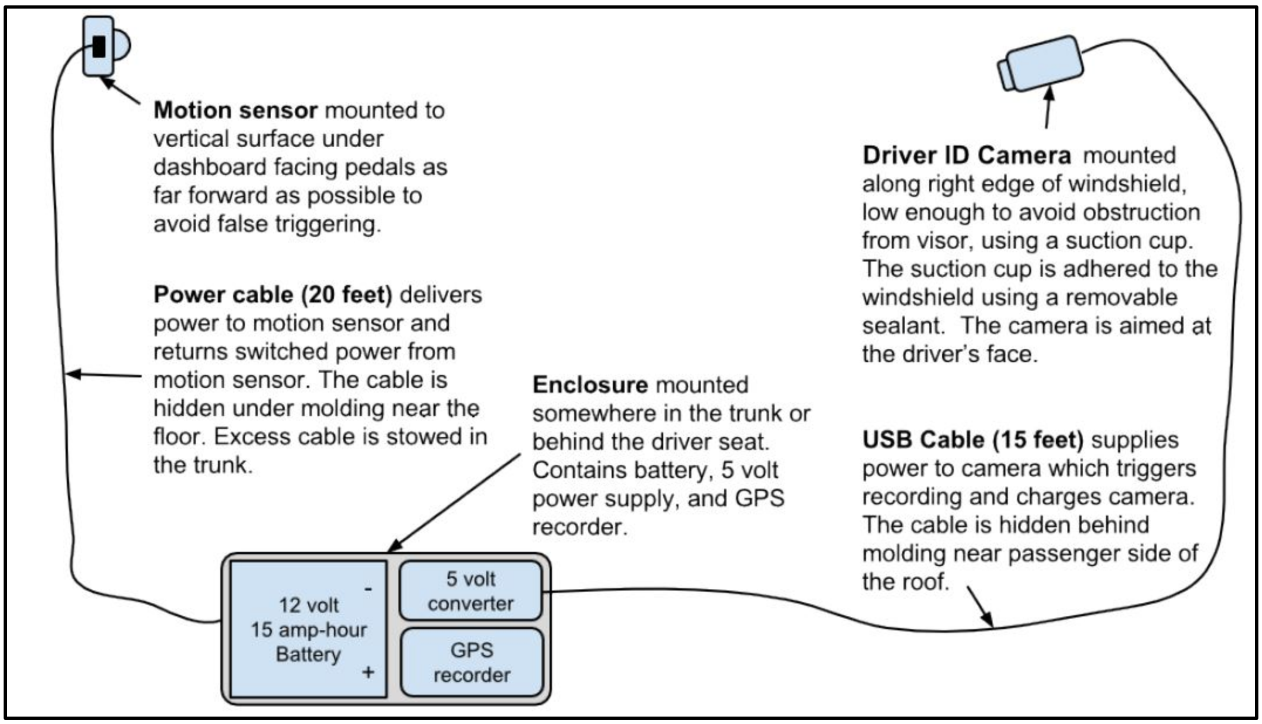


Figure 3. Vehicle Instrumentation.

The equipment remained in the participant's car for approximately one month of "customary" driving. It recorded the time of day and the starting and ending point for each trip, as well as the trip length in miles and duration in minutes. It also captured images of the participants' faces during each trip to confirm that the drivers were study participants. Following equipment removal, the participant received a $100 Visa gift card.

Driving Performance Study Results: Descriptive Statistics

The CDRSs recruited 38 participants, 31 of whom completed all study phases (in-clinic assessment, behind-the-wheel assessment, and driving exposure) and 7 who completed only the in-clinic and behind-the-wheel assessments. Of the 7 participants who did not complete the driving exposure portion of the study, 6 had permits to drive only with a driving instructor or driver rehabilitation specialist until they could pass the VA DMV test, and one participant had second thoughts and withdrew from the (voluntary) study. Following certification of safe driving performance by a CDRS, the VA DMV allows three (and occasionally four) attempts to pass the licensing exams. The study team did not instrument the vehicles belonging to the 6 participants holding a driving instruction permit because their exposure was limited to instruction and practice while driving with the CDRS. Of these 6, one failed the DMV test four times and had his license revoked, one was deemed not safe to drive by the CDRS (and therefore faced license revocation), one passed the DMV test but had DMV-imposed restrictions that were unique among the study participants, and the remaining 3 did not attempt all testing opportunities in the study period.

Table 2 presents the sources of participant referrals. Self-referrals consisted of those who learned of the opportunity through informational sessions at senior centers, senior expos, churches, or from flyers posted in the community.

Table 2. *Study Participant Referral Source*

Referral Source	Number of Participants
Self	17
Physician	14
Family	4
Department of Motor Vehicles	3
Total	**38**

Sample Demographics

Table 3 presents the age and sex distribution for the participants who completed the clinical and behind-the-wheel examinations (clinical sample), and the subset of the clinical sample who also completed the exposure portion of the study (exposure sample). Males comprised more than half of both groups and were an average of 4 to 5 years older than the females. Five males and one female were ineligible to complete the exposure portion of the study because their licenses were restricted to driving with a rehabilitation specialist or driving instructor, and one male declined to have his personal vehicle instrumented.

Table 3. *Age and Sex of the Clinical and Exposure Study Samples*

Study Sample	Males			Females			Total		
	N	Range	$\bar{X}$ (*SD*)	N	Range	$\bar{X}$ (*SD*)	N	Range	$\bar{X}$ (*SD*)
Clinical	27	62-88	75.4 (8.6)	11	66-82	71.2 (5.1)	38	62-88	74.2 (7.9)
Exposure	21	62-88	75.6 (8.5)	10	66-82	70.7 (5.1)	31	62-88	74.0 (7.8)

In-Clinic Assessment

Table 4 summarizes visual acuity and contrast sensitivity performance by sex and for the total sample. Acuity scores ranged from -0.3 to 0.52 (corresponding to Snellen acuities of 20/66 to 20/10), with an average of 0.087 (Snellen 20/24). Three of the 38 participants had acuity scores higher (worse) than 20/40. In terms of contrast sensitivity, 14 participants scored 1.68 or higher (normal) with the remaining 24 participants scoring below normal. There were no meaningful differences across the sexes.

Table 4. *Performance on Vision Tests by Sex*

Vision Test	Males			Females			Total		
	N	Range	$\bar{X}$ (*SD*)	N	Range	$\bar{X}$ (*SD*)	N	Range	$\bar{X}$ (*SD*)
Acuity (LogMAR)	27	-0.3 – 0.52	0.1(0.19)	11	-0.3-0.24	0.07 (0.19)	38	-0.3-0.52	0.09 (0.19)
Contrast Sensitivity (LogCS)	27	1.2–1.92	1.57 (0.16)	11	1.44-1.76	1.64 (0.11)	38	1.2–1.92	1.59 (0.15)

Table 5 presents performance on the rapid pace walk test by sex. Only three of the 38 participants required 9 or more seconds to complete this measure. There were no meaningful differences across the sexes.

Table 5. *Performance on Rapid Pace Walk Test by Sex*

Lower Limb Mobility Test	Males			Females			Total		
	N	Range	$\bar{X}$ (*SD*)	N	Range	$\bar{X}$ (*SD*)	N	Range	$\bar{X}$ (*SD*)
Rapid Pace Walk (s)	27	3.1-9.7	5.6 (1.7)	11	4.3-13.6	6.8 (2.5)	38	3.1-13.7	6.2 (1.96)

Table 6 presents performance on each of the cognitive tests by sex. CDRSs collected measures from all 38 participants for most tests. However, on the Maze test, three participants misunderstood the instructions for Maze 1 and traced every path in the Maze to its end, which increased their completion time beyond the time it would have taken had they drawn a direct path from beginning to end. Because of the misunderstood instructions on the Maze 1 test, the researchers considered Maze 1 as a practice for Maze 2, and excluded Maze 1 and Total Maze time from further analyses. There were no meaningful differences across the sexes.

Table 6. *Performance on Cognitive Tests by Sex*

Cognitive Test	Males			Females			Total		
	N	Range	$\bar{X}$ (*SD*)	N	Range	$\bar{X}$ (*SD*)	N	Range	$\bar{X}$ (*SD*)
MoCA	27	14-30	23.1 (4.8)	11	12-30	23.1 (6.7)	38	12-30	23.1 (5.3)
Trails A (s)	27	19-147.1	55.0 (32.9)	11	23.7-129.8	49.4 (30.3)	38	19-147.1	53.4 (31.9)
Trails B (s)	27	57.4-585	161.8 (110.0)	11	52.5-300	118.2 (74.0)	38	52.5-585	149.2 (101.9)
Maze 1 Time (s)	26	2.0-89.3	19.9 (26.3)	9	3.7-124.5	22.1 (38.9)	35	2.0-124.5	20.5 (29.4)
Maze 2 Time (s)	27	4.0-75.4	22.1 (19.5)	11	5.0-51.8	22.3 (16.1)	38	4.0-75.4	22.2 (18.4)
Maze Total Time (s)	26	7.0-151.1	41.9 (39.6)	9	14-176.4	42.6 (52.4)	35	7.0-176.4	42.1 (42.4)
FAQ Score	27	0-11	2.07 (3.1)	11	0-1	0.2 (0.4)	38	0-11	1.5 (2.8)

Figure 4 presents the distribution of MoCA scores. Among the 38 participants, eight obtained scores consistent with moderate cognitive impairment (scores 10 to 17), 15 consistent with MCI (scores of 18 to 25), and 15 within the normal range (26 or higher).

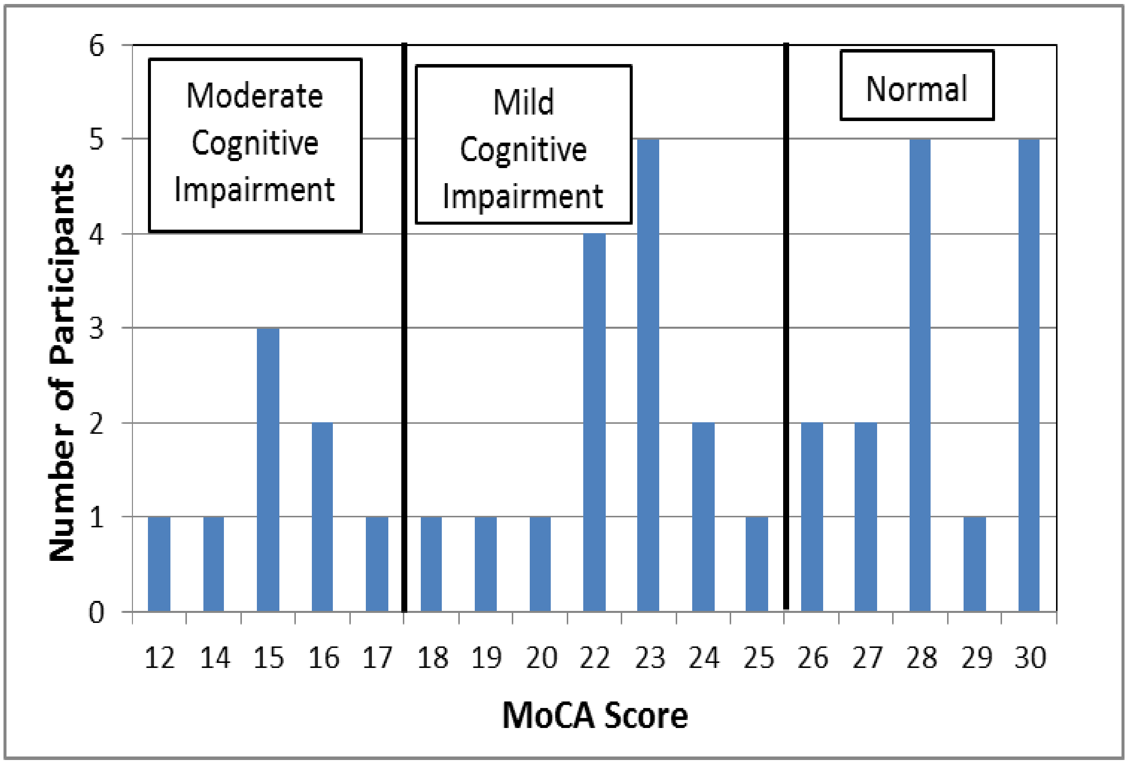


Figure 4. MoCA Score Distribution.

Figure 5 presents the distribution of Trails B scores. Scores for nine participants were consistent with those deemed unsafe to drive at 180 seconds or greater (Roy & Molnar, 2013; Staplin et al., 2013).

Figure 5. Distribution of Trails B Scores.

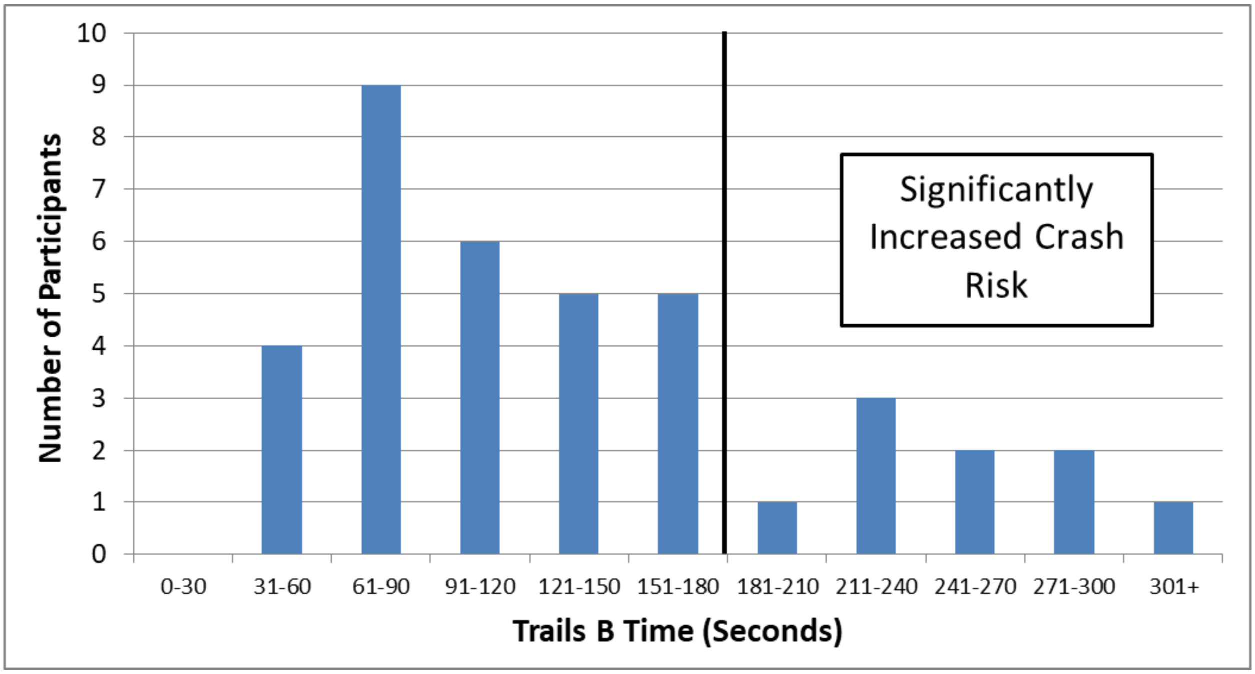


Figure 6 presents completion times for Maze 2. As the procedure for Trail-Making Tests Part A and B state that Trails B time is not valid without the administration of Trails A, the team considered Maze 2 time as valid because of the practice and correction conducted for Maze 1. Scores for nine participants on Maze 2 indicated significantly higher risk of a (prospective) motor vehicle crash (Staplin et al., 2013).

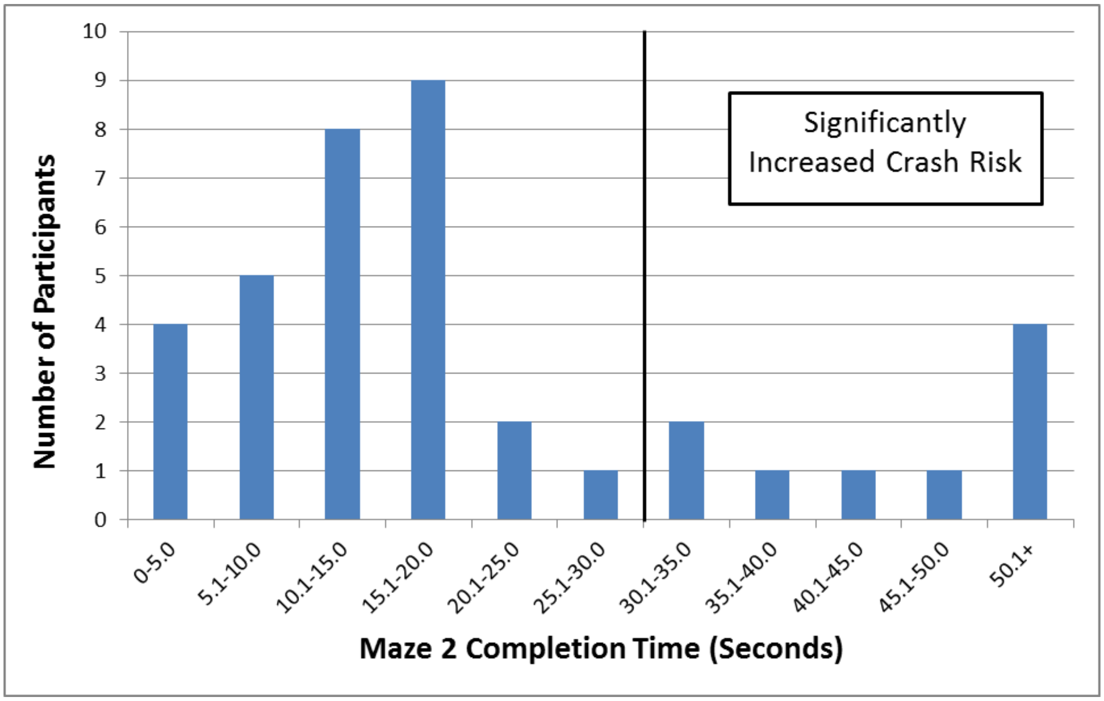


Figure 6. Maze 2 Completion Times.

Figure 7 presents the distribution of FAQ scores. These scores were all self-reported by participants. It may be noted that, in one case where a family member accompanied the participant to the appointment, this person reported a score that diverged greatly from the

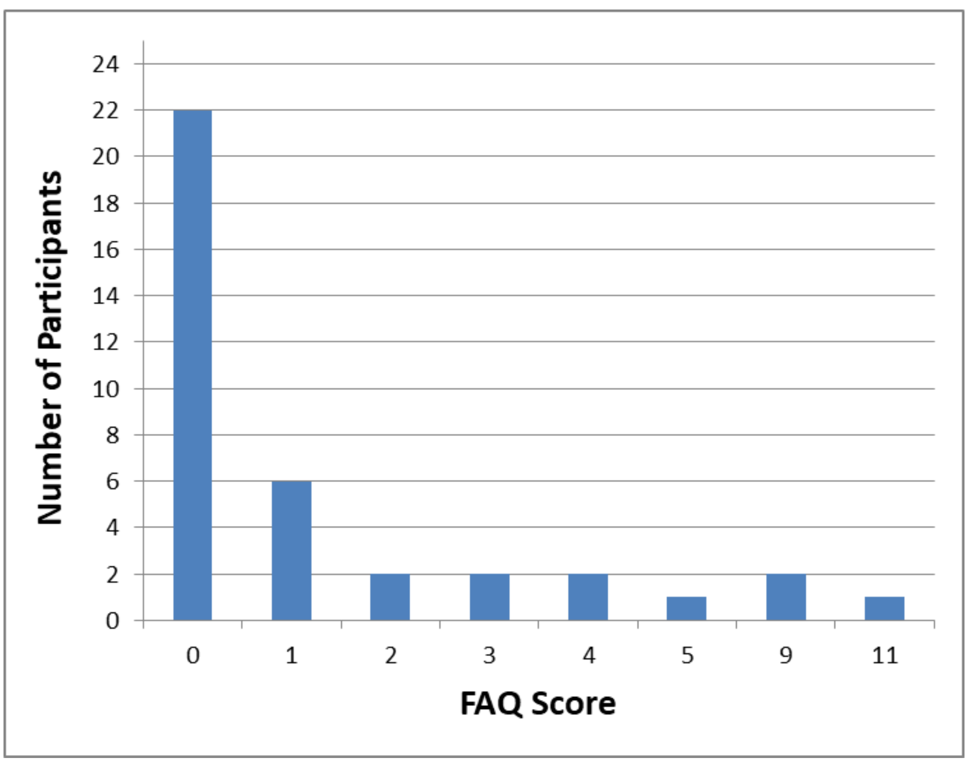


Figure 7. Distribution of FAQ Scores.

participant's self-report. For consistency with the procedures used with the rest of the sample, however, this participant's self-reported score was used in the analyses reported below.

Eighteen participants had no DMV-imposed license restrictions, 19 had corrective lenses restrictions, and six were restricted to driving only under the supervision of a driver rehabilitation specialist or driving instructor. The six participants with a DRS restriction did not participate in the exposure portion of the study. Two physician-referred and two family-member-referred participants received physician- or CDRS-recommended restrictions following their CDRS evaluation or medical examination that may have impacted their driving exposure. One participant with a CDRS-recommended daytime only restriction did not complete the exposure portion of the study. For the other three participants, these physician- and CDRS-recommended restrictions may have affected their exposure study driving patterns.

Table **7** presents the correlation matrix for the clinical measures of cognitive status. There was an inverse relationship between the MoCA and all other variables; higher scores on the MoCA (better performance) were associated with faster (better) times on the Trail-Making and Maze Test and less difficulty with functional tasks.

Table 7. *Cognitive Measures Correlation Matrix*

Measure	MoCA	Trails A Time	Trails B Time	Maze 2 Time	FAQ
MoCA	1				
Trails A Time	-0.415**	1			
Trails B Time	-0.585***	0.526***	1		
Maze 2 Time	-0.512**	0.516***	0.426**	1	
FAQ	-0.280	0.283	0.443**	0.037	1

*p<0.05 **p<0.01 ***p<.001

On-Road Assessment

Table 8 presents summary statistics for each driving skills subset and total score. Total scores for the 38 participants who completed the road test ranged from 0 to 91 (average = 28.2, *SD* = 22.6, median = 25). A t-test indicated no significant difference in overall road test scores by sex. Appendix C shows the score sheet, the total number of participants who made each error, the total error score across participants for each task, as well as totals by subscore.

Table 8. *Road Test Scores by Skill Subgroup*

Statistic	Road Test Points Off			
	Operational Skills	**Tactical Skills**	**Strategic Skills**	**Overall**
Range	0-6	0-73	0-25	0-91
Average	0.74	24.39	3.03	28.16
Standard Deviation	1.80	19.0	5.76	22.58
Median	0	20	0	25

Overall scores were converted to grades as follows:

- 0-24: A, pass with no restrictions,
- 25-49: B, pass with recommendations
- 50-75: C, marginal with restrictions; marginal with training
- 76-99: D, Fail
- 100+: F, Fail

Based on this metric, 18 participants (47.4% of the sample) received "As," 16 (42.1%) received "Bs," 3 (7.9%) received "Cs," and one failed with a score of D. Figure 8 presents road test performance by grade.

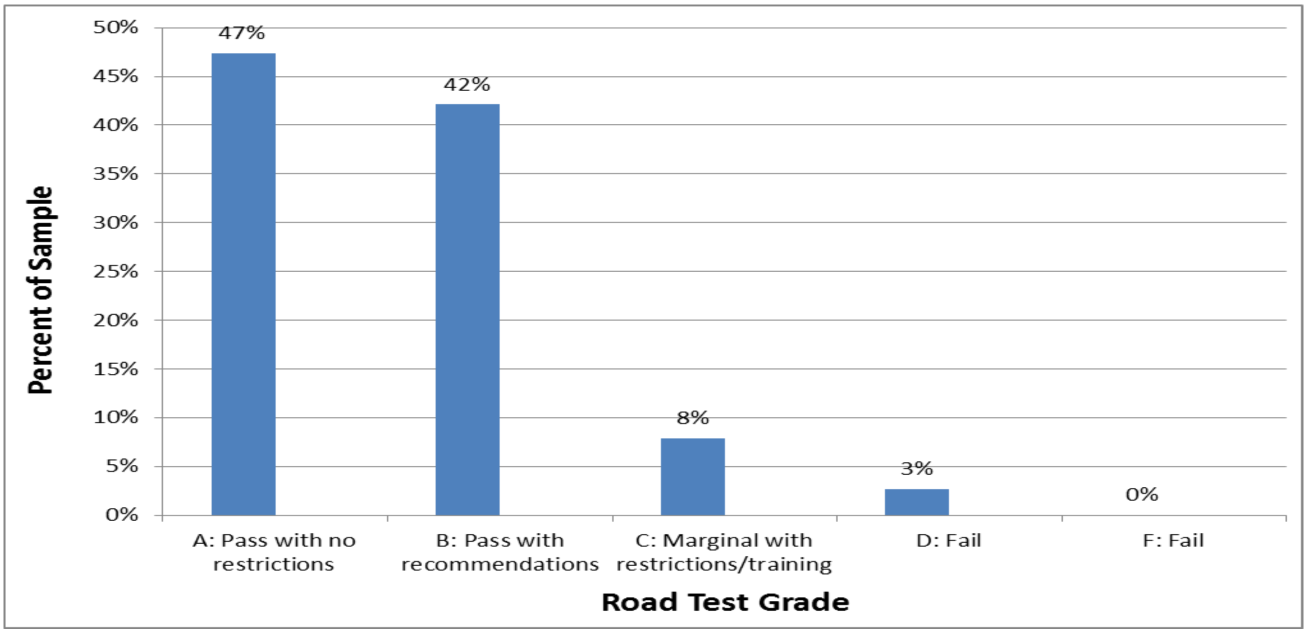


Figure 8. Road Test Performance by Road Test Grade.

Correlations between functional measures and road test performance are shown in Table 9. The MoCA showed the strongest association with road test performance, particularly for the tactical and total road test scores. Lower scores on the MoCA (poorer cognitive status) were associated with larger points-off scores (indicating poorer road test performance). Maze 2 time showed moderate correlations with tactical skills and total road test performance with longer times to complete the maze associated with larger points-off scores (positive correlation). Trails B completion time showed a moderate correlation with strategic skills and total road test performance. The FAQ showed a moderate association with strategic road test scores. All the functional measures showed weak to no association with operational road test performance. However, these are overlearned basic vehicle control skills, which would not necessarily degrade with mild cognitive impairment.

Table 9. *Correlations Between Functional Measures and Road Test Performance*

Road Test Performance Variables	Cognitive Performance Variables				
	MoCA	Trails A Time	Trails B Time	Maze 2 Time	FAQ
Operational Points Off	-0.25	-0.04	0.00	0.11	0.15
Strategic Points Off	-0.44**	0.21	0.42**	0.24	0.40*
Tactical Points Off	-0.63***	0.32*	0.26	0.55***	0.22
Total Points Off	-0.66***	0.32*	0.33*	0.53***	0.30

*p<0.05 **p<0.01 ***p<.001

Figure 9 displays the relationships between performance on the cognitive and road test assessments, with three levels of color coding (green, yellow, and red). The color coding for MoCA and FAQ scores indicates level of cognitive impairment; non-cognitively impaired (green), MCI (yellow), and moderate cognitive impairment (red). These same colors connote crash risk (low, medium, and high) for the Maze and Trails scores, respectively. Road test scores are color coded to denote performance: passing with no restrictions (green), passing with recommendations (yellow), and marginal and failing combined (red). This figure shows, at a glance, the degree of correspondence between categories of function, risk, and driving performance, using the indices employed in this study.

MoCA	Trails B Time	Maze 2 Time	FAQ	Road Test Total Points Off	Road Test Score
12	123	16	1	50	C
14	284	34	3	48	B
15	585	16	5	35	B
15	300	52	0	45	B
15	270	62	9	91	D
16	175	46	0	46	B
16	255	76	0	48	B
17	53	15	1	20	A
18	202	15	4	25	B
19	179	70	0	40	B
20	134	8	0	40	B
22	240	12	11	35	B
22	132	16	0	46	B
22	120	19	2	20	A
22	228	34	2	40	B
23	92	10	0	15	A
23	64	10	0	15	A
23	57	11	1	73	C
23	175	12	9	35	B
23	92	15	1	25	B
24	180	19	1	40	B
24	90	24	0	18	A
25	93	15	0	45	B
26	129	17	1	20	A
26	82	42	0	73	C
27	177	12	0	0	A
27	114	27	0	10	A
28	77	5	0	8	A
28	90	15	0	25	B
28	88	16	0	20	A
28	135	25	4	9	A
28	239	40	0	0	A
29	96	6	0	0	A
30	73	4	0	0	A
30	60	5	0	0	A
30	67	5	0	0	A
30	61	6	3	0	A
30	58	12	0	10	A

	Red	Yellow	Green
MoCA	0-17	18-25	26+
Trails B	180+	80-179	<80
Maze 2	38.1+	31.2-38.0	<31.2
FAQ	6+	1-5	0
Road Test	C-D	B	A

Road Test Scoring Metric

Grade	Points Off	Result
A	0-24	Pass with no restrictions
B	25-49	Pass with recommendations
C	50-75	Marginal with restrictions; Marginal with training
D	76-99	Fail
F	100+	Fail

Figure 9. Relationships Between Cognitive Tests and Road Test Performance, by Participant MoCA Scores.

Driving Exposure

Thirty-one of the 38 participants completed the driving exposure portion of the study from March 2016 to April 2017. However, driving exposure analyses were limited to 29 participants because of insufficient data. In one case, the video camera fell to the floor of the participant's vehicle on the first day of data collection, and because the research team was not aware of this malfunction until the study technician removed the instrumentation from the vehicle at the end of the month, there was no video data for any of the participant's trips. In the other case, the participant made only two trips.

The study team instrumented participants' vehicles as soon as possible following the CDRS evaluation with the goal of obtaining 30 days of driving exposure data. Accommodating participants' schedules and inclement weather resulted in capturing slightly greater than or less than a month for several participants (e.g., participants who completed the in-clinic portion in late fall/early winter and then vacationed or wintered out of State, or when winter weather conditions precluded the technician's travel for equipment removal). Vehicle instrumentation for the 29 participants ranged from 12 to 42 days and averaged 26 days (S*D*=5.5). Excluding the lowest and highest values (12 and 42 days), vehicle instrumentation still averaged 26 days (*SD*=3.9).

For data reduction, the study team defined a trip as beginning at the time a participant first set the vehicle in motion after starting the engine and as ending when the participant reached a destination *and* parked the vehicle (as opposed to vehicle "engine on" time to vehicle "engine off' time). Data coders verified trip beginnings and endings using the video data. This refinement of earlier reduction protocols was necessitated by the many observed idiosyncrasies among study participants. For example, while many participants entered their vehicles, buckled their seat belts, started the engine, and immediately began driving, a subset of participants started the engine but did not begin driving immediately. This subset idled their vehicles in park while using cell phones or performing other in-vehicle non-driving tasks or while walking back into their homes to retrieve items before actually moving the vehicle. During the winter months of the exposure study, some participants turned the engine on and returned to the house, presumably to warm their vehicles before driving. In each of these examples, the researchers coded trip start time based on when the driver set the vehicle in motion.

The operational definition of a "destination" also was refined in this research. Specifically, the data coder did not code a trip ending when a participant momentarily stopped to deposit items at trash/recycle centers, used drive-through banking or fast-food pick-ups, or when stopped momentarily to permit a passenger to enter or exit the vehicle. These situations were apparent in the video data.

Researchers matched video data to the GPS data to obtain speed and distance information about each trip. This was a critical step in data reduction during which researchers applied adjustments to compensate for several technical difficulties encountered during data collection. These difficulties included:

- The camera clock ran too fast, and clock errors accumulated throughout the trip sample for each participant. If the clock was set correctly prior to installation, it was typical for the clock to be too fast by about 3 minutes by the end of an average-length drive.

- The GPS data loggers could take several minutes to obtain the first location fix depending on conditions. As such, there is a variable amount of missing data at the beginning of every GPS file.
- The GPS data logger's internal accelerometer motion sensor sometimes spontaneously activated. Because of this, multiple GPS files were created for some videos.[3]
- The GPS data logger could run on a lower voltage than the camera, and the camera took slightly longer to shut down than the GPS data logger. These characteristics of the in-vehicle instrumentation could result in more GPS files than video files for a given drive.

To compensate for the camera clock artifact, the researchers manually calculated a seconds-offset correction value for each participant's camera data; this was usually subtracted from recorded camera times because the camera ran too fast. Researchers looked at the video and GPS data for the first valid trip and found the points of first and last motion separately for video (first frame where background moves) and GPS (first record with non-zero speed). A match within a few seconds across video and GPS was considered good.

Even after the camera offsets were applied, there were still time errors because the cameras *always* ran too fast. One effect of this, particularly for the shortest trips where multiple trips were merged together in one file, was that the GPS log showed moment-to-moment speeds of "0" mph and "0" distance when the corresponding seconds-offset-corrected video clearly showed movement. This indicated that there were still inaccuracies even after the seconds-offset-corrections were applied. Accordingly, GPS records for such merged trips were filtered out of data analysis, and the researchers applied a 0.1-mile default trip length to any trip known to be valid (based on a visual inspection of the video) but which had missing or truncated GPS coordinates in the trip log. For instances where *long* trips were merged in this fashion, the effects were less detrimental because the amount of time error after seconds-offset-correction was a much smaller percentage of the entire trip duration.

After reduction of the exposure data, the researchers determined that the 29 participants made 2,515 trips, drove a total of 528 hours, and logged 12,575 miles. Table 10 summarizes these characteristics across the 29 participants.

Table 10. *Time and Distance Driven During Exposure Phase (n=29 participants)*

Statistic (per Participant)	Range	Average	Standard Deviation
Number of Trips	14 – 207	86.7	50.3
Driving Hours	2.2 – 39.3	18.2	9.5
Distance (miles)	50.4 – 924.0	433.6	239.3

Radial distance from home. Table 11 summarizes the radial distance travelled from home. The radial distance is the straight-line distance ("as the crow flies"), determined through manual review of locations on Google Earth (i.e., not calculated from GPS coordinates) along the path taken from trip origin to destination. Across all 29 participants, the longest radial distance from home ranged from 4 miles to 203 miles and averaged 30 miles. Among all trips taken by the participants, over three-fourths (77%) were to destinations 5 radial miles from home or closer. Approximately one-fifth (21%) were to destinations that were between 6 and 20 radial

[3] This feature of the GPS data loggers was disabled in the firmware to prevent this from occurring in the future.

miles from the participants' homes. A very small percentage (less than 3%) of trips were to destinations greater than a 20-mile radius from home.

Table 11. *Proportion of Trips Made by Radial Distance of Home (n=29 participants)*

Radius from Home (Miles)	Range	Average	Standard Deviation
≤ 1	9% – 69.6%	41.2%	13.0%
>1 and ≤ 5	0% – 86.6%	33.3%	18.7%
>5 and ≤ 20	0% – 69.4%	22.3%	18.1%
>20	0% – 23.2%	3.2%	5.9%

Figure 10 expands on the information shown in Table 10, and presents the proportion of trips made at each radius-of-home category, on a participant-by-participant basis, sorted from lowest to highest MoCA score. At a glance, this figure shows that participants categorized as having MCI (MoCA scores 18-25 on the x-axis) made a larger percentage of trips closer to home (red and green bars), compared to those with moderate cognitive impairment (scores lower than 18) and those without cognitive impairment (scores 26+).

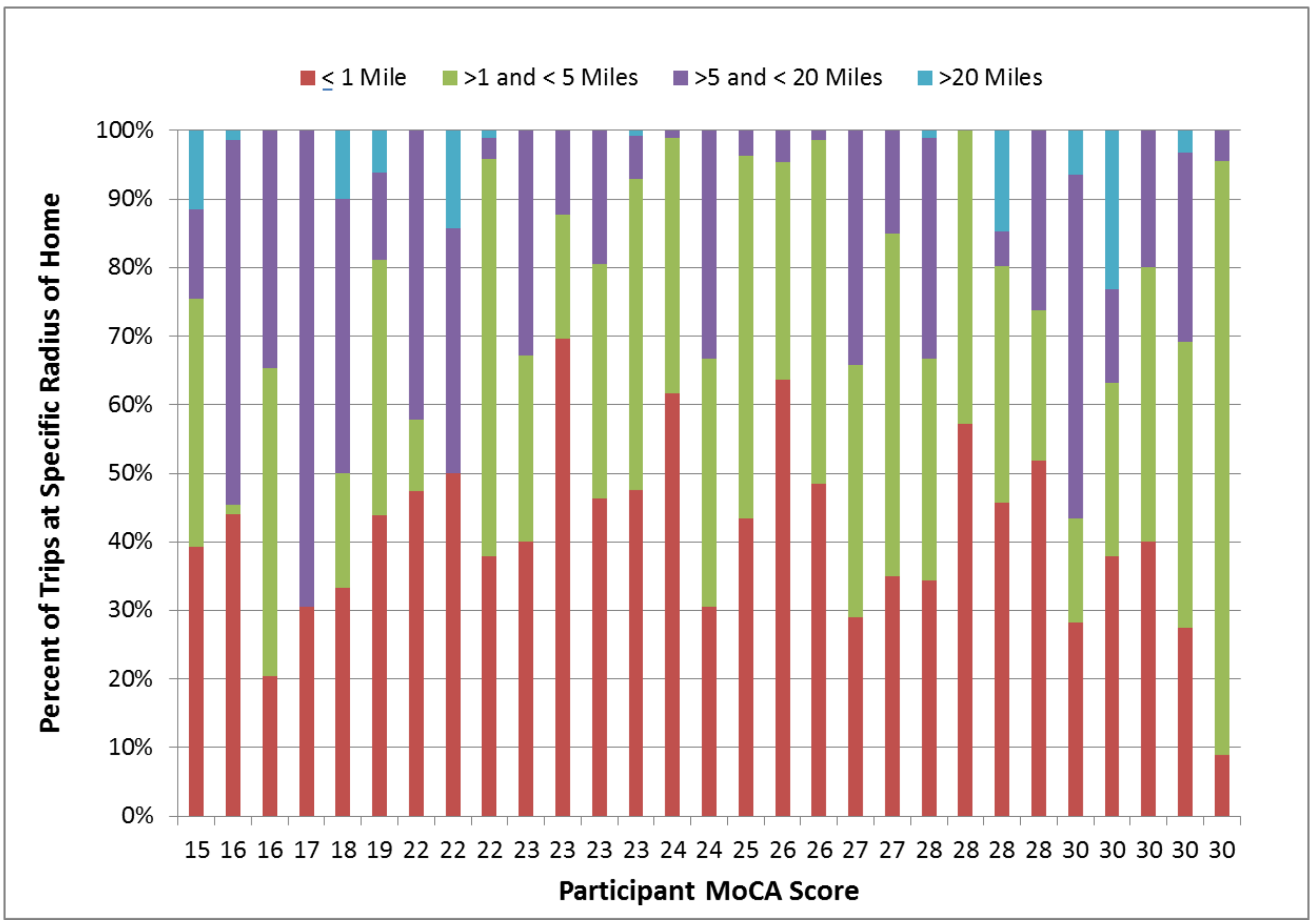


Figure 10. Proportion of Trips by Participants' MoCA Scores and Radius From Home.

Trip distance and duration. Table 12 summarizes trip distance in actual miles driven per trip (as opposed to radial miles from home). The analyst first calculated the minimum, maximum, and average trip distance for each participant. The first three rows in this table present the range, average, and standard deviation across the 29 participants. These data show a large range in the longest trip made by each participant. The All Trips row represents the calculations across 2,515 trips. Table 13 shows trip duration in minutes, calculated as described above, and again, shows a large range in the duration of the longest trip made between participants (i.e., 13 minutes versus over three and one-half hours).

Table 12. *Trip Distance, by Participant (n=29 participants, 2,515 trips)*

Trip Distance (Miles)	Range (Miles)	Average (Miles)	Standard Deviation (Miles)
Minimum trip distance per participant	0.1 – 2.4	0.3	0.5
Maximum trip distance per participant	5.4 – 134.6	30.5	26.4
Average trip distance per participant	1.7 – 15.7	5.6	3.0
All Trips	0.1 – 134.6	5.1	4.4

Table 13. *Trip Duration, by Participant (n=29 participants, 2,515 trips)*

Trip Duration (Minutes)	Range (Minutes)	Average (Minutes)	Standard Deviation (Minutes)
Minimum trip time per participant	0.2 – 5.5	1.8	1.1
Maximum trip time per participant	13.2 – 218.1	60.2	44.0
Average trip time per participant	6.1 – 26.1	13.8	4.7
All trips	0.2 – 218.1	12.6	12.2

Trips on roadways with posted speeds of 60+ mph or greater. Use of Google Earth permitted the identification of trips made on roadways with posted speeds of 60 mph or faster. Sixteen of the 29 participants (55%) made trips on such high-speed roadways. For these 16 participants, the proportion of trips made on roadways with posted speeds of 60+ mph ranged from less than 1% to 50%, and averaged 15%. The proportion of driving time spent on high-speed roads ranged from less than 1% to 21% and averaged 7%. The proportion of miles driven on high-speed roads to total mileage ranged from less than 1% to 45% and averaged 15%.

Maximum speed. Table 14 shows the maximum trip speed summarized across the 29 participants and then across all 2,515 trips. The range shows large variation between the 29 participants in the fastest speed driven on a trip (49 mph versus nearly 85 mph).

Table 14. *Maximum Trip Speed, By Participant (n=29 participants, 2,515 trips)*

Maximum Trip Speed (mph)	Range (mph)	Average (mph)	Standard Deviation (mph)
Highest trip speed per participant	49.1 – 84.5	68.9	8.1
Highest speed all trips	3.7 – 84.5	45.8	13.0

Figure 11 presents the highest speed reached, on a participant-by-participant basis, from lowest to highest MoCA score. While there is no clear-cut pattern, the lowest maximum speeds reached (~ 50 mph) were associated with participants with MCI. However, one participant at the lower end of the MCI scale exceeded 80 mph, similar to speeds exhibited by participants without cognitive impairment.

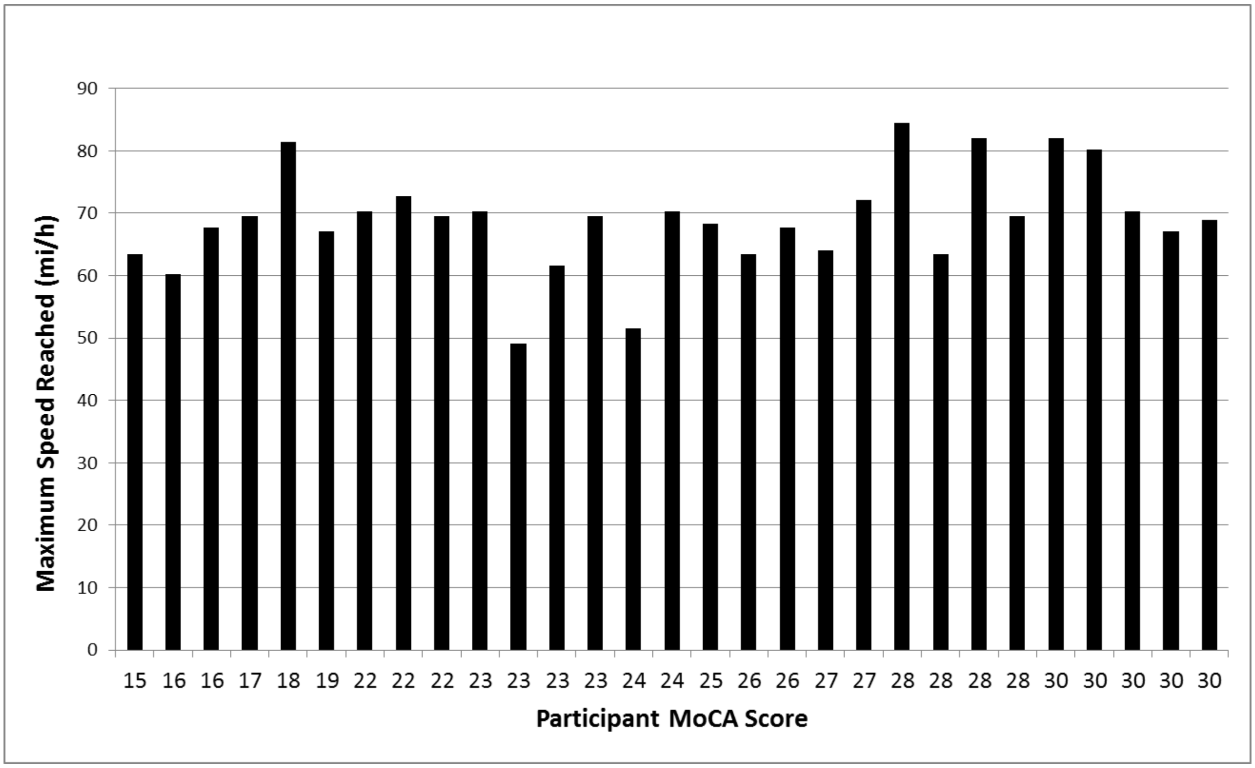


Figure 11. Maximum Speed Reached by Driver.

Trips made during rainfall. The video coder was able to identify when trips were made during rainfall by the presence of raindrops on the windshield and the participant's use of windshield wipers. Twenty-four of the 29 participants (83%) made trips when it was raining at some point during their trip. For these 24 participants, the proportion of trips made during rainy conditions ranged from 0.6% to 17.7% of all trips made and averaged 8%. Overall, for these 24 participants, 7.3% of all trips were made during rainy conditions.

Nighttime trips. The video coder also identified trips made at nighttime, when the driving scene showed darkening skies at dusk through dawn (i.e., low contrast conditions). At times, it was difficult to identify the onset of dusk due to ambient light, but cues such as parking lot lighting and reflections of brake lights from a leading vehicle on the participant's face cued the coder to code the trip as a night trip. Twenty-four of the 29 participants (83%) made trips between dusk and dawn. There was no overlap in the five participants who did not drive during rainy conditions and at night. For the 24 participants who made night trips, the proportion of trips made at night ranged from 1.2% to 29.8% of all trips made and averaged 9.6%. Overall for these 24 participants, 8% of all trips were during low ambient light conditions between dusk and dawn.

Trips during rush-hour periods. The researchers defined rush hour trips as those that began during the morning or evening rush hours (6 to 9 a.m. and 4 p.m. to 7 p.m.). Twenty-eight of the 29 participants started trips during these defined rush-hour periods. Overall, the proportion of trips beginning in these periods was 36.4%, and ranged from 2.4% to 78.3% (average = 35.7%, *SD*=18%). The participant who began 78% of his trips during rush hour drove from home to work and back each day.

Relationship between participants' functional measures and exposure. Table 15 shows correlations between functional measures and driving exposure. There were no strong relationships, but the MoCA showed a moderate positive relationship with both time and distance driven on high-speed roadways ($p<0.05$). Time to complete Trails A had a moderately strong negative correlation with the proportion of trips begun during rush-hour periods ($p<0.05$).

Table 15. *Correlations Between Functional Measures and Driving Exposure Variables*.

Exposure Performance Variables	Cognitive Performance Variables				
	MoCA	Trails A Time	Trails B Time	Maze 2 Time	FAQ
Total Number of Trips	-0.05	-0.09	0.07	0.26	-0.34
Total Driving Hours	-0.08	-0.02	0.22	0.30	-0.26
Total Driving Distance (Miles)	-0.02	0.00	0.26	0.23	-0.24
% of Trips During Rain	-0.24	-0.09	0.06	0.00	0.14
% of Trips at Night	0.17	-0.28	-0.13	-0.14	-0.20
% of Trips begun at Rush Hour	0.12	-0.46*	-0.36	-0.34	0.17
% of Trips Made on 60+ mph Roads	0.27	0.07	0.01	-0.16	-0.01
% of Time Driving on 60+ mph Roads	0.42*	-0.25	-0.11	-0.21	-0.22
% of Miles Driven on 60+ mph Roads	0.45*	-0.26	-0.12	-0.21	-0.22

*p<0.05

Driving Performance Study Results: Statistical Analyses

Regression Analyses

The study team performed multiple regressions to explain the relationships between the cognitive function measures obtained by the CDRS in the clinic and the on-road driving assessment scores as well as between the cognitive function measures and driving exposure.

Relationship between cognitive function and driving performance. The regression model contained five predictors of driving performance:

- MoCA Score;
- Trails A Time;
- Trails B Time;
- Maze 2 Time; and
- FAQ score.

The study team ran separate regression analyses using each of the following road test outcome variables to measure driving performance:

- Operational Skills (e.g., adjust mirror, control brake/accelerator/steering) Points Off;
- Strategic Skills (e.g., route planning, anticipates, separates hazards) Points Off;
- Tactical Skills (e.g., scan environment, lane maintenance, safe gap selection) Points Off; and
- Total Road Test (e.g., operational + strategic + tactical skills points off) Points Off.

Only two of the four statistical models produced statistically significant results: Tactical Points Off ($F=7.18$, $df=5$, $p<0.001$) and Total Points Off ($F=7.82$, $df=5$, $p<0.001$). The five cognitive variables produced a strong correlational coefficient -- .73 and .74 for Tactical and Total Points Off, respectively -- accounting for 46% and 48% of the variance in these two dependent measures, as shown in Figure 12 and Figure 13.

SUMMARY OUTPUT: Tactical Points Off						
Regression Statistics						
Multiple R	0.73					
R Square	0.53					
Adjusted R Square	0.46					
Standard Error	14.03					
Observations	38					
ANOVA						
	df	*SS*	*MS*	*F*	*Significance F*	
Regression	5	7064.41	1412.88	7.18	0.00***	
Residual	32	6294.67	196.71			
Total	37	13359.08				
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	68.52	17.22	3.98	0.00***	33.45	103.59
MoCa	-2.01	0.58	-3.48	0.00**	-3.18	-0.83
Trails A Time	0.00	0.09	0.02	0.99	-0.19	0.19
Trails B Time	-0.06	0.03	-1.86	0.07	-0.12	0.01
Maze 2 Time	0.41	0.16	2.48	0.02*	0.07	0.74
FAQ	1.29	0.96	1.35	0.19	-0.67	3.25
*p<0.05 **p<0.01 ***p<.001						

Figure 12. Regression Output for Cognitive Factors and Road Test Tactical Points Off.

SUMMARY OUTPUT: DV = Total Points Off						
Regression Statistics						
Multiple R	0.74					
R Square	0.55					
Adjusted R Square	0.48					
Standard Error	16.29					
Observations	38					
ANOVA						
	df	*SS*	*MS*	*F*	*Significance F*	
Regression	5	10375.97	2075.19	7.82	0.00***	
Residual	32	8493.08	265.41			
Total	37	18869.05				
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	81.39	20.00	4.07	0.00***	40.65	122.13
MoCa	-2.44	0.67	-3.64	0.00**	-3.80	-1.07
Trails A Time	-0.03	0.11	-0.25	0.80	-0.25	0.19
Trails B Time	-0.06	0.04	-1.49	0.14	-0.13	0.02
Maze 2 Time	0.44	0.19	2.31	0.03*	0.05	0.83
FAQ	2.01	1.12	1.80	0.08	-0.26	4.29
*p<0.05 **p<0.01 ***p<.001						

Figure 13. Regression Output for Cognitive Factors and Road Test Total Points Off.

The estimated linear regression equation for Road Test Tactical Points Off is:

Y = 68.5 – 2.01* (MoCA Score) - 0.002 (Trails A Time) – 0.06 (Trails B Time) + 0.41* (Maze 2 Time) + 1.29 (FAQ Score).

The estimated linear regression equation for Road Test Total Off is:

Y = 81.39 – 2.44* (MoCA Score) - 0.03 (Trails A Time) – 0.06 (Trails B Time) + 0.44* (Maze 2 Time) + 2.01 (FAQ Score).

Where * indicates the coefficient is statistically significant at the 0.05 level.

Appendix D contains the regression results from the statistical models associated with the non-significant results for Operational and Strategic Skills Points Off.

Relationship between cognitive function and driving exposure. The study team entered the same five measures of cognitive function into the regression analyses as predictor variables of driving exposure.

The study team ran separate regression analyses using each of the following exposure outcome variables:

- Total Number of Trips;
- Total Miles Driven;
- Total Hours Driven;
- Percent of Trips Made in Rain;
- Percent of Trips Made at Night;
- Percent of Trips Begun During Rush Hour;
- Percent of Trips on 60+ mph Roadways;
- Percent of Driving Time on 60+ mph Roadways; and
- Percent of Miles Driven on 60+ mph Roadways.

None of the results from the nine models, which are presented in Appendix D, were statistically significant.

Exploring MoCA Relationships to Driving Performance and Exposure

Given the weakness of the combined indicators of cognitive function in predicting on-road assessment scores and especially, exposure outcomes, researchers proceeded with additional analyses focusing on participants' MoCA scores as the independent variable. Based on the definitions provided by the MoCA test developers, participants with MoCA scores of 26 or higher were categorized as non-cognitively impaired (NCI), those with scores of 18 to 25 as having MCI, and those with scores below 18 as moderately cognitively impaired. Table 16 presents performance on the road test (total points off) by MoCA category. Compared to NCI participants, MCI participants scored an average of 3 times as many points off and those categorized as moderately cognitively impaired an average of 4 times as many points off. A t-test indicated a statistically significant difference in road test total points off between NCI group participants and those categorized as cognitively impaired (mild and moderate groups combined, $t=4.47$, $df=36$, $p<0.0001$). The 22-point difference in total points off for those categorized as NCI versus MCI was also statistically significant ($t=3.57$, $df=28$, $p<0.01$).

Table 16. *Road Test Performance, by MoCA Category*

MoCA Category	Number of Participants	Road Test Total Points Off		
		Range	Average	Standard Deviation
Non-Cognitively Impaired	15	0 – 73	11.7	19.0
Mild Cognitive Impairment	15	15 – 73	34.1	15.3
Moderate Cognitive Impairment	8	20 – 91	47.9	20.1
ALL	**38**	**0 – 91**	**28.2**	**22.6**

Six participants made operational skills errors (1 categorized as NCI, 2 categorized as having MCI, and 3 categorized as moderately cognitively impaired). Of the 28 operational skills error points, 15% were contributed by participants in the NCI group, 32% by those in the MCI group, and 50% by those in the moderately cognitively impaired group. Eleven participants made strategic errors (7 with MCI and 4 with moderate cognitive impairment). Of the 115 strategic skills error points, 56.5% were contributed by MCI group participants and 43.5% by those in the moderately cognitively impaired group. Thirty-one participants made tactical skills errors (8 of the 15 from the NCI group and all 23 of the cognitively impaired groups). Of the 927 tactical skills error points, 18.3% were contributed by the NCI group, 47.2% by the MCI group, and 34.4% by the moderately cognitively impaired group. Appendix C shows the road test scoring form, with the number of participants who made errors on each skill and the total points scored off per skill, across the 38 participants who completed the on-road assessment.

Table 17 summarizes the number of days that participants' vehicles were instrumented during the driving exposure phase by MoCA cognitive category. The table provides evidence that vehicle instrumentation days were similar across cognitive status and that driving exposure data were not limited by the length of vehicle instrumentation.

Table 17. *Vehicle Instrumentation Duration by MoCA Category*

MoCA Category	Number of Participants	Vehicle Instrumentation Duration (Days)		
		Range	Average	Standard Deviation
Non-Cognitively Impaired	13	18 - 42	27.8	6.1
Mild Cognitive Impairment	12	19 - 29	24.6	3.2
Moderate Cognitive Impairment	4	12 - 30	23.4	8.3
ALL	**29**	**12 - 42**	**25.8**	**5.5**

Trip counts by MoCA category. Table 18 shows that participants from the MCI group appear to have made the largest proportion of trips (48%), followed by the NCI group (39%), and then the moderate cognitive impairment group (13%). On a per-participant-basis, the MCI group appeared to have the highest trip counts per participant, and the non-cognitively impaired group members appeared to make the fewest number of trips during vehicle instrumentation. However, t-tests indicated that none of the group differences were statistically significantly.

Table 18. *Trip Count Across Sample and by MoCA Category*

MoCA Category	Number of Participants	Trip Count				
		Total	Range	Average*	SD	Median
Non-Cognitively Impaired	13	987	14 - 207	75.9	50.1	68
Mild Cognitive Impairment	12	1194	14 - 168	99.5	52.0	102.5
Moderate Cognitive Impairment	4	334	38- 155	83.5	50.3	70.5
ALL	**29**	**2515**	**14 - 207**	**86.7**	**50.3**	**85**

* No differences were significant.

Driving time and distance by MoCA category. Table 19 appears to show that participants from the moderate cognitive impairment group drove more hours than those in the NCI or MCI groups, with the two later groups driving similar numbers of hours. Similarly, Table 20 appears to show that the moderate cognitive impairment group averaged the most miles per person with little difference in average mileage between the NCI and MCI group participants. However, t-tests indicated that none of the group differences were statistically significantly.

Table 19. *Number of Driving Hours Across Sample and by MoCA Category*

MoCA Category	Number of Participants	Total Driving Hours				
		Total	Range	Average*	SD	Median
Non-Cognitively Impaired	13	218.5	2.2 – 30.6	16.8	9.3	20.3
Mild Cognitive Impairment	12	224.7	5.9 – 39.2	18.7	9.5	19.3
Moderate Cognitive Impairment	4	84.8	11.7 – 39.3	21.2	12.3	16.9
ALL	**29**	**527.9**	**2.2 – 39.3**	**18.2**	**9.5**	**18.8**

* No comparisons were significantly different.

Table 20. *Distance Driven Across Sample and by MoCA Category*

MoCA Category	Number of Participants	Total Distance Driven (Miles)				
		Total	Range	Average*	SD	Median
Non-Cognitively Impaired	13	5538.7	50.4 – 761.1	426.0	273.4	530.0
Mild Cognitive Impairment	12	4992.8	140.8 – 924.0	416.1	207.3	406.1
Moderate Cognitive Impairment	4	2043.9	272.6 – 881.2	511.0	261.7	445.1
ALL	**29**	**12575.5**	**50.4 – 924.0**	**433.6**	**239.3**	**418.8**

* No comparisons were significantly different.

Trip time and distance by MoCA category. Figure 14 presents the proportion of trips made by participants in each cognitive status group by trip duration in 10-minute bins. While the plurality of trips made by participants in all three groups were 10 minutes or less, participants in the MCI group made a larger proportion of these short trips compared to those in the NCI group, and participants in the moderate cognitive impairment group made fewer. Participants characterized as having moderate cognitive impairment made a larger proportion of trips lasting 30 minutes or more compared to those in both the NCI and MCI groups.

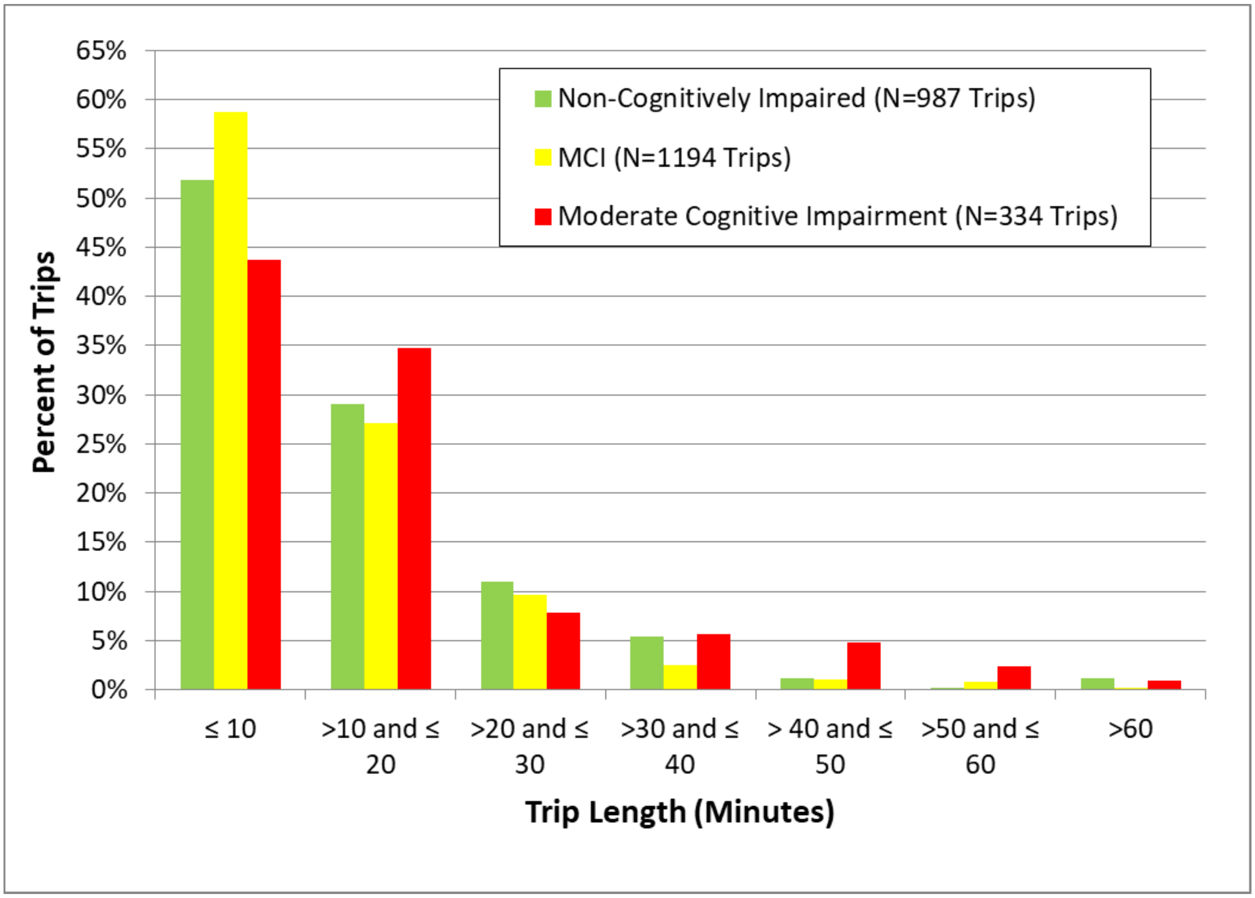


Figure 14. Proportion of Trips by Trip Duration (Minutes) and Cognitive Status Group.

Table 21 summarizes trip duration across the participants in each cognitive status group and shows that average trip length did not differ between the NCI and MCI groups. However, average trip duration for moderate cognitive impairment group participants was approximately 2 minutes longer than MCI and NCI group participants. None of the group differences were statistically significant, and the average trip time for those without cognitive impairment (13.7 minutes) compared to those categorized as cognitively impaired (13.8 minutes for MCI and moderate groups combined) was almost the same.

Table 21. *Trip Duration Across Sample and by MoCA Category*

MoCA Category	Number of Participants	Trip Duration (Minutes)			
		Range	Average per Trip*	SD	Median
Non-Cognitively Impaired	13	8.9 – 26.1	13.7	4.7	12.5
Mild Cognitive Impairment	12	6.1 – 25.4	13.2	5.4	12.0
Moderate Cognitive Impairment	4	12.4 – 18.6	15.7	2.6	16.0
ALL	**29**	**6.1 – 26.1**	**13.8**	**4.7**	**12.5**

* No differences were significant.

Figure 15 presents the proportion of trips made by participants in each cognitive status group by trip distance. While the majority of trips made by participants in all three groups were 5 miles or less, participants characterized as having MCI appear to have made a larger proportion of these short distance trips compared to those without cognitive impairment, and participants characterized as having moderate cognitive impairment appear to have made a smaller proportion. Participants characterized as having moderate cognitive impairment appear to have made a larger proportion of trips from 5 to 10 miles and over 15 miles compared to those in the NCI and MCI groups.

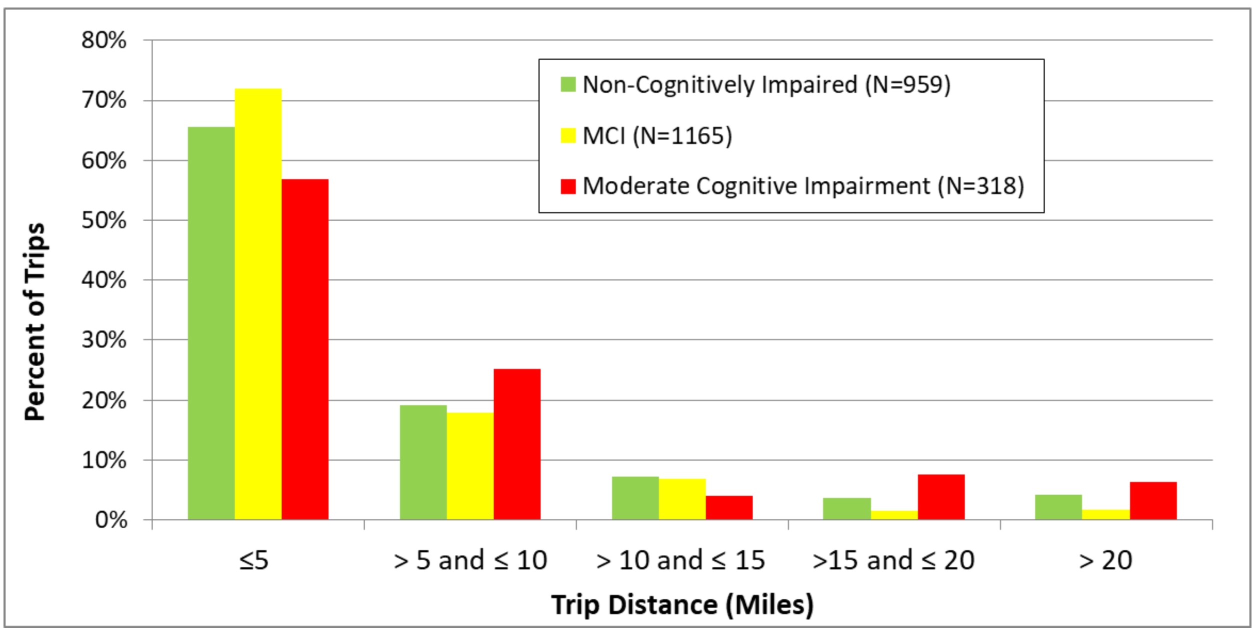


Figure 15. Proportion of Trips by Trip Distance (Miles) and Cognitive Status Group.

Table 22 presents average distance across all trips for participants in each MoCA category. Participants in the NCI and MCI group had nearly identical average trip length. None of the group differences were statistically significant, and the average trip distance for participants categorized as NCI (5.8 miles) compared to participants categorized as cognitively impaired (6 miles for mild and moderate groups combined) was the same.

Table 22. *Trip Distance Across Sample and by MoCA Category*

MoCA Category	Number of Participants	Trip Distance (Miles)			
		Range	Average per Trip*	SD	Median
Non-Cognitively Impaired	13	2.6 – 13.5	5.8	3.1	4.6
Mild Cognitive Impairment	12	1.7 – 15.7	5.7	3.9	4.3
Moderate Cognitive Impairment	4	5.4 – 8.0	6.8	1.2	6.8
ALL	**29**	**1.7 – 15.7**	**5.9**	**3.2**	**5.3**

* No differences were significant.

Trip distance by radius of home and MoCA category. Based upon the distance categories in Table 23, the plurality of trips made by NCI and MCI participants were one mile or less from home. However, the plurality of trips made by participants categorized with moderate cognitive impairment were between 5 and 20 radial miles from home.

Table 23. *Proportion of Trips by MoCA Category and Radial Distance From Home*

MoCA Category	Number of Participants	Percent of Trips Made from Radius of Home:			
		≤ 1 Mile	>1 Mile and ≤ 5 Miles	>5 Mile and ≤ 20 Miles	> 20 Miles
Non-Cognitively Impaired	13	38.0%	36.6%	21.1%	4.2%
Mild Cognitive Impairment	12	46.4%	36.8%	15.4%	1.5%
Moderate Cognitive Impairment	4	30.7%	27.9%	38.9%	2.5%
ALL	**29**	**43.0%**	**34.9%**	**20.4%**	**1.7%**

Figure 16 shows that participants in the MCI group appear to have made larger percentages of trips within 5 miles of home (83%) compared to non-cognitively impaired participants (75%), while participants with moderate cognitive impairment appear to have made a smaller percentage (59%).

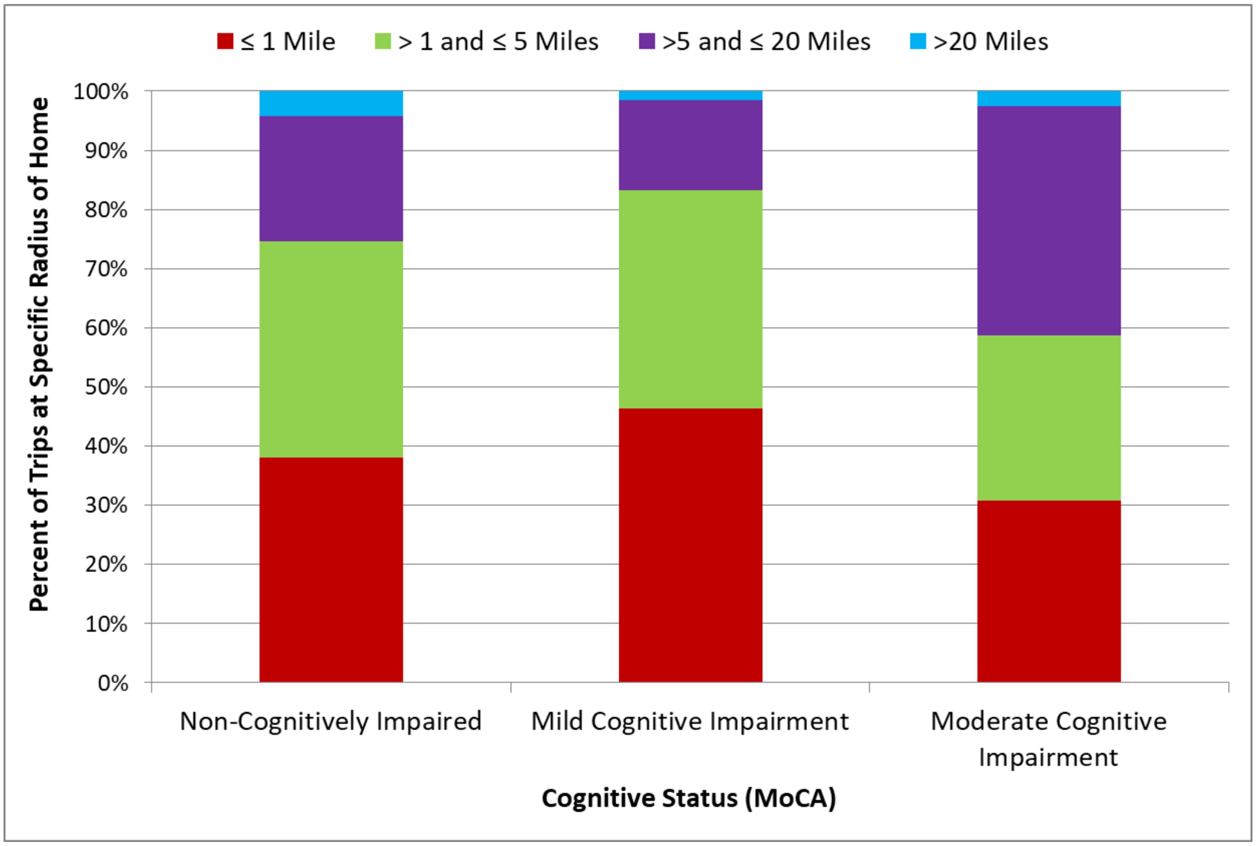


Figure 16. Proportion of Trips by MoCA Category and Radius From Home.

Trips on roadways with posted speeds of 60 mph or greater by MoCA category. As shown in Table 24, a larger proportion of participants without cognitive impairment appear to have made trips on high-speed roadways compared to participants in both cognitive impairment groups, which did not differ from each other. Also, participants categorized as non-cognitively impaired appear to have made larger percentages of their trips on high-speed roadways, and spent more driving time and mileage on these roadways, then those categorized in either cognitive impairment group. Participants categorized as moderately cognitively impaired accounted for the smallest proportions of trips, driving time, and mileage on high-speed roadways.

Table 24. *Driving Exposure on Roadways With Posted Speeds of 60+ mph, by MoCA Category.*

MoCA Category	Number of Participants	Proportions on Roadways With Posted Speed Limits of 60+ mph			
		% of Sample	% of Trips	% of Time	% of Mileage
Non-Cognitively Impaired	13	61.5%	10.0%	8.9%	21.8%
Mild Cognitive Impairment	12	50%	3.7%	1.4%	3.3%
Moderate Cognitive Impairment	4	50%	1.2%	0.3%	0.6%
ALL	**29**	**55%**	**5.8%**	**4.3%**	**11.0%**

Percentage of trips by maximum trip speed for each MoCA category. As shown in Figure 17, the plurality of trips taken by participants categorized as non-cognitively impaired as well as those with MCI had maximum speeds from 35 to 44 mph; however, the plurality of trips taken by participants categorized with moderate cognitive impairment reached maximum speeds from 45 to 55 mph. The proportion of trips taken with maximum speeds less than or equal to 35 mph shows larger proportions by participants categorized with moderate cognitive impairment (24%), followed by the MCI group (17%) and then NCI group (16%). The proportion of trips taken with maximum speeds greater than 55 mph shows larger proportions by NCI group participants (30%), followed by the moderate cognitive impairment group participants (26%) and then the MCI group (21%). Of the 36 trips with maximum speeds greater than 75 mph, 35 were taken by NCI group participants and 1 by a participant with MCI. There was no significant difference in maximum speed reached between NCI group participants and those categorized as cognitively impaired (mild and moderate groups combined).

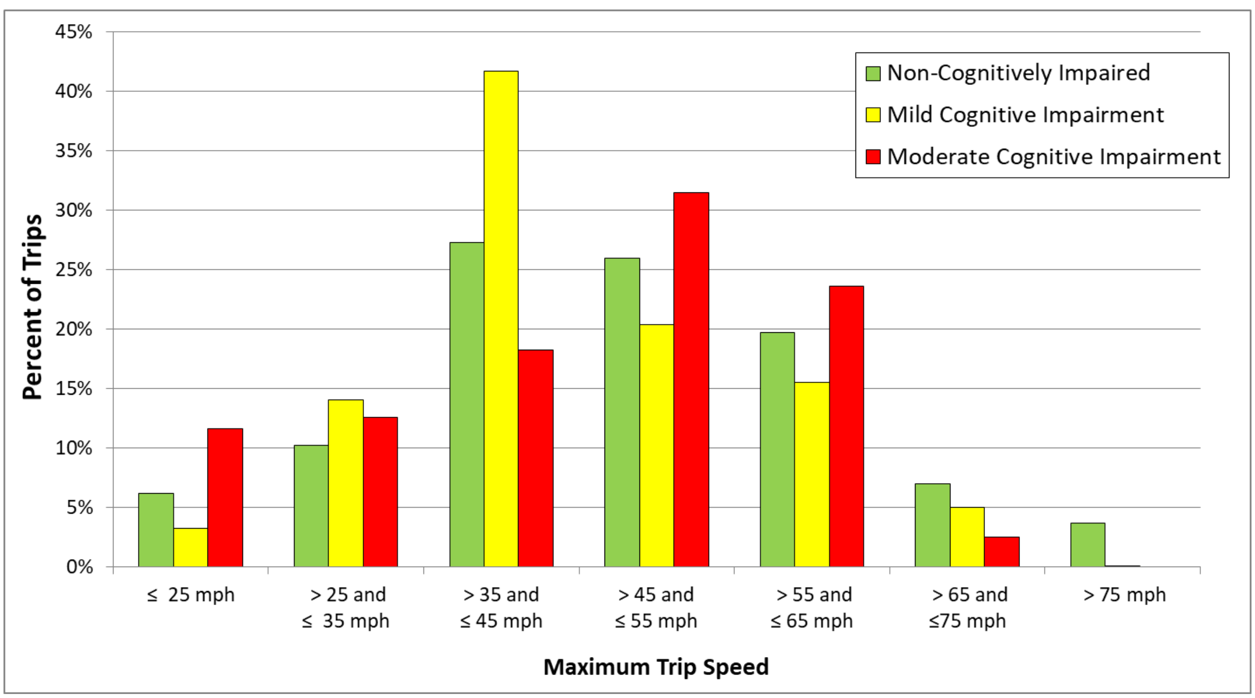


Figure 17. Percent of Trips by Maximum Speed and MoCA Category.

Trips made in the rain and at night by MoCA category. As shown in Table 25, more than three-quarters of participants in all cognitive status groups drove at nighttime and in the rain. However, less than 10% of all trips in each cognitive status group were made at night and in the rain.

Table 25. *Trips Made in the Rain and at Night, by MoCA Category*

MoCA Category	Driving in the Rain		Driving at Night	
	% of Group	**% of Trips**	**% of Group**	**% of Trips**
Non-Cognitively Impaired	76.9%	5.8%	76.9%	9.1%
Mild Cognitive Impairment	83.3%	7.9%	83.3%	8.1%
Moderate Cognitive Impairment	100%	9.7%	100%	4.7%
All	**82.8%**	**7.3%**	**82.8%**	**8.1%**

Rush hour trips by MoCA category. All but one participant, who was categorized as non-cognitively impaired, made trips that began in rush hour. While participants in the moderate cognitive impairment group appear to make the smallest proportion of trips in rush-hour periods (25%), there was little difference in the proportion of trips during rush-hour periods for NCI and MCI group participants (40% and 37%, respectively).

Discussion and Conclusions

This cross-sectional investigation of the relationship between older drivers' cognitive status and their performance on CDRS-administered comprehensive driving assessments yielded results that were consistent with contemporary theories of cognitive aging and provided insights that should be of practical value to clinicians. Differences in driving exposure that emerged from a naturalistic data collection component in this study were more ambiguous.

A review of the relatively few prior studies that have directly addressed MCI and driving informed the design for this research. This review indicated broad agreement that people with mild cognitive impairment can be differentiated from those without cognitive impairment and those with dementia on tests of functional activity. There is evidence that drivers with MCI are more aware of their cognitive deficits than those with dementia and are more likely to self-regulate accordingly, driving less than older adults without cognitive impairment and avoiding situations they find more challenging.

This understanding initially suggested a between-groups research design, where the performance and exposure of non-cognitively impaired older drivers would be contrasted with that of age-matched drivers with MCI. However, the 'tests of functional activity' used by researchers in this area commonly include a combination of clinical measures and reports by drivers (or knowledgeable others) about their ability to independently perform various IADLs. Given the subjective nature of these reports, the resulting classifications of cognitive status are characterized by boundaries that are far from distinct. Anecdotally, one current participant self-reported a Functional Activities Questionnaire (FAQ) score of '3' while his daughter's responses to same questions yielded a score of '22' *(higher scores indicate greater impairment)*.

This perspective suggested an approach of classifying participants' cognitive status along a spectrum, then applying a regression model that incorporated multiple measures found to significantly predict older driver crash risk in previous research, to predict differences in road test scores and exposure. The measures selected were the Trail-making and Maze tests, which target visual search, divided attention, and visuospatial ability; it is worth mentioning that the planning aspects of both Trails B and Maze also are associated with executive function by some researchers. No measure of processing speed (e.g., Useful Field of View) was included, as the CDRSs supporting this study relied on paper-and-pencil measures only.

In addition to the FAQ and the specific measures of cognitive status noted above, the regression model included the score on a test battery -- the MoCA -- that addressed each of the previously highlighted domains, but augmented these measures with items that screen for deficits in short-term memory (delayed recall), language/ verbal fluency, and concentration.

None of the models used to predict differences in exposure were significant. The only significant outcomes of the regression analyses showed that MoCA scores accounted for the greatest variance in total road test scores and in scores for tactical driving tasks, by a wide margin. In other words, the more general index of cognitive status appeared to have greater utility in identifying participants whose road test performance could place them at risk, compared to measures focused on specific domains of cognition found in previous research to be the best predictors of crash involvement.

At first, this outcome may seem counterintuitive. But in fact, it is a useful reminder of the inherent differences between a measure of traffic safety that is explicit and unambiguous, i.e., *crashes*, and surrogate measures that support inferences about the *likelihood* of a crash. A driver's crash experience over a period long enough to capture all meaningful variation in risk exposure cannot be equated to a snapshot of his/her performance obtained under one particular set of operating conditions at a single point in time, in an unfamiliar vehicle, with all of the attendant pressures of a formal assessment. A prior NHTSA study[4] found that CDRS ratings and errors coded from naturalistic driving videos were only modestly correlated, raising questions about the extent to which drivers' performance during an on-road evaluation represents their behavior during everyday driving. Also worth noting is that drivers behave in an on-road assessment in response to verbal instructions from the CDRS; the MoCA's inclusion of a verbal fluency component may help explain this instrument's superior strength of association with driving performance outcomes.

The preeminence of MoCA scores in accounting for variance in road test performance suggested that, in fact, a between-groups analysis based on its classification of participants as *not cognitively impaired (NCI)*, *MCI*, or *moderately cognitively impaired* could be fruitful. Relying on guidance provided by the MoCA test developers, participants with scores of 26 or higher were categorized as NCI, those with scores of 18 to 25 as having mild cognitive impairment, and those with scores below 18 as moderately cognitively impaired. Those participants categorized with MCI and as moderately cognitively impaired scored an average of 3 and 4 times as many points off the road test, respectively, as those without cognitive impairment. Furthermore, differences in road test performance between NCI and MCI participants, and between NCI and all impaired participants -- based on MoCA scores -- were statistically reliable.

Analyses of exposure data using MoCA classifications did not yield statistically significant differences, but several interesting patterns emerged. First, it was expected that participants classified as impaired would restrict their exposure to more challenging driving conditions. This was confirmed by data showing that a larger *proportion* of participants in the NCI group made trips on high-speed roadways compared to participants in both cognitive impairment groups (which did not differ from each other). Also, the NCI participants made larger *percentages* of their trips on high-speed roadways compared to those in either cognitive impairment group, and spent more driving *time and mileage* on these roadways. Participants categorized as moderately cognitively impaired accounted for the smallest proportions of trips, driving time, and mileage on high-speed roadways.

This pattern did not always hold for more global measures of exposure, however. When examining average trip duration (driving time) and average trip distance (miles) per participant, the results for those classified as MCI were modestly lower than for NCI participants but the *highest* values were associated with those classified as moderately cognitively impaired. Getting lost and taking circuitous routes explained this increased exposure. Researchers observed one instance of getting lost for a participant categorized as having moderate cognitive impairment. This person returned to the trip origin (not the participant's home) after driving 19 minutes over a distance of 6 miles. It was apparent from the video that the participant received directions, and

---

[4] NHTSA Contract DTNH22-05-D-05043, Task Order 11, Older Drivers, Self-Screening Tools, and Evaluating On-Road Performance.

then re-started the trip from that origin and eventually returned home (a distance of 28 miles and duration of 52 minutes). Google Earth showed circuitous travel paths for multiple trips by participants whose MoCA scores indicated cognitive impairment.

Multiple study limitations must be acknowledged. While the obtained sample size was adequate for the present analyses, and study recruitment methods produced a mix of rural and urban participants, a larger sample was targeted in our research plan. As described earlier, data collection involved the work of two different CDRSs to perform the on-road assessments, and although they used the same evaluation protocol the inherent differences in test routes between sites (as well as participant-to-participant differences in traffic conditions within sites) remains a potential source of variance in outcome measures. It is also important to note that the same CDRS performed the clinical assessments and the on-road assessments in each location, i.e., in scoring driving performance these professionals were not blind to the cognitive status of study participants. And as noted earlier, the reliability of the self-report data describing participants' dependence on others to carry out instrumental activities of daily living was called into question.

Notwithstanding these qualifications, researchers can offer tentative conclusions that should be of value to practitioners, particularly occupational therapy generalists. As these clinicians evaluate their older clients, they must be concerned with a wide range of activities of daily living, plus IADLs. To have available a rapid screening tool for cognitive impairment that can classify people into groups that significantly differ in terms of a key IADL, driving performance -- and specifically, tactical driving errors -- enables a referral with confidence for those who are classified with mild (or greater) cognitive impairment to a driver rehabilitation specialist for a comprehensive driving assessment. And regardless of the outcome, such referrals can only serve to maintain community mobility for older persons, either by working with these clients to ameliorate or accommodate recognized deficits, or by assisting their transition to alternative transportation options where they live.

Finally, the results in this study clearly point to a need for longitudinal research with a larger sample to reveal reliable patterns or trends in driving performance and exposure that are associated with cognitive aging. This applies as well to attempts to gauge the actual safety impact of the observed performance and exposure differences, in this study and others.

References

Ahmed, S., de Jager, C., & Wilcock, G. (2012). A comparison of screening tools for the assessment of mild cognitive impairment: preliminary findings. *Neurocase, 18*(4), 336-351.

Albert, M. S., DeKosky, S. T., Dickson, D., Dubois, B., Feldman, H. H., Fox, N. C., . . . Phelps, C. H. (2011). The diagnosis of mild cognitive impairment due to Alzheimer's disease: recommendations from the National Institute on Aging and Alzheimer's Association workgroup. Alzheimer's and Dementia, 1-10.

Alzheimer's Association (2015). 2015 Alzheimer's Disease Facts and Figures, *Alzheimer's & Dementia, Volume 11*, Issue 3.

Carr, D. B., LaBarge, E., Dunnigan, K., & Storandt, M. (1998). Differentiating drivers with dementia of the Alzheimer type from healthy older persons with a traffic sign naming test. *Journal of Gerontology: Medical Sciences, 53A*, M135-M139.

Daigneault, G.1., Joly, P. & Frigon, J. Y. (2002). Executive functions in the evaluation of accident risk of older drivers. *Journal of Clinical and Experimental Neuropsychology,* 24(2):221-38.

Duchek, J., Carr, D. B., Hunt, L., Roe, C. M., Xiong, C., Shah, K., & Morrie, J. C. (2003). Longitudinal driving performance in early-stage dementia of the Alzheimer type. *Journal of the American Geriatrics Society*, *51*, 1342-1347.

Eby, D. W., Silverstein, N. M., Molnar, L. J., LeBlanc, D., Adler, G., Gottlieb, … Way, J. (2009). *Fitness to Drive in Early Stage Dementia: An Instrumented Vehicle Study*. (Report Number MCASTL-2009-03) Ann Arbor, MI: University of Michigan Transportation Institute.

Freitas, S., Simões, M. R., Alves, L., & Santana, I. (2013). Montreal Cognitive Assessment validation study for mild cognitive impairment and Alzheimer Disease. *Alzheimer Disease and Associated Disorders, 27(1), 37-43.*

Freitas, S., Simões, M. R., Maroco, J., Alves, L., & Santana, I. (2012). Construct validity of the Montreal Cognitive Assessment (MoCA). *Journal of the International Neuropsychological Society, 18*, 242-250.

Herbel, S., Rosenbloom, S., Stutts, J., & Welch, T. (2006). *The Impact of an Aging Population on Systems Planning and Investment Policies.* (Final Report, NCHRP Project 8-36: Task 50). Washington, DC: Transportation Research Board. Available at http://statewideplanning.org/wp-content/uploads/59_NCHRP8-36-50.pdf

Michon, J. A. (1985). A critical view of driver behavior models: what do we know, what should we do? In L. Evans & R. C. Schwing (Eds.). *Human Behavior andTraffic Safety,* pp. 485-520. New York: Plenum Press.

Moafmashhadi, P., & Koski, L. (2013). Limitations for interpreting failure on individual subtests of the Montreal Cognitive Assessment. *Journal of Geriatric Psychiatry and Neurology, 26*(1), 19-28.

Nasreddine, Z. S., Phillips, N. A., Bedirian, V., Charbonneau, S., Whitehead, V., Collin, I., . . . Chertkow, H. (2005). The Montreal Cognitive Assessment, MoCA: a brief screening tool for mild cognitive impairment. *Journal of the American Geriatric Society, 53*, 695-699.

Pfeffer, R. I., Kurosaki, T. T., Harrah, C. H., Chance, J. M., & Filos, S. (1982). Measurement of functional activities in older adults in the community. *Journal of Gerontology, 37*(3), 323-329.

Petersen, R. C. (2011). Mild cognitive impairment. *The New England Journal of Medicine, 364*(23), 2227-2233.

Petersen, R. C. (2004). Mild cognitive impairment as a diagnostic entity. Journal of Internal Medicine, 256, 183-194.

Roy, M., & Molnar, F. (2013). Systematic review of the evidence for Trails B cut-off scores in assessing fitness to drive. *Canadian Geriatrics Journal*, *16*(3).

Silverstein, N. M., Flaherty, G., & Tobin, T. S. (2002). *Dementia and Wandering Behavior: Concern for the Lost Elder*. New York, NY: Springer.

Silverstein, NM (2008). *Alzheimer's disease and fitness to drive*. In: D. Eby, & L J. Molnar, 2008 North American License Policies Workshop Proceedings. AAA Foundation for Traffic Safety.

Staplin, L., Gish, K. W., Lococo, K. H., Joyce, J. J., & Sifrit, K. J. (2013). The maze test: A significant predictor of older driver crash risk. *Accident Analysis and Prevention*, *50*, 483-489.

Staplin, L., Gish, K., & Wagner, E. (2003). MaryPODS revisited: updated crash analysis and implications for screening program implementation. *Journal of Safety Research*, *34*, 389-397.

Teng, E., Becker, B., Woo, E., Knopman, D., Cummings, J., & Po, H. (2010). Utility of the functional activities questionnaire for distinguishing mild cognitive impairment from very mild Alzheimer disease. *Alzheimer Disease and Associated Disorders*, *24*(4), 348-353.

Trzepacz, P. T., Hochstetler, H., Wang, S., Walker, B., & Saykin, A. J. (2015). Relationship between the Montreal Cognitive Assessment and Mini-Mental State Examination for assessment of mild cognitive impairment in older adults. *BMC Geriatrics, 15*:107. doi: 10.1186/s12877-015-0103-3.

Uc, E. Y., Rizzo, M., Anderson, S. W., Shi, Q., & Dawson, J. D. (2005). Driver landmark and traffic sign identification in early Alzheimer's disease. *Journal of Neurology, Neurosurgery & Psychiatry, 76*, 764-768.

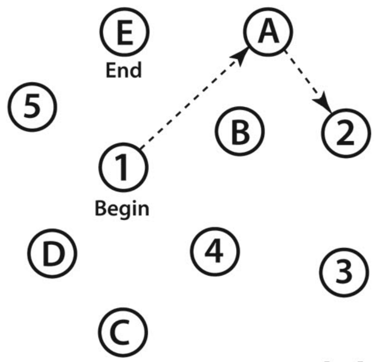
Winblad, B., Palmer, K., Kivipelto, M., Jelic, V., Fratiglioni, L., Wahlund, L. -O., . . . Petersen, R. C. (2004). Mild cognitive impairment - beyond controversies, towards a consensus: report of the International Working Group on Mild Cognitive Impairment. *Journal of Internal Medicine, 256*, 240-246.

Appendix A: Montreal Cognitive Assessment

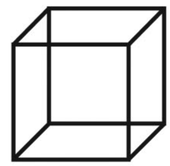
MONTREAL COGNITIVE ASSESSMENT (MOCA)
Version 7.1 Original Version

NAME :
Education : **Date of birth :**
Sex : **DATE :**

VISUOSPATIAL / EXECUTIVE | POINTS



[ ]



Copy cube

[ ]

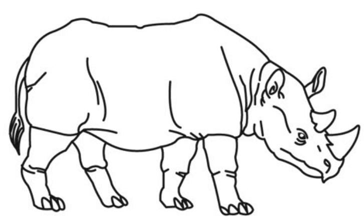
Draw CLOCK (Ten past eleven)
(3 points)

[ ] Contour [ ] Numbers [ ] Hands

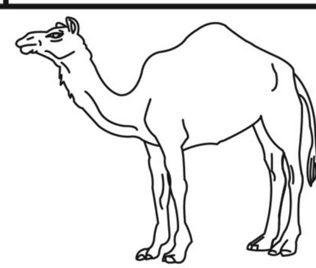
___/5

NAMING

[ ]



[ ]



[ ]

___/3

MEMORY Read list of words, subject must repeat them. Do 2 trials, even if 1st trial is successful. Do a recall after 5 minutes.

	FACE	VELVET	CHURCH	DAISY	RED
1st trial					
2nd trial					

No points

ATTENTION Read list of digits (1 digit/ sec.).
Subject has to repeat them in the forward order [ ] 2 1 8 5 4
Subject has to repeat them in the backward order [ ] 7 4 2
___/2

Read list of letters. The subject must tap with his hand at each letter A. No points if ≥ 2 errors
[ ] F B A C M N A A J K L B A F A K D E A A A J A M O F A A B
___/1

Serial 7 subtraction starting at 100 [ ] 93 [ ] 86 [ ] 79 [ ] 72 [ ] 65
4 or 5 correct subtractions: **3 pts**, 2 or 3 correct: **2 pts**, 1 correct: **1 pt**, 0 correct: **0 pt**
___/3

LANGUAGE Repeat : I only know that John is the one to help today. [ ]
The cat always hid under the couch when dogs were in the room. [ ]
___/2

Fluency / Name maximum number of words in one minute that begin with the letter F [ ] _____ (N ≥ 11 words)
___/1

ABSTRACTION Similarity between e.g. banana - orange = fruit [ ] train – bicycle [ ] watch - ruler
___/2

DELAYED RECALL	Has to recall words **WITH NO CUE**	FACE [ ]	VELVET [ ]	CHURCH [ ]	DAISY [ ]	RED [ ]	Points for UNCUED recall only	___/5
Optional	Category cue							
	Multiple choice cue							

ORIENTATION [ ] Date [ ] Month [ ] Year [ ] Day [ ] Place [ ] City
___/6

 www.mocatest.org Normal ≥ 26 / 30

TOTAL ___/30
Add 1 point if ≤ 12 yr edu

Administered by: ______________________________

Montreal Cognitive Assessment (MoCA)

Administration and Scoring Instructions

The Montreal Cognitive Assessment (MoCA) was designed as a rapid screening instrument for mild cognitive dysfunction. It assesses different cognitive domains: attention and concentration, executive functions, memory, language, visuoconstructional skills, conceptual thinking, calculations, and orientation. Time to administer the MoCA is approximately 10 minutes. The total possible score is 30 points; a score of 26 or above is considered normal.

1. Alternating Trail-Making:

Administration: The examiner instructs the subject: "Please draw a line, going from a number to a letter in ascending order. Begin here [point to (1)] and draw a line from 1 then to A then to 2 and so on. End here [point to (E)]."

Scoring: Allocate one point if the subject successfully draws the following pattern: 1-A-2-B-3-C-4-D-5-E, without drawing any lines that cross. Any error that is not immediately self-corrected earns a score of 0.

2. Visuoconstructional Skills (Cube):

Administration: The examiner gives the following instructions, pointing to the **cube**: “Copy this drawing as accurately as you can, in the space below”.

Scoring: One point is allocated for a correctly executed drawing.

- Drawing must be three-dimensional
- All lines are drawn
- No line is added
- Lines are relatively parallel and their length is similar (rectangular prisms are accepted)

A point is not assigned if any of the above criteria are not met.

3. Visuoconstructional Skills (Clock):

Administration: Indicate the right third of the space and give the following instructions: “Draw a **clock**. Put in all the numbers and set the time to 10 past 11”.

Scoring: One point is allocated for each of the following three criteria:

- Contour (1 pt.): the clock face must be a circle with only minor distortion acceptable (e.g., slight imperfection on closing the circle);
- Numbers (1 pt.): all clock numbers must be present with no additional numbers; numbers must be in the correct order and placed in the approximate quadrants on the clock face; Roman numerals are acceptable; numbers can be placed outside the circle contour;
- Hands (1 pt.): there must be two hands jointly indicating the correct time; the hour hand must be clearly shorter than the minute hand; hands must be centered within the clock face with their junction close to the clock center.

A point is not assigned for a given element if any of the above criteria are not met.

4. Naming:

Administration: Beginning on the left, point to each figure and say: “Tell me the name of this animal”.

Scoring: One point each is given for the following responses: (1) lion (2) rhinoceros or rhino (3) camel or dromedary.

5. Memory:

Administration: The examiner reads a list of 5 words at a rate of one per second, giving the following instructions: “This is a memory test. I am going to read a list of words that you will have to remember now and later on. Listen carefully. When I am through, tell me as many words as you can remember. It doesn’t matter in what order you say them”. Mark a check in the allocated space for each word the subject produces on this first trial. When the subject indicates that (s)he has finished (has recalled all words), or can recall no more words, read the list a second time with the following instructions: “I am going to read the same list for a second time. Try to remember and tell me as many words as you can, including words you said the first time.” Put a check in the allocated space for each word the subject recalls after the second trial. At the end of the second trial, inform the subject that (s)he will be asked to recall these words again by saying, “I will ask you to recall those words again at the end of the test.”

Scoring: No points are given for Trials One and Two.

6. Attention:

Forward Digit Span: Administration: Give the following instruction: “I am going to say some numbers and when I am through, repeat them to me exactly as I said them”. Read the five number sequence at a rate of one digit per second.

Backward Digit Span: Administration: Give the following instruction: “Now I am going to say some more numbers, but when I am through you must repeat them to me in the backwards order.” Read the three number sequence at a rate of one digit per second.

Scoring: Allocate one point for each sequence correctly repeated, (N.B.: the correct response for the backwards trial is 247).

Vigilance: Administration: The examiner reads the list of letters at a rate of one per second, after giving the following instruction: “I am going to read a sequence of letters. Every time I say the letter A, tap your hand once. If I say a different letter, do not tap your hand”.

Scoring: Give one point if there is zero to one errors (an error is a tap on a wrong letter or a failure to tap on letter A).

Serial 7s: Administration: The examiner gives the following instruction: “Now, I will ask you to count by subtracting seven from 100, and then, keep subtracting seven from your answer until I tell you to stop.” Give this instruction twice if necessary.

Scoring: This item is scored out of 3 points. Give no (0) points for no correct subtractions, 1 point for one correction subtraction, 2 points for two to three correct subtractions, and 3 points if the participant successfully makes four or five correct subtractions. Count each correct subtraction of 7 beginning at 100. Each subtraction is evaluated independently; that is, if the participant responds with an incorrect number but continues to correctly subtract 7 from it, give a point for each correct subtraction. For example, a participant may respond “92 – 85 – 78 – 71 – 64” where the “92” is incorrect, but all subsequent numbers are subtracted correctly. This is one error and the item would be given a score of 3.

7. Sentence repetition:

Administration: The examiner gives the following instructions: “I am going to read you a sentence. Repeat it after me, exactly as I say it [pause]: **I only know that John is the one to help today.”** Following the response, say: “Now I am going to read you another sentence. Repeat it after me, exactly as I say it [pause]: **The cat always hid under the couch when dogs were in the room.”**

Scoring: Allocate 1 point for each sentence correctly repeated. Repetition must be exact. Be alert for errors that are omissions (e.g., omitting "only", "always") and substitutions/additions (e.g., "John is the one who helped today;" substituting "hides" for "hid", altering plurals, etc.).

8. Verbal fluency:

Administration: The examiner gives the following instruction: “Tell me as many words as you can think of that begin with a certain letter of the alphabet that I will tell you in a moment. You can say any kind of word you want, except for proper nouns (like Bob or Boston), numbers, or words that begin with the same sound but have a different suffix, for example, love, lover, loving. I will tell you to stop after one minute. Are you ready? [Pause] Now, tell me as many words as you can think of that begin with the letter F. [time for 60 sec]. Stop.”

Scoring: Allocate one point if the subject generates 11 words or more in 60 sec. Record the subject’s response in the bottom or side margins.

9. Abstraction:

Administration: The examiner asks the subject to explain what each pair of words has in common, starting with the example: “Tell me how an orange and a banana are alike”. If the subject answers in a concrete manner, then say only one additional time: “Tell me another way in which those items are alike”. If the subject does not give the appropriate response (fruit), say, “Yes, and they are also both fruit.” Do not give any additional instructions or clarification. After the practice trial, say: “Now, tell me how a train and a bicycle are alike”. Following the response, administer the second trial, saying: “Now tell me how a ruler and a watch are alike”. Do not give any additional instructions or prompts.

Scoring: Only the last two item pairs are scored. Give 1 point to each item pair correctly answered. The following responses are acceptable: Train-bicycle = means of transportation, means of travelling, you take trips in both; Ruler--watch = measuring instruments, used to measure. The following responses are **not** acceptable: Train-bicycle = they have wheels; Ruler-watch = they have numbers.

10. Delayed recall:

Administration: The examiner gives the following instruction: "I read some words to you earlier, which I asked you to remember. Tell me as many of those words as you can remember." Make a check mark (√) for each of the words correctly recalled spontaneously without any cues, in the allocated space.

Scoring: **Allocate 1 point for each word recalled freely without any cues.**

Optional:

Following the delayed free recall trial, prompt the subject with the semantic category cue provided below for any word not recalled. Make a check mark (√) in the allocated space if the subject remembered the word with the help of a category or multiple choice cue. Prompt all non-recalled words in this manner. If the subject does not recall the word after the category cue, give him/her a multiple choice trial, using the following example instruction, "Which of the following words do you think it was, NOSE, FACE, or HAND?" Use the following category and/or multiple choice cues for each word, when appropriate:

FACE:	category cue: part of the body	multiple choice: nose, face, hand
VELVET	category cue: type of fabric	multiple choice: denim, cotton, velvet
CHURCH:	category cue: type of building	multiple choice: church, school, hospital
DAISY:	category cue: type of flower	multiple choice: rose, daisy, tulip
RED:	category cue: a colour	multiple choice: red, blue, green

Scoring: **No points are allocated for words recalled with a cue.** A cue is used for clinical information purposes only and can give the test interpreter additional information about the type of memory disorder. For memory deficits due to retrieval failures, performance can be improved with a cue. For memory deficits due to encoding failures, performance does not improve with a cue.

11. Orientation:

Administration: The examiner gives the following instructions: "Tell me the date today". If the subject does not give a complete answer, then prompt accordingly by saying: "Tell me the [year, month, exact date, and day of the week]." Then say: "Now, tell me the name of this place, and which city it is in."

Scoring: Give one point for each item correctly answered. The subject must tell the exact date and the exact place (name of hospital, clinic, office). No points are allocated if subject makes an error of one day for the day and date.

TOTAL SCORE: Sum all subscores listed on the right-hand side. Add one point for an individual who has 12 years or fewer of formal education, for a possible maximum of 30 points. A final total score of 26 and above is considered normal.

http://www.mocatest.org/

Appendix B: Functional Activities Questionnaire (FAQ)

Functional Activities Questionnaire

Administration

Ask informant to rate patient's ability using the following scoring system:

- Dependent = 3
- Requires assistance = 2
- Has difficulty but does by self = 1
- Normal = 0
- Never did [the activity] but could do now = 0
- Never did and would have difficulty now = 1

Writing checks, paying bills, balancing checkbook	
Assembling tax records, business affairs, or papers	
Shopping alone for clothes, household necessities, or groceries	
Playing a game of skill, working on a hobby	
Heating water, making a cup of coffee, turning off stove after use	
Preparing a balanced meal	
Keeping track of current events	
Paying attention to, understanding, discussing TV, book, magazine	
Remembering appointments, family occasions, holidays, medications	
Traveling out of neighborhood, driving, arranging to take buses	
TOTAL SCORE:	

Evaluation

Sum scores (range 0-30). Cutpoint of 9 (dependent in 3 or more activities) is recommended to indicate impaired function and possible cognitive impairment.

Pfeffer RI et al. Measurement of functional activities in older adults in the community. J Gerontol 1982; 37(3):323-329. Reprinted with permission of The Gerontological Society of America, 1030 15th Street NW, Suite 250, Washington, DC 20005 via Copyright Clearance Center, Inc.

www.healthcare.uiowa.edu/familymedicine/fpinfo/Docs/functional-activities-assessment-tool.pdf

Appendix C: Road Test Performance Summary

Operational Skills	*N S's w/ Errors*	*Total Error Score*
Independent access to vehicle (1)	0	0
Negotiation of driver door (1)	0	0
Adjusts seat (3)	0	0
Adjusts wheel (3)	0	0
Adjusts mirrors (3)	0	0
Fastens seat belt (3)	1	3
Ignition Control (3)	0	0
Proper gear selection (3)	1	6
Brake control (3)	2	9
Accelerator control (3)	0	0
Steering (5)	0	0
Identify speedometer (5)	0	0
Signal ability (5)	0	0
Dashboard controls (5)	0	0
Wiper/Cruise controls (5)	0	0
Parking brake engagement (5)	2	10
Operational Points Off	***6***	***28***

Strategic Skills	*N S's w/* Errors	*Total* Error Score
Correct and safe decisions		
Residential (5)	2	10
City (5)	0	0
Limited access hwy (5)	0	0
Route planning (5)	2	10
Route logically sequenced (5)	0	0
Remembers and executes the route in the preplanned order (5)	4	20
Regulates conversation appropriately (5)	4	20
Knowledge of rules of the road (5)	2	10
Decisions in advance of Maneuvers (5)	0	0
Separates hazards (5)	0	0
Observes cues from other road users (5)	2	10
Anticipates(5)	0	0
Attention – "looked but didn't see" (5)	3	15
Processing speed(5)	0	0
Followed directions (5)	4	20
Strategic Points Off	***11***	***115***

SCORING: TOTAL POINTS OFF= (A – 0-24; pass with no restrictions), (B – 25-49; pass with recommendations), (C – 50-75; marginal with restrictions; marginal with training), (D – 76-99; Fail), (F – 100 up; Fail)

A vertical mark beside an item indicates points off (tally). The point value of each item is in parenthesis. Each item may have several vertical marks beside it representing the errors that were committed more than one time. Multiply the number of vertical marks times the point value in parenthesis to get the Points Off for that item (total).

100 or more Total Points Off is a failure.

	N S's w/Errors	**Total Error Score**
TOTAL ROAD POINTS	31	1070

Tactical Skills	*N S's w/ Errors*	*Total Error Score*
Visual Skills:		
Scans environment (10)	4	50
Use of mirrors (5)	0	0
Blind spot checks (5)	7	40
Awareness of signage (5)	6	50
Checks speedometer (5)	0	0
Vehicle Position:		
Lane maintenance (5)	8	70
Drives in proper lane (5)	14	120
Follow distance/Lateral Cushion (5)	1	5
Stopping position (5)	5	30
Response to other traffic (5)	1	5
Intersections/Turns *(Right)*		
Check Traffic (5)	0	0
Proper Lane (5)	4	25
Speed (3)	0	0
Safe gap selection/yield (10)	0	0
Complete stop (10)	1	10
Intersections/Turns *(Left)*		
Check traffic (5)	1	5
Proper Lane (5)	5	45
Speed (3)	0	0
Safe gap selection/yield (10)	0	0
Complete stop (10)	0	0
Intersections/Through or Turning		
Runs red light (100)	0	0
Runs stop sign (100)	0	0
Lane changes:		
Check traffic (5)	1	5
Position (3)	2	6
Speed (3)	0	0
Lane (5)	0	0
Safe gap selection/yield (10)	1	10
Merges on/off limited access hwy		
Judgment of space (5)	0	0
Signaling (5)	5	30
Speed regulation (5)	1	5
Visual scanning/Blind spot (5)	0	0
Vehicle Handling:		
Judge and regulate speed (5)	9	55
Smooth steering (5)	1	5
Smooth accelerator (5)	0	0
Smooth braking (5)	0	0
Appropriate use of signals (5)	19	310
Response to traffic signal (5)	2	15
Parking: Approach (3)	1	3
Position (3)	2	9
Speed (3)	0	0
Backing: Check Traffic (5)	0	0
Position (3)	1	3
Speed (3)	0	0
Safe/yield (10)	1	10
3-pt turn around (5)	0	0
Tactical Points Off	**31**	**927**

Appendix D: Analysis Results for Non-Significant Regression Models

SUMMARY OUTPUT: DV = Operational Points Off

Regression Statistics	
Multiple R	0.38
R Square	0.15
Adjusted R Square	0.01
Standard Error	1.79
Observations	38

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	5	17.33	3.47	1.09	0.39
Residual	32	102.04	3.19		
Total	37	119.37			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	4.32	2.19	1.97	0.06	-0.15	8.78
MoCa	-0.12	0.07	-1.66	0.11	-0.27	0.03
Trails A Time	-0.01	0.01	-0.81	0.42	-0.03	0.01
Trails B Time	0.00	0.00	-1.18	0.25	-0.01	0.00
Maze 2 Time	0.01	0.02	0.55	0.59	-0.03	0.05
FAQ	0.14	0.12	1.15	0.26	-0.11	0.39

SUMMARY OUTPUT: DV = Strategic Points Off

Regression Statistics	
Multiple R	0.54
R Square	0.29
Adjusted R Square	0.18
Standard Error	5.20
Observations	38

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	5	361.87	72.37	2.68	0.04
Residual	32	865.11	27.03		
Total	37	1226.97			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	8.55	6.38	1.34	0.19	-4.45	21.56
MoCa	-0.31	0.21	-1.45	0.16	-0.74	0.13
Trails A Time	-0.02	0.03	-0.56	0.58	-0.09	0.05
Trails B Time	0.01	0.01	0.73	0.47	-0.02	0.03
Maze 2 Time	0.02	0.06	0.35	0.73	-0.10	0.15
FAQ	0.58	0.36	1.62	0.12	-0.15	1.30

SUMMARY OUTPUT: DV = Total Number of Trips

Regression Statistics	
Multiple R	0.53
R Square	0.28
Adjusted R Square	0.13
Standard Error	47.07
Observations	29

ANOVA

	df	SS	MS	F	Significance F
Regression	5	20014.87	4002.97	1.81	0.15
Residual	23	50956.92	2215.52		
Total	28	70971.79			

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%
Intercept	85.02	79.15	1.07	0.29	-78.70	248.75
MOCA	0.52	2.64	0.20	0.84	-4.94	5.99
TrailsA	-1.21	0.61	-1.98	0.06	-2.47	0.05
TrailsB	0.25	0.26	0.96	0.35	-0.28	0.77
Maze2Time	1.18	0.83	1.41	0.17	-0.55	2.90
FAQ	-13.12	9.94	-1.32	0.20	-33.67	7.44

SUMMARY OUTPUT: DV = Total Hours Driven

Regression Statistics	
Multiple R	0.58
R Square	0.34
Adjusted R Square	0.19
Standard Error	8.57
Observations	29

ANOVA

	df	SS	MS	F	Significance F
Regression	5	856.61	171.32	2.33	0.07
Residual	23	1690.39	73.50		
Total	28	2547.01			

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%
Intercept	10.80	14.42	0.75	0.46	-19.02	40.62
MOCA	0.26	0.48	0.55	0.59	-0.73	1.26
TrailsA	-0.28	0.11	-2.56	0.02*	-0.51	-0.05
TrailsB	0.10	0.05	2.06	0.05	0.00	0.19
Maze2Time	0.20	0.15	1.32	0.20	-0.11	0.51
FAQ	-2.00	1.81	-1.10	0.28	-5.74	1.74

*p<0.05 **p<0.01 ***p<.001

SUMMARY OUTPUT: DV=Total Miles Driven						
Regression Statistics						
Multiple R	0.57					
R Square	0.33					
Adjusted R Square	0.18					
Standard Error	216.27					
Observations	29					
ANOVA						
	df	*SS*	*MS*	*F*	*Significance F*	
Regression	5	527843.02	105568.60	2.26	0.08	
Residual	23	1075774.29	46772.80			
Total	28	1603617.31				
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	126.75	363.65	0.35	0.73	-625.53	879.02
MOCA	10.10	12.14	0.83	0.41	-15.03	35.22
TrailsA	-6.87	2.80	-2.46	0.02*	-12.66	-1.08
TrailsB	3.02	1.17	2.58	0.02*	0.60	5.45
Maze2Time	2.75	3.83	0.72	0.48	-5.18	10.67
FAQ	-54.92	45.65	-1.20	0.24	-149.35	39.51
*p<0.05 **p<0.01 ***p<.001						

SUMMARY OUTPUT: DV=Percent of Trips Made in Rain						
Regression Statistics						
Multiple R	0.37					
R Square	0.14					
Adjusted R Square	-0.05					
Standard Error	0.05					
Observations	29					
ANOVA						
	df	*SS*	*MS*	*F*	*Significance F*	
Regression	5	0.01	0.00	0.74	0.60	
Residual	23	0.07	0.00			
Total	28	0.08				
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	0.18	0.09	1.98	0.06	-0.01	0.37
MOCA	0.00	0.00	-1.28	0.21	-0.01	0.00
TrailsA	0.00	0.00	-1.15	0.26	0.00	0.00
TrailsB	0.00	0.00	0.71	0.49	0.00	0.00
Maze2Time	0.00	0.00	-0.32	0.75	0.00	0.00
FAQ	0.00	0.01	0.22	0.83	-0.02	0.03

SUMMARY OUTPUT: DV=Percent of Trips Made at Night						
Regression Statistics						
Multiple R	0.41					
R Square	0.17					
Adjusted R Square	-0.01					
Standard Error	0.07					
Observations	29					
ANOVA						
	df	*SS*	*MS*	*F*	*Significance F*	
Regression	5	0.02	0.00	0.92	0.48	
Residual	23	0.12	0.01			
Total	28	0.15				
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	0.09	0.12	0.73	0.47	-0.16	0.34
MOCA	0.00	0.00	0.23	0.82	-0.01	0.01
TrailsA	0.00	0.00	-1.58	0.13	0.00	0.00
TrailsB	0.00	0.00	1.20	0.24	0.00	0.00
Maze2Time	0.00	0.00	-0.27	0.79	0.00	0.00
FAQ	-0.02	0.02	-1.10	0.28	-0.05	0.01

SUMMARY OUTPUT: DV= Percent of Trips Begun During Rush Hour						
Regression Statistics						
Multiple R	0.51					
R Square	0.26					
Adjusted R Square	0.09					
Standard Error	0.18					
Observations	29					
ANOVA						
	df	*SS*	*MS*	*F*	*Significance F*	
Regression	5	0.26	0.05	1.59	0.20	
Residual	23	0.75	0.03			
Total	28	1.00				
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	0.66	0.30	2.17	0.04*	0.03	1.28
MOCA	-0.01	0.01	-0.55	0.59	-0.03	0.02
TrailsA	0.00	0.00	-1.44	0.16	-0.01	0.00
TrailsB	0.00	0.00	-0.07	0.94	0.00	0.00
Maze2Time	0.00	0.00	-0.18	0.86	-0.01	0.01
FAQ	0.03	0.04	0.73	0.47	-0.05	0.11
*p<0.05 **p<0.01 ***p<.001						

SUMMARY OUTPUT: DV= Percent of Trips on 60+ mph Roadways						
Regression Statistics						
Multiple R	0.39					
R Square	0.16					
Adjusted R Square	-0.03					
Standard Error	0.14					
Observations	29					
ANOVA						
	df	*SS*	*MS*	*F*	*Significance F*	
Regression	5	0.08	0.02	0.85	0.53	
Residual	23	0.44	0.02			
Total	28	0.52				
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	-0.21	0.23	-0.93	0.36	-0.69	0.26
MOCA	0.01	0.01	1.23	0.23	-0.01	0.03
TrailsA	0.00	0.00	0.89	0.38	0.00	0.01
TrailsB	0.00	0.00	0.36	0.72	0.00	0.00
Maze2Time	0.00	0.00	-0.82	0.42	-0.01	0.00
FAQ	0.00	0.03	-0.10	0.92	-0.06	0.06

SUMMARY OUTPUT: Percent of Hours Driven on 60+ mph Roadways						
Regression Statistics						
Multiple R	0.55					
R Square	0.31					
Adjusted R Square	0.16					
Standard Error	0.06					
Observations	29					
ANOVA						
	df	*SS*	*MS*	*F*	*Significance F*	
Regression	5	0.04	0.01	2.03	0.11	
Residual	23	0.09	0.00			
Total	28	0.12				
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	-0.12	0.10	-1.15	0.26	-0.33	0.09
MOCA	0.01	0.00	1.89	0.07	0.00	0.01
TrailsA	0.00	0.00	-1.47	0.16	0.00	0.00
TrailsB	0.00	0.00	1.82	0.08	0.00	0.00
Maze2Time	0.00	0.00	-0.32	0.75	0.00	0.00
FAQ	-0.01	0.01	-1.07	0.30	-0.04	0.01

SUMMARY OUTPUT: DV= Percent of Miles Driven on 60+ mph Roadways						
Regression Statistics						
Multiple R	0.57					
R Square	0.32					
Adjusted R Square	0.18					
Standard Error	0.13					
Observations	29					
ANOVA						
	df	*SS*	*MS*	*F*	*Significance F*	
Regression	5	0.18	0.04	2.21	0.09	
Residual	23	0.37	0.02			
Total	28	0.55				
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	-0.29	0.21	-1.36	0.19	-0.73	0.15
MOCA	0.02	0.01	2.12	0.04*	0.00	0.03
TrailsA	0.00	0.00	-1.51	0.14	-0.01	0.00
TrailsB	0.00	0.00	1.80	0.08	0.00	0.00
Maze2Time	0.00	0.00	-0.15	0.88	0.00	0.00
FAQ	-0.03	0.03	-0.97	0.34	-0.08	0.03
*p<0.05 **p<0.01 ***p<.001						

DOT HS 812 577
January 2019

U.S. Department
of Transportation

National Highway
Traffic Safety
Administration

NHTSA

13687-010419-v4