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16. Abstract

This project investigated the effect of selected medical conditions on the exposure and performance of older drivers. A review of recent literature, followed by a panel meeting with driving safety experts, prioritized four medical conditions for further study: chronic obstructive pulmonary disease (COPD), age-related macular degeneration (AMD), Parkinson's disease, and peripheral neuropathy. Driving exposure and performance analyses were carried out for four samples of drivers 60 and older with the specified medical conditions and healthy, age-matched controls: a *primary* sample (n= 27) and a larger *augmented* sample (n = 58) of drivers recruited at Roger C. Peace Rehabilitation Hospital in Greenville, SC, a set of older drivers from the SHRP2 naturalistic driving study (n = 203), and a smaller subset of older SHRP2 drivers who traversed specific freeway ramps and acceleration lanes in the Tampa/St. Petersburg, Florida, area (n = 36). Participants in the primary and augmented samples underwent a clinical (physical and cognitive) assessment and an on-road driving evaluation by a certified driver rehabilitation specialist (CDRS). For the most part, the older drivers classified in the aforementioned groups based on medical diagnosis were not functionally different. Planned analyses revealed no significant group differences for driving exposure among the primary and augmented samples. For the SHRP2 broad sample analysis, the exposure of older drivers with (self-reported) medical conditions was significantly reduced on a number of measures. Performance between the groups with and without medical conditions was equivalent in virtually all respects based on CDRS scores for the primary and augmented samples and on vehicle kinematic data and crash and near-crash events for the SHRP2 samples. A panel discussion at the project's conclusion sought input from professionals at continuing care retirement communities on identifying residents who are at-risk for driving and how to overcome the organizational and personal barriers to addressing this issue when residents experience diminished driving performance.

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Executive Summary

This study explored the effects of selected medical conditions common among older adults on their ability to drive safely, and how these conditions may affect when, where, and how much they drive (exposure). A literature review served as the starting point for this investigation; its findings supported eight medical conditions as candidates for further study in this project. A panel of driving safety professionals (physicians and driver rehabilitation specialists) met to critically discuss the literature review and narrow the candidates to the top four priorities for data collection and analysis. These efforts led to a focus on the following medical conditions: diabetes-related peripheral neuropathy, age-related macular degeneration (AMD), Parkinson's disease, and chronic obstructive pulmonary disease (COPD).

Data collection initially relied on referrals from physicians in the Greenville Health System (Greenville, South Carolina) who specialize in treating the medical conditions of interest. This approach resulted in a sample of 27 drivers 60 and older, including 8 diagnosed with one of the targeted medical conditions (but no other medical conditions severe enough to potentially impair driving), and 19 healthy, age-matched controls. This was designated as the *Primary Sample*.

Given this restricted sample size, with too few drivers to analyze effects for any specific medical condition in relation to the controls, an *Augmented Sample* was defined by supplementing the Primary Sample with 31 additional drivers recruited at the same institution, and clinically assessed by the same staff members, during performance of another, concurrent NHTSA project. The Augmented Sample was composed of 15 drivers with one of the targeted medical conditions – including 9 with neuropathy – and 43 healthy, older controls.

Data collection systems installed in Primary Sample drivers' vehicles for approximately a month provided exposure measures; no exposure data were available for the drivers added to form the Augmented Sample. Both the Primary and Augmented Sample participants underwent a clinical (physical and cognitive) assessment and an on-road driving evaluation by a certified driver rehabilitation specialist (CDRS) at Roger C. Peace (RCP) hospital in Greenville, SC. The on-road performance of drivers in both samples was also scored through CDRS review of in-vehicle video recorded during the standard evaluation, using a 100-point Behaviorally Anchored Rating Scale (BARS) developed in this research study.

Analyses showed no significant differences between the healthy older controls and a "combined medical conditions" (CMC)" group for any driving exposure measure (miles driven; trip duration; or percent of trips by distance, time of day, road type, adverse weather, and route familiarity) for the Primary Sample. Neither were there any significant group differences in BARS scores for either the Primary or the Augmented samples, including, within the Augmented Sample, a comparison of the healthy, older controls with the neuropathy subgroup. However, regression analysis revealed that for the Augmented Sample, worse performance on the Trail Making Test Part B was significantly associated with worse driving performance as indicated by the BARS score.

To further broaden the study, the research team expanded the technical approach to mine data in the naturalistic driving study (NDS) database generated in the second Strategic Highway

Research Project (SHRP2). Many among the more than 3,000 drivers participating in the SHRP2 study had self-reported medical conditions, including Parkinson's disease, peripheral neuropathy, and COPD; and instrumentation in SHRP2 drivers' cars included cameras, radar, and other sensors that recorded performance and exposure information that could be analyzed to address many variables of interest in this research. Finally, all SHRP2 study participants had completed tests assessing a range of physical, cognitive, and psychomotor functional abilities in common with those measured by the Greenville Health System staff.

Analyses of the SHRP2 dataset first examined exposure differences among 7 drivers with Parkinson's disease, 46 drivers with peripheral neuropathy, 25 drivers with COPD, and 129 drivers (controls) 65 and over with no reported medical conditions. Findings of note were that drivers in the control group averaged:

- more total trips and a higher average number of trips per day than drivers in the CMC group;
- more trips per day than the neuropathy and the COPD subgroups but not more than the Parkinson's subgroup;
- longer maximum trip duration than drivers in the CMC group and the neuropathy subgroup;
- a higher percentage of trips on urban freeways than drivers with Parkinson's; and
- a higher proportion of miles driven at 60- to 70 mph than the neuropathy subgroup.

Analysis of the SHRP2 dataset compared the performance of the controls and medical conditions drivers in terms of the number of crash and near-crash events, including fault as assigned by a data coder. Analyses showed no reliable differences between groups in the proportion of drivers with a crash or near-crash. Regression analysis indicated a significant association between number of trips per day and near crashes; understandably, as the former increased so did the latter. These analyses also demonstrated isolated, counterintuitive associations between declining functional status indicators and reduced crash involvement.

A more restricted analysis of SHRP2 data tested for performance differences between controls and drivers with medical conditions in two dozen freeway merging situations in the Tampa/St. Petersburg area. The included ramps and acceleration lanes differed according to geometries that were classified as "less favorable" versus "more favorable" by a traffic engineer. While analyses showed main effects on performance measures including maximum and average speed, brake applications, and time headway to lead vehicles as a function of ramp design, the only significant difference between groups was that medical conditions drivers exhibited a higher cumulative time headway $\geq$3.5 seconds than drivers without medical conditions, and only before reaching the ramp gore.

At the end of this project, a panel discussion gathered insights from professionals at continuing care retirement communities (CCRCs) who were in a position to assess, advise, and counsel their residents about driving risks. The discussants included CCRC administrators, social service workers, registered nurses, a nurse practitioner, and an activities program coordinator. This group identified a series of steps commonly taken to address potentially unsafe resident drivers that proceeded from:

- a conversation with the resident; to

- a formal letter to the resident; to
- a formal letter to the department of motor vehicles (DMV), if earlier steps were ineffective.

The CCRC panelists noted various ways in which risky drivers were identified through observation at their facilities and described organizational and personal barriers to addressing this topic with residents that included administrative barriers, legal concerns, and resident trust issues.

The conclusions drawn from this research are that, first, the *diagnosed* medical conditions prevalent among older drivers that were the focus in this project did not necessarily support an expectation of performance (or safety) deficits. Panelists noted that those with medical conditions of the highest priority for affecting driving according to the safety professionals consulted in this project appeared to self-restrict their exposure in terms of total trips taken and trip duration (shorter), time of day (less during peak traffic periods), and speed (lower speed roadways). Still, it is demographically likely that increasing numbers of drivers will develop age-related functional impairments, cognitive and otherwise. This trend dictates caution when considering that many may escape diagnosis or not comply with their physicians' advice to limit when, where, or how much they drive.

Introduction and Research Objectives

Many have raised concerns about a potential safety impact of the coming surge in the number and proportion of aging motorists using the Nation's streets and highways. Whether this impact is experienced primarily among older road users themselves—as a consequence of their increased frailty and vulnerability to serious injury—or it affects system safety more broadly, the need to better understand factors that may predispose this population to increased crash risk and to develop countermeasures to reduce such crash involvements defines a current research priority.

One factor that distinguishes older drivers from their younger and middle-aged counterparts is a higher prevalence of medical conditions as well as the medications used to treat them. Often, the medical conditions that are more prevalent among older people lead to impairments in visual, cognitive, or psychomotor functions needed to drive safely (Carr, Schwartzberg, Manning, & Sempek, 2010). Similarly, while some medications restore function and improve mobility for those who would otherwise be unable to drive, a wide array of potentially driver impairing (PDI) prescriptions and over-the-counter medications have been associated with a significant increase in crash risk (LeRoy & Morse, 2008).

The current understanding of how medical conditions can affect driving is based on the opinions of medical (including rehabilitation) professionals or traffic safety experts, or it has been derived from simulation research. Other studies have compared the driving records of drivers whose licenses were restricted as a result of reported medical conditions to those of matched controls with the same conditions who had full driving privilege (Vernon, Diller, Cook, Reading, Suruda, & Dean, 2002). However, there is a dearth of empirical data about the relationships between medical conditions common among older adults and either performance or safety outcomes of drivers under realistic driving situations. Further, few studies have explored how persons with such conditions may limit their driving exposure.

A previous NHTSA study, *Taxonomy of Older Driver Behaviors and Crash Risk* (Staplin, Lococo, Martell, & Stutts, 2012), identified a number of medical conditions that medical professionals and driver rehabilitation specialists considered likely to undermine older drivers' performance and safety. Objective information about effects of these conditions on specific driving tasks that are risky for older drivers could improve clinicians' ability to advise their older patients and inform those at licensing agencies who determine the license status of (medically referred) older drivers. Such information could also be the starting point in developing countermeasures to allow those with the conditions to continue driving safely.

At the outset of the current study, a literature review (see Lococo, Staplin, & Schultz, 2017) highlighted eight medical conditions common among older adults as the strongest candidates for more in-depth consideration:

- *Diabetes*. Prevalence: 11% among those 20 and older in the population as a whole, which increases with age to 27% for those 65 and older. Risk also increases for people who are overweight, people who do not exercise regularly, and who have low HDL cholesterol, high triglycerides, or high blood pressure. Diabetes can result in vision impairment as well as loss of or altered sensation in the extremities. Medications to control diabetes can cause hypoglycemia, which in turn can cause a number of driver impairing symptoms.

- *Dementia.* Prevalence: 13% of Americans 65 and older have Alzheimer's disease, with the proportion increasing to 43% of those 85 and older. Ten to 20% of people 65 and older have mild cognitive impairment (MCI), and 15% of these progress from MCI to dementia each year, with nearly half of all people who have consulted a physician about MCI symptoms developing dementia in three or four years. Dementia is associated with impairments in memory, executive function, spatial orientation, judgment, insight, and impulsivity.
- *Glaucoma.* Prevalence: 2% among people 65 to 69, 3% among those 70to 74, 4% among those 75 to 79, and 8% among people 80 and older. Glaucoma produces a gradual constriction in the peripheral visual field, which can result in a total loss of vision. However, the condition is painless, and patients are often unaware that they are suffering any visual field deficits. Drivers suffering from open-angle glaucoma and peripheral visual field loss may fail to see and yield to cars or pedestrians approaching from the side and fail to see and stop at stop signs.
- *Hepatic encephalopathy*. While the literature did not document a high prevalence for this condition, some of the factors that trigger hepatic encephalopathy could be especially relevant to older adults: medications that affect the nervous system (such as tranquilizers or sleep medications), dehydration, and low oxygen levels. Physical and cognitive symptoms include mild confusion, forgetfulness, poor concentration, and poor judgment. Severe symptoms include movement disorders, extreme anxiety, seizures, severe confusion, sleepiness or fatigue, and slow movement.
- *Age-related macular degeneration*. Prevalence: 1% among people 65 t o 69, 2% among those 70 to 74, 3% among those 75 to 79, and 12% among those 80 and older. AMD is the leading cause of blindness in the 65-and-older age group; more people have glaucoma and cataracts, but fewer with cataracts and glaucoma become blind.
- *Obstructive sleep apnea*. This is a common though often undiagnosed (and under-treated) condition. Prevalence estimates range from 4 to 24% for men across all ages, and 2 to 9% for women. However, the prevalence may be higher based on questionnaire results showing that the risk increases linearly with age, with estimates of 19% among people 18 to 29, 25% among those 30 to 49, and 33% among those 50 to 64. The risk remains high after 65 (21%). Affected individuals have fragmented sleep periods, leading to chronic sleep deprivation, excessive daytime sleepiness, and some impairment of cognitive function.
- *Parkinson's disease*. Estimated prevalence: 2% of Medicare beneficiaries. This is the second most common neurodegenerative disease after Alzheimer's and is associated with both physical and cognitive symptoms. Cognitive dysfunction in Parkinson's patients includes deficits in memory, attention, abstract reasoning, and information processing speed, coupled with an inability to accurately judge one's own limitations. Physical symptoms include muscle rigidity and stiffness, tremors, slow movement, and balance and walking impairments. Medication to improve these symptoms causes excessive, unpredictable daytime sleepiness.

- *Stroke*. Estimated prevalence: 3%. Prevalence increases with age and is higher in females. Prevalence among those 60 to 79 is 7% for males and 8% for females. Among those 80 and older this increases to 14% for males and 15% for females. Stroke symptoms can include vision and motor impairments, sensory loss (numbness or loss of sensation) and cognitive impairments. Strokes/cerebral vascular accidents are a major cause of hemianopia (inattention/neglect to one hemisphere of vision). Other symptoms include memory loss, impairment of executive functions and aphasia, and muscle weakness or paralysis. An estimated 30 to 50% of stroke survivors return to driving, but many do not undergo any formal evaluation of their driving abilities or receive advice before resuming driving (see Schultheis & Fleksher, 2009).

Building upon these findings, a driving safety professional panel including physicians and driver rehabilitation specialists prioritized four conditions – including one not highlighted in the literature review – for the planned efforts to measure driving exposure and performance: **diabetes-related peripheral neuropathy**, **AMD**, **Parkinson's disease**, and **COPD**.

Following the panel proceedings, researchers developed a plan to measure driving exposure and performance of age-matched older adults with and without the targeted medical conditions using complementary data collection strategies. Naturalistic data collection obtained through instrumentation of study participants' cars, supplemented by data mining in the naturalistic driving study (NDS) database compiled in the SHRP2 provided exposure information. Certified driver rehabilitations specialists provided driver performance data, based on behind-the-wheel evaluations. A supplemental SHRP2 data mining exercise complemented this effort. Extensive clinical examinations documented medical conditions and medication use as well as a range of functional status measures for both the drivers recruited for instrumented vehicle exposure measures and CDRS evaluations and for those included in the SHRP2 NDS sample.

Collectively, the efforts outlined above were designed to address the following research questions:

- What medical conditions that are common among older adults are most likely to undermine their driving performance, and at what level of severity (for each condition) is it likely that safety will be compromised?
- What are specific effects of the most problematic medical conditions – defined in terms of both prevalence and potential for impairment – on driving performance?
- Do drivers with each of the most problematic conditions limit their driving exposure to reduce risk? If so, how?
- To what extent and in what ways do professionals at continuing care retirement centers (CCRC) identify medically at-risk older drivers and interact with them and their families to help them adjust driving habits or to cease driving?

Driving Safety Professional Panel

This section summarizes the discussion and conclusions of 12 driving safety professionals who provided first-hand knowledge about their experience regarding the effects of medical conditions and medications on driving performance, particularly among older drivers. This meeting built upon the findings of the literature review, which identified eight medical conditions as candidates for further study in this project: diabetes, dementia, glaucoma, hepatic encephalopathy, AMD, obstructive sleep apnea (OSA), Parkinson's disease, and stroke.

The purpose of the meeting was to select, ideally through a consensus among the expert panelists, *four* medical conditions to prioritize for driving exposure and performance data collection and analysis. This determination rested upon additional input from the experts about the types of hazardous errors they expected to see in drivers with each candidate condition, countermeasures and strategies drivers with these conditions might use to continue driving safely, and how likely the affected drivers were to incorporate such countermeasures.

Panel Procedures

Appendix A presents a list of panelists and the meeting agenda. The panelists included noted occupational therapists/driver rehabilitation specialists and physicians (many of whom serve on their State's DMV Medical Advisory Boards). In addition to the panelists, the meeting included the NHTSA task order manager, the NHTSA Older Driver Program manager, and staff from the project research team. The panel was moderated by the project principal investigator (PI).

Following introductions and a description of the project and purpose of the panel, the PI asked panelists to comment on the eight candidate conditions, as well as the six recommended for exclusion based on the literature review, and whether other conditions merited further study. The initial discussion incorporated three decision factors considered critical in selecting the final four conditions:

1) the severity of the crash risk associated with hazardous driving errors linked to each condition;
2) the availability and effectiveness of countermeasures to mitigate each condition; and
3) the anticipated prevalence of each of the candidate medical conditions in the foreseeable future.

After discussion, the panelists ranked the candidate conditions separately for two of these three factors, concern about crash risk and anticipated prevalence. Later, participants generated a composite ranking, and discussed the tradeoffs in decision factors, to establish a clear rationale for selecting four medical conditions for further study. The panel closed with a discussion of the research challenges and possible solutions as well as preliminary inclusion and exclusion criteria for the four selected medical conditions.

Panelists' Feedback on Literature Review

Panelists first commented that physicians are often unaware of the effects of medical conditions on driving performance and do not always associate medical conditions (diagnoses) with functional impairment. Physicians on the panel commented that physicians generally receive limited training relating medical conditions to driving and do not consistently counsel patients about how medical conditions may affect function, including driving performance, unless the condition is severe.

Panelists broadly agreed that one of the eight candidate conditions should be removed: *hepatic encephalopathy*. Physicians indicated that it was not common among the population of referred or crash-involved drivers, and when it was, it was treated like vertigo.

Next, panelists discussed several medical conditions as potential research priorities that were not on the list of candidates emerging from the literature review: *epilepsy*, *substance abuse*, *depression*, *hemaniopia*, *cataracts*, *retinitis pigmentosa*, and *chronic obstructive pulmonary disorder (COPD)*. Following a discussion of each, only COPD remained on the list of candidates. Due to its prevalence in the older population and its potential impairing effects on cognition, panelists indicated that new information on the effect of COPD on driving performance and exposure would be a valuable contribution to the evidence-based literature and would be useful to physicians in counseling their COPD patients about driving.

Panelists also reviewed the table of conditions by prevalence included in the literature review and took issue with the prevalence estimates provided for obstructive sleep apnea (OSA). Physicians indicated that estimates of the population susceptible to having OSA and actually having OSA are two different things. The actual prevalence of those diagnosed with OSA is less than those susceptible to having it. A physician panelist estimated that 6 to 9% of the general population was diagnosed with OSA, and panelists agreed that prevalence estimates for this condition included in the literature review were high.

Panelists' Development of Recommendations

Level of concern about crash risk. For the eight conditions that remained on the list for consideration for further study – diabetes, dementia, glaucoma, COPD, AMD, OSA, Parkinson's disease, and stroke – the panelists considered the types of driving errors associated in the literature review with each condition and/or their observations in their own practices. This discussion formed the basis of a subsequent exercise to rank order these conditions in terms of their priority for data collection in this project. Table 1 presents specific effects on performance linked to the medical conditions remaining under consideration with additional notes summarizing panelists' concerns about why a given condition could lead to hazardous driving errors.

Table 1. Hazardous Errors Linked to Specific Medical Conditions

Medical Condition	Hazardous Errors Identified in Literature Review	Additional Hazardous Errors Identified by Panelists	Panelist Comments
Diabetes	• Loss of consciousness due to poor glucose control (e.g., driving over the centerline or off of the roadway edge) • Automatic driving during hypoglycemia (e.g., disorientation, lost, no memory of driving to destination)	• Sensory loss in feet (e.g., pedal confusion, late braking, unintended acceleration, and pressing both pedals at the same time)	• Loss of visual fields would need to be controlled or screened for in order to study the effects of just peripheral neuropathy. • Contrast sensitivity should be measured
Dementia	• Stopping for no apparent reason, often in unsafe circumstances • Failure to yield to oncoming traffic when turning left on green ball signal indication. • Unsafe gap judgment • Failure to check blind spots before merging or changing lanes • Erratic steering • Inability to monitor and control vehicle speed (too fast and too slow) • Drifting into other lanes or off road • Driving while pressing brake and accelerator simultaneously • Looking without seeing/poor scanning & observation of other traffic and signs • Failing to respond in time to avoid a crash; lack of anticipatory or defensive driving skills	• Pedal errors • Driving on the wrong side of the road (going the wrong way) • Confusion • Getting lost	• Very mild to mild dementia should be studied • Should be measured with the Clinical Dementia Rating Scale (CDR 0.5 to 1.0)
Glaucoma	• Slower speed • Lane boundary crossings • Longer brake response time to stop sign • Failure to see and yield to pedestrians • Failure to see and stop for a stop sign • Failure to yield to oncoming vehicles	• Difficulty merging and turning, particularly on multi-lane roads • Difficulty with speed maintenance when moving between sunny and cloudy situations • Failure to see signs, resulting in speeds not appropriate for posted speed limits	
Age-Related Macular Degeneration	• Delayed braking response times to stop signs • Driving too slowly • Crossing edgelines and centerlines • Failure to check blind spots while merging	• Driving through stop signs and traffic lights (central field deficits) • Hitting pedestrians and cyclists (contrast sensitivity loss)	
Obstructive Sleep Apnea	• Centerline and edgeline crossings • Large, erratic steering movements (post-microsleep as correction for lane deviations) • Failure to maintain speed (frequent and variable speed adjustments)	• Lack of awareness leading to vigilance problems • Any of the errors listed for dementia can occur with severe untreated OSA • Slowed cognitive processing, resulting in staying stationary when a traffic light turns green or the left turn arrow is illuminated • Violations of lane assignment signs and pavement markings	• Would be interesting to look at CPAP and non-CPAP-treated patients • Should be dropped from further study because more prevalent in the young- and middle-aged population

Medical Condition	Hazardous Errors Identified in Literature Review	Additional Hazardous Errors Identified by Panelists	Panelist Comments
Parkinson's disease	• More likely to make tactical errors (e.g., failure to obey rules of the road, speed, and basic driving maneuvers) than strategic or operational errors • Slow brake reaction time • Lane observance errors • Stop sign errors • Turn and lane change errors • Speed control errors (too slow) • Begin deceleration closer to traffic signals and stop beyond the optimal position for signals compared to controls • More at-fault safety errors compared to controls (erratic steering, lane deviation, shoulder incursion, stopping or slowing in unsafe circumstances, and unsafe intersection behavior) during a sign identification task and a navigation task	• Slow decision time to brake (cognitive) and slow to initiate leg movement for braking (physical) • All the hazardous errors made by patients with dementia • Slowness of movement when checking blind spots and making lane changes, so that when they finally make the maneuver, the traffic situation has changed	
Stroke	• Erratic steering • Lane deviation • Shoulder incursion • Stopping or slowing in unsafe circumstances • Unsafe intersection behavior	• Hemianopia/visual field loss errors	• Specify a post-stroke interval to make sure function has stabilized • With a small sample size, probably better to specify one side of the brain to narrow the focus on impairments
COPD	Condition added by panelists	• All errors listed for dementia • Lack of endurance and fatigue leading to slower reaction times predominantly during transitions in and out of vehicle and during parking maneuvers • Temporary lapses of attention leading to lane position deviation, delayed reactions at intersections, navigation errors • Anxiety resulting in slowing on approaches to intersections "so nervous they can't drive straight" • Oxygen storage in vehicle may interfere with vehicle control	

Each panelist indicated their level of concern about each medical condition, based on the likelihood that it would impair driving performance and result in increased crash risk. They rated conditions on a scale of 1 (lowest level of concern) through 8 (highest level of concern).

Figure 1 presents the results of this exercise, averaged across the 12 panelists. Dementia received the highest level of concern for crash risk and the lowest variability in rank across all panelists. Parkinson's disease and stroke followed as the second- and third-ranked conditions raising panelists' concern for crash risk, with very similar averages, with stroke receiving less variability in rankings. Diabetes followed as the fourth-ranked condition of concern, COPD as fifth, and OSA as sixth. The two vision conditions, AMD and glaucoma, ranked seventh and eighth in concern based on likelihood of increased crash risk.

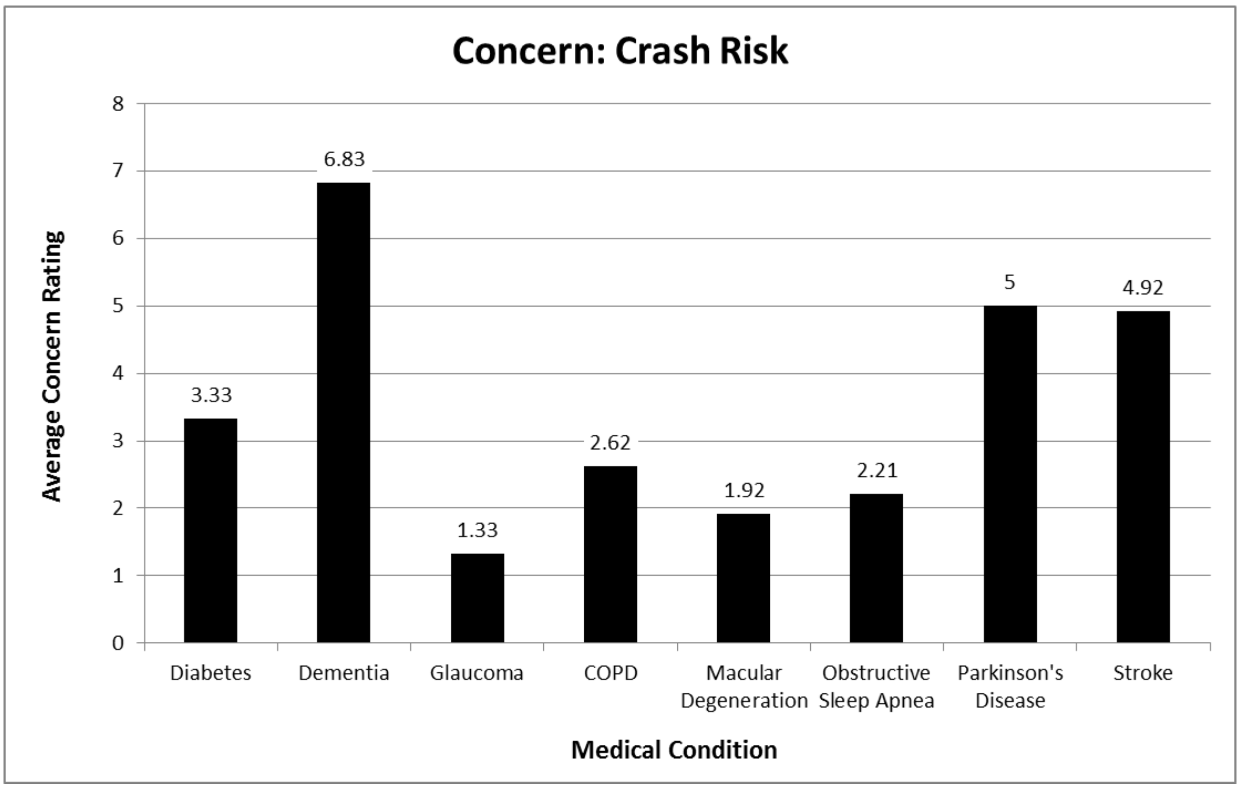

Figure 1. Panelists' ratings indicating level of concern for crash risk, by medical condition.

Availability of countermeasures. The panel discussion next focused on the availability of countermeasures for each medical condition and the likelihood drivers would implement them.

Diabetes. Panelists agreed that physicians, including podiatrists, do not talk to patients about diabetes and driving. They noted that if physicians would link proper diabetes management to retaining driver's licenses, patients would be more likely to implement physicians' recommendations for treatment. The CDRSs pointed to the American Podiatric Association (APA) as a particular physician group that should be targeted for education. APA physicians measure foot sensation and promote proper foot care. However, they may not link loss of foot sensation to impaired driving ability or know that there is equipment available to compensate for peripheral neuropathy (e.g., hand controls), so they don't consistently refer patients to CDRSs for evaluation for hand controls. Panelists noted these countermeasures:

- Using hand controls as a countermeasure for peripheral neuropathy;
- Checking blood sugars before driving (and stopping to re-check them on long trips)
- Teaching drivers with diabetes to respect the disease and manage it by adhering to their diet, eating regularly, and using their medications appropriately.

Dementia/mild cognitive impairment. Patient awareness of the effects of dementia on driving in the very early stages of dementia is important because drivers are more likely to accept restrictions and eventual loss of licensure when they have been involved in the discussions and planning. Panelists offered that some States restrict people with mild levels of dementia to driving in familiar areas, but others do not because of concern that people may forget they have driving restrictions. Finally, one CDRS indicated that it's not just the diagnosis that needs to be considered but also the deficits, particularly for drivers who have no insight into their impairments so cannot compensate. Panelists noted that medications have been a minimally effective treatment and little is known about their effect on driving safety.

Countermeasures for drivers with dementia include:

- Frequent re-evaluations of driving performance,
- Patient and family education about dementia and planning to meet the person's mobility needs when they can no longer drive safely.
- Driver education for patients with mild cognitive impairment to help counteract bad habits that impact time for decision-making. As an example, one CDRS taught clients to stop far behind a leading vehicle so that they could see that vehicle's tires.
- An electronic device that would allow families to find the vehicle if a driver with mild dementia gets lost.
- Cognitive retraining to address age-related slowing in processing speed and possibly for patients recovering from strokes and traumatic brain injury, although its effectiveness in patients with mild cognitive impairment or dementia is not known.

Glaucoma/AMD. Panelists noted many countermeasures for drivers with glaucoma:

- Trip planning, including driving in familiar areas, during the daytime, in good weather and good visibility conditions, and driving without passengers.
- Keeping glasses prescriptions current for best corrected refractive error, coupled with filters for glare control (the eyecare specialist selects filters for use on cloudy days and sunny days for use in wrap-around sunglasses), and bioptic telescopic lenses.
- Replacing progressive lenses with distance only lenses because of the blur in the sides of progressive lenses.
- Teaching visual scanning strategies to accommodate visual field loss.
- A GPS with verbal directions to help with navigation (with instructions not to manipulate the device while driving).

Sleep apnea. Panelists noted that there are few countermeasures for sleep apnea and considered drivers unlikely to implement them. These include:

- Using a continuous positive airway pressure (CPAP) machine, which panelists noted that people do not like to use even though they are quite effective. CPAP requires two weeks of nightly use to become effective, and only one night of non-use renders them ineffective. Convincing patients to understand the disease, its effects on driving, and how CPAP can improve performance may increase compliance.
- Weight loss was also mentioned as a countermeasure, but panelists considered drivers unlikely to implement it.
- Paying close attention to driving close to home because people often relax their vigilance within a mile or two of home.

Parkinson's disease (PD). Low-tech adaptive equipment was offered as a counter-measure for drivers with PD. Specifically:

- Use mirrors to help with blind spots and chest straps for involuntary movement/ dyskinesia and postural support. These are easily accepted by patients, but physicians aren't aware of such countermeasures and don't counsel patients or refer them to driving evaluators.
- Plan trips to limit driving, use less complicated routes, drive in only in familiar areas, and choose times to drive when feeling less impaired by medications or the disease (driving during "on" times). Panelists noted that this works well early in the disease progression for those who are aware that they have "highs" and "lows." Drivers can check in with a significant other to confirm self-perception of their more capable times.
- Get regular checkups with physicians and rehabilitation specialists.
- Do exercises to amplify movement and improve postural control.

Panelists added that some Parkinson's medications produce impairing side effects, such as sudden onset of sleep, hallucinations, and dyskinesia. Driving under these conditions is not safe.

Stroke. Panelists indicated that there is great potential for remediation for patients who have had strokes but that they should delay driving (instead of canceling driving) until they fully recover from the event. Next, they should have an evaluation to identify any need for adaptive equipment, and if so to undergo training. One CDRS indicated that cognitive retraining can be effective for some stroke patients.

Chronic obstructive pulmonary disease (COPD). Panelists noted that it is important for people with COPD to keep their oxygen saturation above 90% – some physicians have stated that oxygen levels shouldn't drop below 92% – due to psychomotor slowing when oxygen levels drop. Panelists suggested many countermeasures for drivers with COPD:

- Stop smoking.
- Use oxygen while driving; a finger clamp allows measuring oxygen levels in the car.
- Keep a short-acting inhaler available at all times.
- Use energy conservation techniques, such as lowering hand/arm position on the steering wheel, use of power steering, resting after transferring into the car and taking deep breaths before beginning driving.
- Do not drive on hot, humid days or cold days (due to the bronchospastic component of COPD), and warming the car interior before entry in the winter and cooling with the air conditioner before entry in the summer.

Anticipated prevalence of candidate medical conditions. Panelists rated the eight medical conditions to indicate their level of concern about each of the medical conditions based on their *anticipated prevalence in the next 10- to 20 years*.

As COPD was not a condition described in the literature review, panelists conferred about the best estimates for its prevalence before undertaking the rating exercise. Citing current literature (Akinbami & Liu, 2011), they agreed that the best evidence available indicated that COPD was highest among women 65 to 84 years old (10%), and among men 75 to 84 (11%). Physician panelists noted a controversy in the criteria and definition of COPD, so prevalence estimates may vary. They also mentioned that the prevalence of COPD in the older driver population, while high, may not increase at the same rate as other medical conditions because of attrition due to death with this disease. However, with a decrease in smoking, this too may change.

Figure 2 presents the results of this exercise, averaged across the 12 panelists. As with the ratings for crash risk, dementia emerged as the condition of top concern for safety, based on the anticipated prevalence of this condition in the older driver population. Diabetes and stroke were rated second and third; both conditions were also among the top four for crash risk concern.

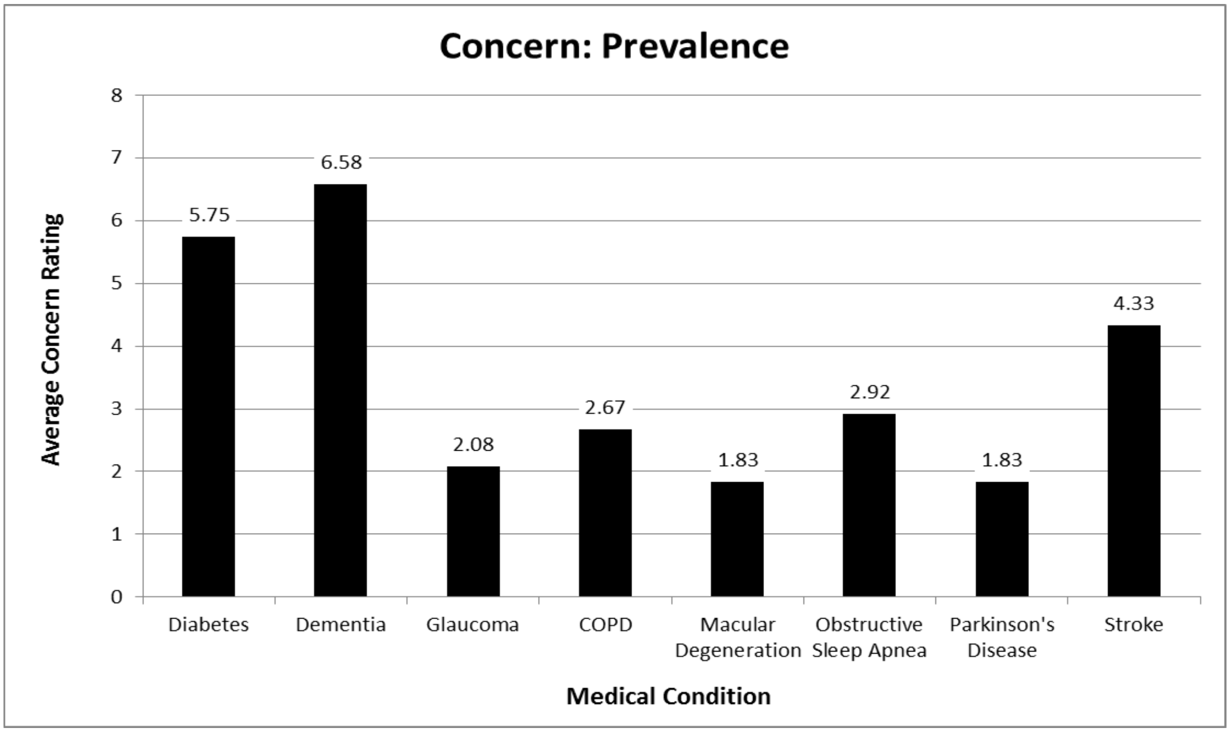

Figure 2. Panelists' ratings indicating level of concern based on prevalence, by medical condition.

OSA was rated as fourth, followed by COPD, glaucoma, and AMD. Parkinson's disease was ranked last in level of concern based on prevalence; this condition represents the largest change in ranking compared to concern for crash risk, where it was ranked second highest.

Overall prioritization of medical conditions. Project staff presented the combined average rankings of the eight medical conditions across the two decision criteria (likelihood of errors leading to crashes and anticipated prevalence) with equal weighting of both factors. The results of these combined rankings are presented below in Figure 3.

Dementia, stroke, and diabetes ranked first, second, and third, remaining among the top four conditions as when ranked on the individual criteria for crash risk and prevalence. Parkinson's disease moved into fourth place. COPD and OSA were ranked fifth and sixth, while the two vision conditions, AMD and glaucoma, ranked seventh and eighth respectively.

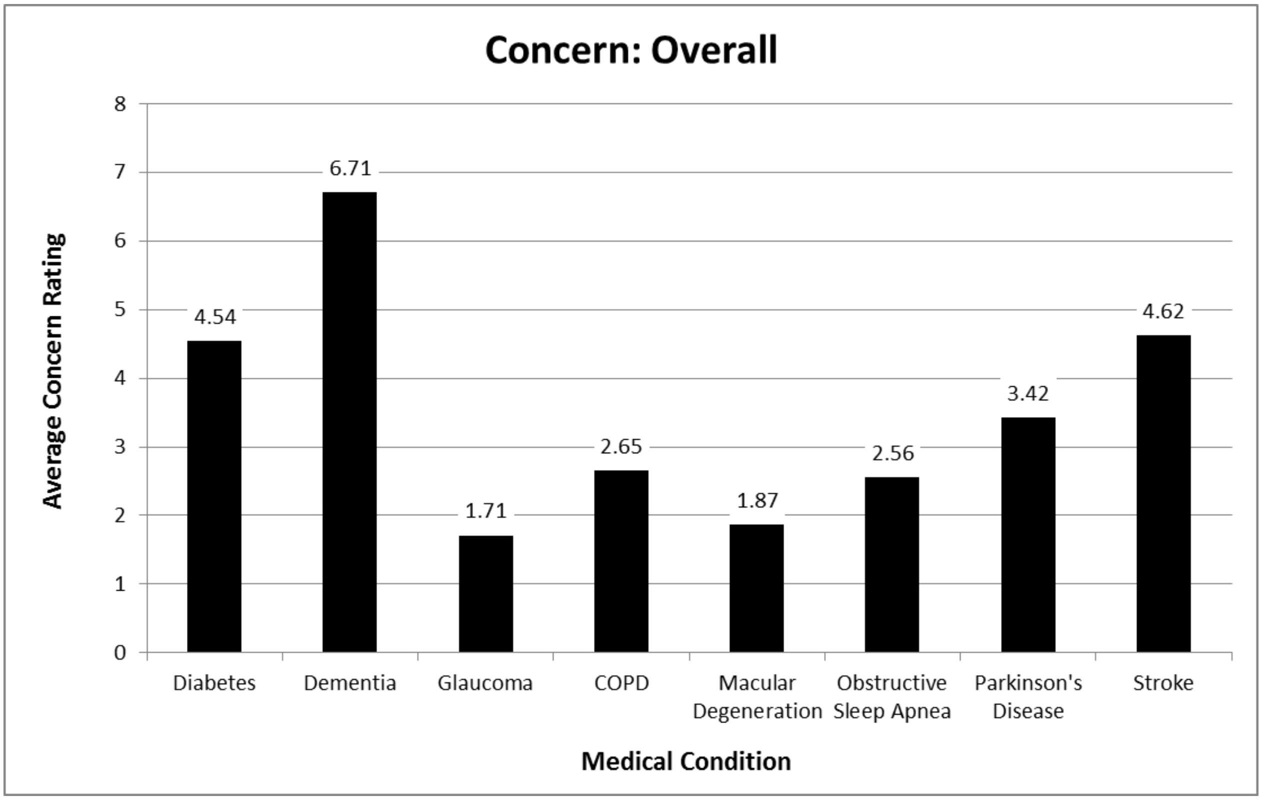

Figure 3. Combined ratings for crash likelihood and prevalence, weighted equally.

Panelists agreed that the conditions selected for data collection in this project should be those where *(1) the knowledge gained would have the biggest impact on the medical community's need for information to counsel their patients; (2) there are gaps in the evidence-based data on driving safety;* and *(3) it was feasible to obtain meaningful and interpretable results, taking into account our planned research design with limited sample sizes.*

Although the two rating activities did not place COPD among the top four conditions of concern for crash risk or prevalence, panelists agreed that there is a glaring hole in the evidence-based knowledge about driving safety and COPD. Patients with COPD comprise a large proportion of physicians' caseloads, but physicians are not aware that the condition might increase driving risk based on its effects on cognitive function (particularly encephalopathy, but also inattention and psychomotor slowing).

Panelists also agreed that although the two vision conditions were ranked last in level of concern based on crash risk and prevalence, physicians and eye care specialists were not addressing the driving risks of people with these conditions. Often driver rehabilitation specialists are the first professionals who relate these functions to driving safety for their clients. Panelists reported that physicians typically clear referred patients to drive as long as they meet the acuity standard, even when they have significantly restricted visual fields and/or very poor contrast sensitivity. Ophthalmologists did not address driving, and as a result, DMVs issued unrestricted licenses to these drivers.

Panelists agreed that physicians have limited knowledge and therefore can provide limited patient education in the area of visual deficits (visual fields and contrast sensitivity) that could be addressed by including a visual condition in this study. The vision specialist indicated that AMD, which is associated with poor contrast sensitivity, would manifest itself even during the daytime as a driver moves between bright sun and shadows. Thus, drivers would experience the effects during times that older adults normally drive (daytime and in good weather). Although AMD is less prevalent than glaucoma, its manifestations are more severe. In addition, including a glaucoma group in the study would require expensive equipment (e.g., Goldman perimeter) to obtain an accurate measurement of visual fields.

Although dementia was rated as a top concern and panelists agreed that there is a considerable lack of awareness among physicians about mild cognitive impairment and driving, they also agreed that dementia should be excluded as a priority for data collection in this study on the basis of the longevity of driving by this population. Once diagnosed with dementia, driving cessation usually occurs within several years. On the other hand, some argued that getting these drivers to stop driving is often difficult and it would be useful to have performance data to determine when it becomes unsafe. After further discussion, panelists agreed that with the small sample size planned for this study (20 subjects per medical condition), the findings may provide no information beyond what is already known. Dementia is a condition with a greater knowledge base regarding driving safety than most other conditions. Another reason to exclude it from further study in this project was that it has the fewest countermeasures available for implementation.

While stroke was a high concern based on crash risk and prevalence, panelists agreed that the generalizability of the findings would be unclear given the large variability in impairment caused by stroke and the small sample size planned for this study. Panelists indicated that Parkinson’s disease, like stroke, can affect both physical and cognitive function and requires driver awareness of their impairments for safe driving. They suggested including only one of these conditions for study and argued that Parkinson’s disease would be a better choice because it is a more defined condition.

Diabetes remained in the list of conditions recommended for further study because it is prevalent and increasing in the older population. Because of the limited sample size, panelists recommended careful inclusion criteria focusing on chronic problems (end organ disease), rather than acute problems (hypoglycemia), and that the study should focus on peripheral neuropathy (loss of foot sensation) rather than the visual effects of diabetes (diabetic retinopathy).

Finally, panelists agreed that OSA should not be considered for further study in this project. The condition is already monitored (at least for commercial vehicle operators), and it is less prevalent in the older population than in younger and middle-aged people.

Inclusion/exclusion criteria for sample recruitment. The meeting concluded with a discussion of inclusion and exclusion criteria for the four medical conditions recommended for the following phase of this project: diabetes with peripheral neuropathy, AMD, Parkinson's disease, and COPD.

Agreed-upon inclusion criteria for all four medical conditions groups (and controls) included age (60 to 90 years old) and visual acuity (the State DMV requirement in South Carolina, which is 20/70 or better in one eye, for anything short of blindness in the other eye). Exclusion criteria for all study groups included other medical conditions that could affect driving performance (dementia, glaucoma, OSA, stroke, traumatic brain injury, multiple sclerosis, substance abuse) and previous driver interventions (except for cataract removal).

In addition, panelists agreed that sex was not an important selection/ recruitment criterion for any group. Panelists recommended that contrast sensitivity be measured and documented but not be used as an inclusion or exclusion criterion except for the AMD group. Regarding the planned road test, panelists recommended that parking lot and parking garage maneuvers should be included because these may uncover performance deficits for the diabetic neuropathy group (pedal errors), the COPD group (fatigue), and the AMD group (difficulty controlling speed when moving between shade and sun).

Inclusion and exclusion criteria specific to each of the prioritized medical conditions, as recommended by the driving safety professionals in this panel, are listed below.

Diabetes-related peripheral neuropathy

Inclusion Criteria

- Sensory loss in feet, measured with 8g Weinstein monofilament.
- Allow *central visual* field impairment (but do not require it as inclusion criterion) because it may be difficult to recruit subjects who have peripheral neuropathy who do not also have diabetic retinopathy. Many drive safely with *central visual* impairments.
- With or without insulin therapy.

Exclusion Criteria

- Peripheral visual field loss, defined as ever having been treated for peripheral visual field loss or measured with automated perimetry as less than 120 degrees, following referral.
- Hand controls.

Age-related macular degeneration (AMD)

Inclusion Criteria

- Non-neovascular form (dry form).
- Allow use of sunglasses for drivers who usually wear them.
- 50% of sample with less than 1.0 log contrast sensitivity (measured with MARS or Pelli Robson chart).

Exclusion Criteria

- Wet form of AMD.

Parkinson's disease.

Inclusion Criteria

- Mild and moderate stage Parkinson's disease.

Exclusion Criteria

- Cognitive effects of Parkinson's disease.
- Clients who have undergone LSVT BIG Training.
- Use of chest straps for trunk stability.
- Parkinsonism (include Parkinson's disease only).

Chronic obstructive pulmonary disease (COPD).

Inclusion Criteria

- Medical Research Council (MRC)[1] classification 4 and 5 with oxygen (or 50% of the sample with oxygen, 50% without oxygen).
- May use a wheelchair for fatigue/endurance issues.

Exclusion Criteria

- Use of wheelchair for driving or for lower limb impairments.

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[1] The MRC breathlessness scale includes five statements describing the range of respiratory disability from none (Grade 1) to almost complete incapacity (Grade 5). Subjects choose a phrase that best describes their condition, e.g., "I only get breathless with strenuous exertion" (Grade 1) or "I am too breathless to leave the house" (Grade 5). The score is the number that best fits the patient's level of activity. (See Stenton, 2008.)

Driving Exposure and Performance Measurement Methods

The research methodology includes a description of the study samples, driving exposure data collection procedures, in-clinic measures of functional status, and driving performance data collection. The research team obtained driving exposure and driving performance data through controlled and naturalistic field studies as well as through extractions from the SHRP2 naturalistic driving database maintained by the Virginia Tech Transportation Institute (VTTI). The field and in-clinic data collection procedures were reviewed and approved by Institutional Review Boards at Clemson University and the Greenville Health System; the Chesapeake IRB determined that the analyses of SHRP2 data were exempt from IRB oversight.

Study Samples

Primary sample. Researchers recruited participants for the field and in-clinic data collection efforts primarily through referrals to the Driving Rehabilitation Program at the Roger C. Peace (RCP) Rehabilitation Hospital in Greenville, SC. All referrals were screened by hospital staff for potential enrollment in the study. Members of the research team met with physicians and staff within the Greenville Health System (GHS) to inform them about the study opportunity and requirements for participation. Recruitment flyers were posted in physicians' offices in the departments of family medicine, internal medicine, geriatrics, and other locations within the hospital that experience a large volume of older adult foot traffic, including the hospital's community wellness center and volunteer office. Additionally, all individuals referred for a driving evaluation at RCP were screened by research team members for potential study participation.

Because it was unknown exactly when individuals with conditions of interest would present, this study relied on a "rolling recruitment" method where subjects were recruited for any condition of interest – AMD, COPD, Parkinson's disease, diabetic peripheral neuropathy, or healthy older controls – at any time. Research staff contacted referred potential participants via phone to confirm that they met general inclusion/exclusion criteria. Individuals who appeared to meet study criteria were scheduled for an appointment to complete the consent form and have the in-vehicle (exposure data collection) instrumentation installed in their own cars. Inclusion/exclusion criteria were as follows:

<u>Inclusion Criteria</u>

- 60 and older
- Valid driver license
- Minimum of three years of driving experience
- Drove to/from a minimum of 3 destinations (3 separate trips) per week
- Met the South Carolina vision requirement for licensure
- Could read, write, and speak English
- Was available to complete the study within 8 weeks
- Drove a (2- or 4-door) passenger vehicle (rather than an SUV or pickup truck) as their "everyday vehicle" (i.e., the same class of vehicle they would drive during the on-road performance evaluation)

- Able to wear comfortable, snug-fitting shoes such as tennis shoes or walking shoes (no flip-flops, sandals, high-heeled shoes, clogs, work boots, etc.)
- Met medical criteria to fall within only one of the five study groups
- Gave informed consent to participate in the study

Exclusion Criteria

- Had a driving evaluation administered by a driver rehabilitation specialist (DRS) within the previous year
- Was actively receiving treatment from an occupational therapist (OT)
- Used orthopedic support braces for right lower extremity (casts, splits, boots) at the time of data collection
- Had been told by their doctor not to drive, for any reason
- Was absent proprioception[2]
- Had a reported history of stroke or seizure disorder, dementia, glaucoma, obstructive sleep apnea, substance abuse, or traumatic brain injury
- Had undergone LSVT BIG training
- Had had any injury or problem with the right leg in the previous year that affected the ability to walk
- Used hand controls or a left-foot accelerator to drive, or chest straps for trunk stability

Additional characteristics for the study groups:

- Participants qualified for the diabetes with peripheral neuropathy group reported symptoms of peripheral neuropathy in their feet, and did *not* have a diagnosis of Parkinson's disease, AMD, or COPD.
- Participants qualified for the Parkinson's group had a diagnosis of mild or moderate stage Parkinson's disease (but not Parkinsonism), and did *not* have a diagnosis of diabetes, AMD, or COPD.
- Participants qualified for the AMD group had the non-neovascular form (dry form), and did *not* have a diagnosis of diabetes, Parkinson's, or COPD.
- Participants qualified for the COPD group had a 3, 4, or 5 on the Medical Research Council Dyspnea Scale, and did *not* have a diagnosis of diabetes, Parkinson's disease, or AMD. COPD participants could use a wheelchair for fatigue/endurance issues but must have been able to stand and walk from the wheelchair to the vehicle and transfer independently.

At the first study visit, a researcher explained the study in detail, and the potential participant was given the opportunity to read the consent form and ask questions regarding the study before signing. All participants received a copy of the consent form.

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[2] Proprioception is sometimes defined as the ability to sense stimuli from the body regarding position, motion, and equilibrium. Even a blindfolded person knows through proprioception if an arm is above the head or down by the side of the body. Proprioception can be disturbed by many neurological disorders and can sometimes be improved through a type of specialized type of sensory integration occupational therapy.

The research team also recruited participants into a comparison group of healthy, normally aging drivers through the flyers posted in physicians' offices in the Greenville Hospital System. These subjects similarly met the inclusion and exclusion criteria described above, *except* they presented without a diagnosis of neuropathy, Parkinson's disease, AMD, or COPD; and had not been diagnosed with any other medical or neurological condition that, in the opinion of the referring physician, was likely to impact their ability to drive safely. These study participants are referred to as "controls" in this report.

Augmented sample. The Primary Sample recruited using the method described above was supplemented by incorporating 24 control drivers and 7 with peripheral neuropathy from another NHTSA project carried out simultaneously at RCP Hospital, called "Older Drivers' Foot Movements."[3] The research team augmented the sample in this way because the earlier study involved the same research team and recruiting methods in the same hospital setting as the current study. Both studies assessed drivers using the same clinical and on-road evaluation techniques by the same staff. However, inclusion criteria in the "Older Drivers' Foot Movements" project did not dictate that those presenting with peripheral neuropathy have a diagnosis of diabetes. Also, no exposure data were collected in that project, so no exposure analysis was possible for the Augmented Sample.

SHRP2 sample. The second Strategic Highway Research Program (SHRP2) Naturalistic Driving Study (NDS) populated a comprehensive *naturalistic driving database* including roadway, driver, and environment data to help analyze the role driver behavior plays in crash risk. SHRP2 included 3,247 drivers from six states. Overall, the study's participants traveled 49,657,037 miles during 6,650,519 trips; their own cars were instrumented with cameras, radar, and other sensors. Detailed information on the SHRP2 NDS in-vehicle data acquisition systems (DAS) and data collection methodology can be found in the *Naturalistic Driving Study: Field Data Collection Report S2-S07-RW-1* (Blatt et al., 2015) and other published reports available at the Transportation Research Board's SHRP2 publication site.[4] In addition, a large percentage of the roadways traveled upon by the drivers enrolled in the SHRP2 study were mapped in order to record various geometric design characteristics, and these data were compiled in a *roadway information database*. Researchers in the current study compared SHRP2 drivers with and without (self-reported) medical conditions on selected measures of exposure and performance.

All SHRP2 study participants completed tests assessing perception, cognition, and psychomotor and physical abilities. Specific tests included a clock drawing test, Conners' Continuous Performance Test, Optec 6500 Vision Testing (for acuity, day and night contrast sensitivity, color vision, and peripheral vision), the Jamar Grip Strength test, and a computer-based functional screening program that included the Trail-Making Tests Parts A and B, the Useful Field of View (UFOV) subtest 2, and the Rapid Pace Walk test. Researchers documented participants' health, medical conditions and medications, and driving knowledge and history. Most important, self-reported medical conditions among the SHRP2 sample included *Parkinson's disease, peripheral neuropathy,* and *COPD*, three of the four medical conditions of interest in this project.

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[3] NHTSA Contract DTNH22-11-D-00223, Task Order 2

[4] www.trb.org/StrategicHighwayResearchProgram2SHRP2/PublicationsSHRP2.aspx

The research team obtained SHRP2 data for the planned analyses in this project from the Virginia Tech Transportation Institute (VTTI). VTTI manages and coordinates researchers' access to the SHRP2 NDS database. This database is vast, containing personally identifying information (PII) including video recordings of participants, as well as exposure and vehicle kinematic data. VTTI protects PII by de-identifying drivers through driver ID numbers (e.g., Driver 001, 002, 003, etc.). The InSight SHRP2 NDS website[5] provides details and examples of the data collected, along with data dictionaries and instructions for processing data requests. VTTI required the PI to execute a data-sharing agreement before performing the extraction and delivery of the specific data elements necessary for each approved analysis.

The data-sharing agreement executed with VTTI defined four analysis groups for *broad sample analyses* using data from all SHRP2 study locations. A fifth group was defined for a *site-specific analysis* keyed to merging maneuvers on freeways in a single state (Florida).

Broad sample analysis. For the broad sample analysis, the research team applied the following inclusion/exclusion criteria. First, data were requested only for drivers 65 and older. Next, controls (n = 129), drivers with Parkinson's disease (n = 7), drivers with peripheral neuropathy (n = 46), and drivers with COPD (n = 25) were identified according to these data specifications (all medical conditions were self-reported):

Controls (healthy older drivers)

Day Far Acuity Both Eyes = 20/50 or better
Peripheral Vision Right Eye = 70 degrees or more
Peripheral Vision Left Eye = 70 degrees or more
Heart Conditions = none
Respiratory Conditions = none
Nervous System and Sleep Conditions = none
Brain Conditions = none
Limited Flexibility = No
Severe Arthritis = No
Muscle and Movement Disorders = No
Other Musculoskeletal Disorders = No
Other Heart Conditions = No
Other Brain Conditions = No
Other Nervous System or Sleep Conditions = No
Other Respiratory Conditions = No
Multiple Medical Conditions = No
Multiple Medications = No

Parkinson's

Day Far Acuity Both Eyes = 20/50 or better
Peripheral Vision Right Eye = 70 degrees or more
Peripheral Vision Left Eye = 70 degrees or more
Nervous System and Sleep Conditions =
Parkinson's Disease
Multiple Medical Conditions = No
Multiple Medications = No

Peripheral Neuropathy

Day Far Acuity Both Eyes = 20/50 or better
Peripheral Vision Right Eye = 70 degrees or more
Peripheral Vision Left Eye = 70 degrees or more
Nervous System and Sleep Conditions =
Peripheral Neuropathy (any extremity)
Multiple Medical Conditions = No
Multiple Medications = No

COPD

Day Far Acuity Both Eyes = 20/50 or better
Peripheral Vision Right Eye = 70 degrees or more
Peripheral Vision Left Eye = 70 degrees or more
Respiratory Conditions =
Chronic Obstructive Pulmonary Disease
Multiple Medical Conditions = No
Multiple Medications = No

[5] https://insight.shrp2nds.us/home

Four drivers were inadvertently identified for inclusion in both the peripheral neuropathy and COPD groups as they had self-reported both conditions. These drivers were included in analyses using an aggregated Medical Conditions group but not in analyses specific to particular medical conditions.

The research team requested the following for all drivers in each of the four Groups above:

a) Trip data as required to provide specific SHRP2 variables and necessary calculations to generate the derived data elements identified by our research team.
b) Selected driver demographic information as it applies to drivers in each of the four Groups as defined by our research team.
c) A file containing selected safety information as it applies to drivers in each of the four Groups as defined by our research team.

See Appendix B for the specific SHRP 2 variables requested from VTTI for the broad sample analyses and the variable definitions.

Site-specific analysis. The drivers selected for the site-specific analysis were those who, among the four groups defined as described above, traversed one or more targeted ramp-freeway merge locations in the Tampa-St. Petersburg, FL area. Thirty-six older drivers from the SHRP2 NDS sample traversed a targeted freeway ramp, 13 with medical conditions (COPD, neuropathy, Parkinson's) and 23 without (controls).

The ramps targeted for data analysis were single lane entrance ramps and terminals of controlled access roads of functional class (FC) 1 and 2 that involve an entrance maneuver. Functional Class 1 roads allow for high volume, maximum speed traffic movement between and through major metropolitan areas. Access to the road is usually controlled. Functional Class 2 roads include roads used to channel traffic to Functional Class 1 roads for travel between and through cities in the shortest amount of time.

Out of the 99 FC1 and FC2 single lane Florida (Tampa/St. Petersburg area) ramps, 31 involved an entrance maneuver. These ramps included tapered and parallel speed change lanes, as well as loop and straight ramps. A consulting traffic engineer evaluated these ramps on the basis of their geometrics and general layout to discriminate categories of "less favorable" versus "more favorable" designs. The evaluation criteria reflected AASHTO guidelines for single-lane free flow terminals/entrances. Specifically, the minimum length of acceleration lane given by these guidelines in the *Green Book* (AASHTO, 2011) was compared to the available acceleration lane length.

For each study ramp, the minimum length given by the *Green Book* was compared to the sum of the length of the speed change lane (SCL), that is, the distance from the painted nose of the gore to the beginning of the taper (when the lane becomes narrower than 3.6m) and the distance from the controlling feature to the painted nose, to determine if it met the design criterion for the minimum acceleration length. The controlling feature is the ramp curvature (when $R \leq 300m$) or the crossroad terminal. The painted nose is the location where the freeway edgeline and ramp meet. The research team selected 24 ramps for data analysis - 13 that were associated with more favorable design conditions and 11 that were associated with less favorable design conditions. A plan view of each ramp in the analysis set is presented in Appendix C.

Using the roadway information database, the research team provided VTTI with link IDs for each location/ramp of interest, including a reference GPS coordinate (node) corresponding to the tip of the painted gore at each junction. The study team asked VTTI to extract vehicle kinematic data (speed, acceleration, time headway, and braking events) for the 36 older SHRP2 drivers for each traversal of a freeway ramp targeted in the site-specific analysis. This data request specified the need for separate files for each driver at each site, one corresponding to the kinematic measures of interest during the 15 seconds *before* the driver passed a node and the other pertaining to the 15 seconds *after* passing the node.

Driving Exposure Data Collection Procedures

Technicians installed driving exposure data loggers in Primary Sample drivers' vehicles, and then they removed them after approximately one month of data collection.

The data acquisition system (see Figure 4) consisted of a GPS receiver, JPEG camera, accelerometer, micro-SDHC slot for local data storage, and OBD-II cord. The OBD-II port in each driver's car served as the power source for the data collection system and was used to detect when the engine was running in some makes/models. Figure 5 shows the data logger with the clear plastic cover to the side. Note that the cable attached to the top allowed this unit to be mostly hidden behind the rearview mirror.

Pre-installation configuration. The data logger was configured before installation in study participants' vehicles such that the device's firmware controlled its operation via vehicle status information obtained through the OBD-II port (from which it also drew power) or through information provided by accelerometer and/or GPS units contained within the logger. This information allowed the system to determine when the vehicle was moving and when it stopped – for long enough to define the end of a "trip" instead of a temporary stop, e.g., at a red light. This information was also used for power management so that camera/image and GPS data were being recorded and stored only when the car was being driven.

The data logger firmware looked for a file called "prefs.txt" in the root directory of the micro-SDHC card included in the device. If it existed, parameter settings were used to configure the device with respect to such operational variables as the accelerometer threshold to denote "start trip" and "stop trip" status, the interval at which the camera acquired images, and – critically – the "startup mode," which denoted whether vehicle movement information was acquired from the OBD interface or from the accelerometer. If the prefs.txt file did not exist, the system used default settings which specified an accelerometer threshold of 25 milli-G (where G is the gravitational constant), a camera image acquisition interval of 1 second, and the use of accelerometer information in startup mode.

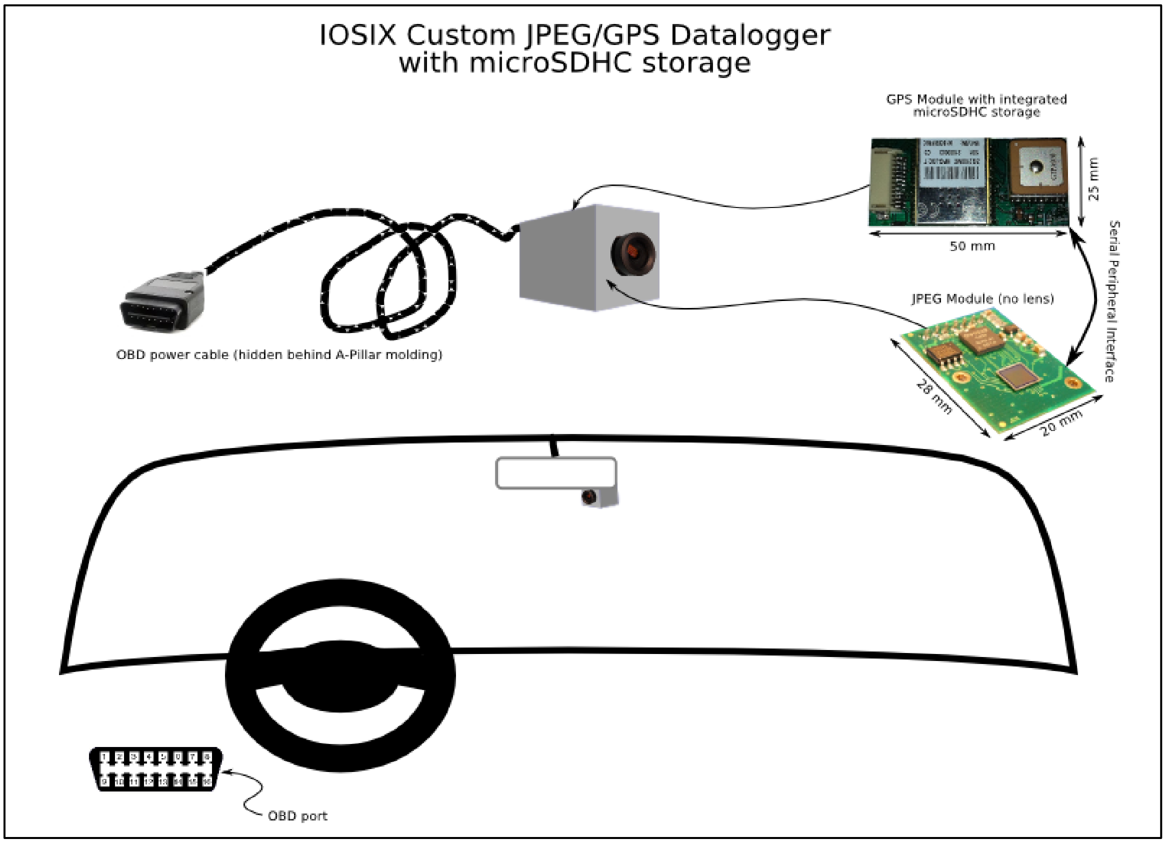

Figure 4. In-vehicle exposure data acquisition system.

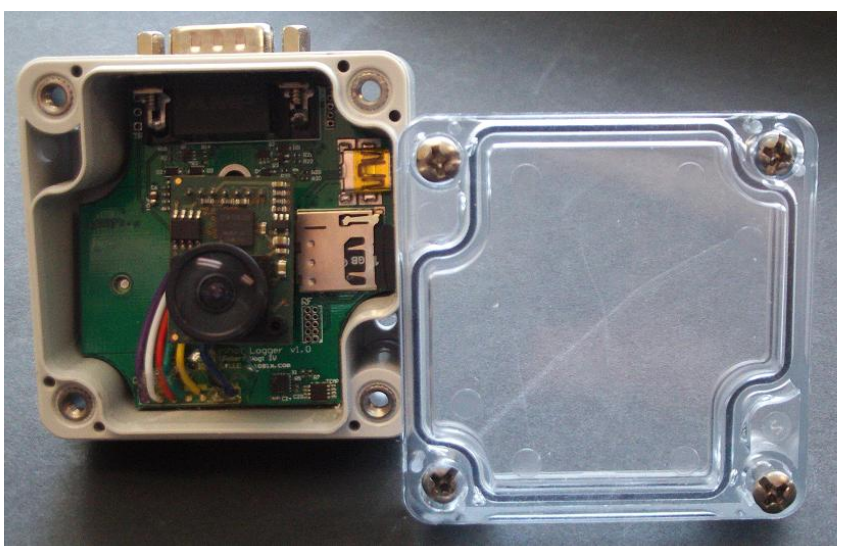

Figure 5. GPS logger and camera unit in data acquisition system.

Note that the data logger firmware only supported the subset of OBD-II port types found in the current fleet that employed the “CAN bus” (a subsystem that transfers data between components inside the microprocessor). Since the CAN bus didn't start appearing in cars until 2003, the OBD startup mode would not work in vehicles older than 2003. That is why the default setting for startup mode was to use the accelerometer. Some cars sold in the United States from 2003 through 2007 and ***all*** cars sold in the United States beginning in 2008 use the CAN bus.

For this study, a trip was determined to end when there had been no accelerations 25 mG or higher for at least 5 minutes. This threshold prevented stopping at traffic lights from producing a spurious trip break.

Installation and removal of exposure data collection system. A research team member greeted study participants as they arrived at RCP Hospital, explained the study, administered the informed consent, obtained signatures from the participant, and provided instructions to the driver. During these activities, the study coordinator requested the car keys in order for a technician, working in parallel, to begin instrumenting the participant's vehicle.

The installation consisted of testing the battery, mounting the data logger on the windshield, hiding the cable, and plugging the OBD cable into the vehicle’s OBD port. All of these steps were completed with the vehicle engine off. Installation time varied by vehicle but it took as little as 5 minutes or as long as 15 minutes depending on the difficulty hiding the cable, finding the OBD port, and attaching the enclosure to the windshield.

If the battery test indicated a bad battery, the participant was notified and asked for permission to replace their battery for the duration of the study. Technicians took care to preserve satellite radio and other vehicle settings prior to disconnecting the battery.

Step 1: Attach data logger to windshield. The data logger was mounted behind and, when possible, just to the right of the rearview mirror, so that the lens was just visible along the bottom edge of the rearview mirror; Figure 6 shows the data logger from the driver's perspective after installation. Anything hanging from the rearview mirror that could obstruct the camera view of the driver was relocated or the mounting location for the data logger was altered. Once the enclosure housing the data logger was attached, the camera was fairly easy to align because: 1) the camera lens was centered flat against the window on the enclosure and 2) the camera captured 130 degrees horizontally which made it relatively insensitive to alignment errors. The technician attached the logger securely using a suction cup with silicone sealer.

Figure 6. Data logger installed in vehicle.

Step 2: Hide the cable. The technician hid the cable behind panels along the edge of the windshield, panels along the edge of the door, and behind panels and carpeting under the dashboard. Any excess cable was tied together and tucked out of sight in a location under the dash that did not interfere with the fuse box and would not get damaged by motion of the pedals, emergency brake, or other mechanical interfaces.

Step 3: Plug in the data logger. The OBD-II port was typically located under the driver's side dashboard in vehicles built in 1996 or later. The logger simply plugged into the OBD-II port. Before plugging the logger into the vehicle, a micro-SDHC card was inserted into the micro-SDHC slot.

After a participant completed in-vehicle data collection, the driver returned to Clemson/GHS for equipment removal. A research team member unplugged the cable from the OBD-II port and pulled the cable out from under the molding around the windshield and A-pillar. The technician removed the suction cup from the windshield, scraped off any residual silicone sealant from the windshield, and replaced any items that were removed/relocated to prevent obstructing the camera during data collection.

Data processing. Analysts sorted raw data from the GPS+camera data logging system into separate year-month folders (e.g., 2012-APR), which contained separate month-day folders for each day of travel for each subject (e.g., APR-12). These month-day folders contained data streams separated by trip. As noted, trip start was operationally defined as acceleration greater than 25 milli-G and trip end as 5 minutes where GPS speed was 0 km/h or acceleration was less than 25 milli-G.

Data processing software created files from the raw GPS data containing:

- driver ID;
- trip number;
- latitude and longitude data for each trip, formatted for import into Google Earth;
- speed in miles per hour;
- total distance from beginning of trip; and
- a single keyhole markup language (KML) file containing all the GPS data for each trip for a driver.

Once imported into a database, these data were further processed to obtain additional variables including average trip speed, maximum acceleration, maximum deceleration, maximum speed and other descriptive statistics by trip for each subject.

The research team was able to view the KML in mapping programs such as Google Earth and ArcGIS Explorer Desktop. Figure 7 shows the combined KML in ArcGIS Explorer Desktop.

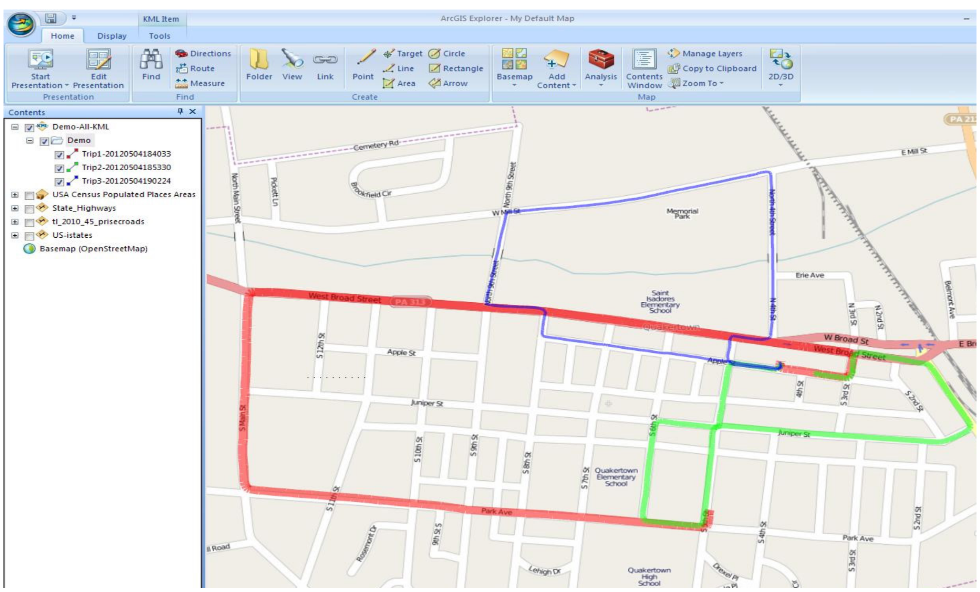

Figure 7. KML files displayed to show routes driven by test subjects.

The example in Figure 7 shows three trips with Trip 1 plotted in red with the widest line, Trip 2 plotted in green with a smaller width line, and Trip 3 plotted in blue with the thinnest line. The KML was structured so that one mouse click could turn on all trips, an individual trip, or a selected set of trips on/off on the map for each driver.

The camera captured snapshots (640x480 pixels, JPEG compressed) every second during a trip. These images were saved in a year-month folder and a month-day subfolder named using the same format as for GPS data; this permitted syncing the JPEG and GPS data for analysis since they both used identical GPS timestamps. Each snapshot was linked to GPS coordinates via the timestamp embedded in the filename. Knowing the GPS coordinates of each snapshot permitted the display of a camera view at all locations along a route where pictures were taken.

The image files for each trip were automatically processed and linked together in an AviSynth (.avs) file; this enabled the snapshots to be analyzed like a normal video but on a frame-by-frame basis. The data coder was able to view the AVS files using a program called VirtualDub (http://virtualdub.sourceforge.net/).

Figure 8 shows a frame in VirtualDub with the frame number (lower left) and timestamp (lower right) overlaid on the frame. Nighttime images sometimes required a brightness/contrast boost filter in order for the coder to identify the driver's face (e.g., if there were no street lights).

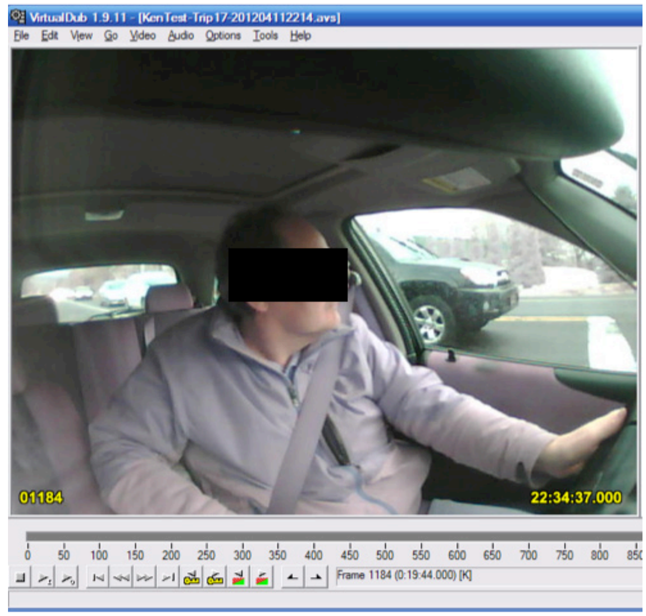

Figure 8. Example of AVS image data.

Data coding. A trained research assistant[6] coded image data (sequential still-frames); the same research assistant coded all of the video for all subjects to ensure consistency. For each valid trip (where a study participant was the driver), the following variables or conditions were coded: (1) trip distance; (2) trip duration; (3) trip length band; (4) time-of-day band; (5) road type; (6) the presence/absence of adverse weather (rain or fog); and (7) an indicator of route familiarity. Data coding details follow.

Total valid trips. Each trip was coded as valid or invalid. A valid trip consisted of a visible subject and a clear starting and stopping point. An invalid trip consisted of a driver other than the participant, a trip for the purpose of data collection device maintenance, instances where the camera was activated but vehicle was not in motion (e.g., parked in driveway or garage), and/or cases where the driver was not visible. A trip was also considered invalid if the GPS text file recorded a 0.0 mile distance. If fewer than 12 valid trips were recorded for a subject, that driver's data were not coded for analysis, as this violated a key inclusion criterion for study participation.

Trip distance. A trip began with the onset of the video data collection and ended when the ignition was turned off. For some trips, the GPS logger dropped the signal for a number of seconds and then picked it back up again. By viewing the AVS file, the data coder determined

[6] The data coder obtained certification through the Collaborative Institutional Training Initiative (CITI) course for Human Subjects Research in the social and behavioral sciences.

when such interruptions connoted a break in a single trip, versus separate trips, by noting the driver's clothes and the road surroundings as well as the KML route continuity. The coder determined a count of total trips and calculated average trips per day and minimum/maximum trip distance. To verify distance when there were GPS signal dropouts, the coder compared the GPS file with the KML file using Google Earth's ruler function; the coder was able to follow the route point-by-point to calculate the distance. The coder zoomed in to adjust the ruler's path for the most accurate result.

Time duration. The coder viewed each video frame-by-frame to ensure the trip was uninterrupted and calculated total time (hh:mm:ss) spent driving, based on the starting and stopping point of each trip. After each trip duration was determined, the minimum and maximum trip durations were noted, and average trip length was calculated.

Trip length bands. After confirming trip distance, the coder noted a trip length band for each trip. The bands, in miles, were as follows: <1, 1-2.5, 2.6-5.0, 5.1-10, 10.1-20, and >20. After each band was recorded, the percentage of trips per band was determined.

Time of day. The coder determined time of day from the time recorded on the AVS and KML files (recorded in Universal Time) present at the onset of the trip. Trips were then sorted into one of the following time-of-day categories: midnight to 10 a.m. (before 10 a.m.); 10 a.m. to 3 p.m.; 3 p.m. to 8 p.m.; 8 p.m. to midnight (after 8 pm). The coder calculated the percentage of trips in each time-of-day category.

Road type. The coder used the KML file and Google Earth's *street view* to determine road type. Road types included: *low-speed/residential*; *low-speed/commercial*; *arterial/multi-lane*; *2-lane rural highway*; and *limited access/freeway*. Low-speed residential locations included rural, suburban residential and urban residential areas. Low-speed residential roads were those in such areas with 25 to 35 mph speed limits and no stop-lights or businesses visible. Low-speed commercial included low-to-moderate capacity roads with 25 to 35 mph speed limits and visible stop-lights and/or businesses. Arterials were defined as multi-lane (usually two lanes in each direction) roadways with speed limits ranging from 35 to 55 mph. Two-lane rural highways were defined as roads with one lane in each direction (for the majority of the trip) and speed limits of 45 to 55 mph. Limited access/freeways were defined as roads with speed limits of 55 mph or greater and with dividers, ramps for on/off access, and/or no intersections. The coder used the Google Earth ruler function to determine distance driven (in miles), by road type. Distances by road type were summed to verify that they equaled the total miles driven (*distance* variable) for each trip. Because many subjects traveled the same roads, speed limit and road type for each road encountered were labeled in Google Earth to ensure consistency in coding.

Adverse (inclement) weather. Adverse or inclement weather included foggy, rainy, or wet conditions as determined by the coder seeing rain, or wet car windows or road surfaces when reviewing videos. The coder totaled trips with adverse weather and calculated the percentage of trips taken in adverse weather after reviewing all of a subject's videos.

Familiarity. Routes a driver followed more than once were classified as high familiarity, or "common." Coders identified common trips by looking at each trip overview on Google Earth (KML file) and identifying overlapping routes. Most trips were either entirely on a common or uncommon route. However, some trips were a mix of common and uncommon routes. In any event, the coder used the ruler function in Google Earth to measure the amount of miles driven for each part (common or uncommon) of the route. The coder then summed the miles driven on common and uncommon routes and calculated these measures as a percentage of total miles driven for each subject.

In-Clinic Measures of Functional Status

After the *Primary Sample* participants completed driving exposure data collection, they returned to the clinic to have the instrumentation removed from their cars and to complete an in-clinic functional evaluation session. The participants in the *Augmented Sample* completed the in-clinic session immediately after consenting to participate in the study. Participants from both subgroups were required to "pass" the in-clinic evaluation (i.e., to demonstrate the conditions and symptom severity levels of interest, without manifesting any exclusion criteria) in order to proceed to the on-road evaluation.

The in-clinic evaluation was a 2.5- to 3-hour session that began by a researcher recording each driver's medical history, including all medical conditions and medications. Then an OT performed a standardized assessment offered by the Driving Rehabilitation Program at RCP Hospital, which is comprised of a physical evaluation, a neuropsychological evaluation, a perceptual-motor evaluation, and a vision screening (conducted using a Stereo Optec 5000P vision testing machine). In addition, the OT recorded specific study-related measures including the participants' hip, ankle, and knee ranges-of-motion and limb segment lengths.

Specific tests conducted within each functional modality and relevant to the research objectives were as follows:

- Physical Assessments
  - Upper extremity: shoulder flexion, extension, adduction-abduction, internal rotation, external rotation; elbow extension-flexion; forearm supination and pronation; wrist flexion and extension; and digit strength. Range of motion scored as within normal limits or within functional limits; actual measurement only if below functional limit.
  - Lower extremity: hip flexion and extension, knee extension-flexion, ankle dorsiflexion, and plantar flexion. Range of motion scored as within normal limits or within functional limits; actual measurement only if below functional limit.
  - Neck range of motion (rotation, flexion, extension).
  - Hand strength and coordination: gross grasp, 9-hole peg test, gross upper and lower extremity coordination.
  - Brake reaction time.
  - Upper and lower extremity sensation: light touch and proprioception. Recorded as intact, impaired, or absent.
- Neuropsychological Battery
  - Symbol Digit Modalities Test.
  - Trail Making A and B.
  - Benton 3-D Constructional Praxis Test.

- Visual-Perceptual Battery
    - Peripheral vision.
    - Near and far visual acuity.
    - Color perception.
    - Far lateral and vertical phoria.
    - Near lateral phoria.
    - Far depth perception.
    - Far fusion.
    - Sign recognition.
    - Occulomotor positions.
    - Letter cancellation test.

The OT assessed proprioception by standing behind the participant, positioning a joint of one extremity (e.g., left elbow) and asking the participant to imitate the position with the other. Scoring was as follows:

- Absent: Participant is unable to identify body part being moved or in what position it is placed.
- Impaired: Participant is able to identify body part being moved or its position but is unable to identify both; responds inconsistently or noticeably slower than expected.
- Intact: Participant consistently identifies body part moved and in what position it is placed.

  Note: Those with scores indicating impairment could be included in the Primary Sample peripheral neuropathy group. Intact proprioception was required for the other groups.

Contrast sensitivity was measured using a Pelli-Robson wall chart with 16 triplets of Sloan letters arranged in 8 rows of 2 triplets each. The contrast within each triplet was equal, with contrast decreasing from one triplet to the next by 0.15 units, reading from left to right and continuing on successive rows. Log CS ranged from 0.00 to 2.25. Participants stood 1 meter from the chart and named each letter in succession. Sensitivity was measured as the faintest triplet for which participants named two of three letters correctly.

To assess peripheral neuropathy, the DRS completed threshold testing with the 20-piece Touch-Test Sensory Evaluators (Semmes-Weinstein monofilaments). This instrument provided a non-invasive evaluation of cutaneous sensation levels throughout the body with objective, repeatable results. Each evaluator is calibrated to deliver its targeted force within a 5% standard deviation.

The monofilament was held at a 90-degree angle against the skin until it bowed. It was held for 1.5 seconds and then removed. The OT instructed participants to look away during testing and to respond when they felt the stimulus by saying “touch” or “yes.” The stimulus was applied to the same location up to 3 times to elicit a response for monofilaments labeled 1.65 to 4.08 (0.008 g -1.0 g)[7] and only once for filaments labeled 4.17 through 6.65 (1.4 g – 300 g). The

[7] The Semmes Weinstein monofilaments are labeled to give a linear scale of perceived intensity (a logarithmic scale of applied force). Handle markings = Log10 of (10 x force in milligrams).

OT applied the filament labeled 2.83 (0.07 g) first. If the participant responded to this stimulus in all sites, normal cutaneous sensation was documented, and the examination was complete. If the participant did not respond to the stimulus, the process was repeated with the next larger monofilament. When the participant indicated a response, the OT noted the filament size. Threshold levels as indicated in the table in Appendix D were used to interpret test results.

Three tests of functional capacity were added to the standard Driving Rehabilitation Program battery:

- UFOV Subtests 1 & 2 (Primary Sample only),
- Rapid Pace Walk (Primary Sample only) or Timed Up and Go test (Augmented Sample only), and
- Functional Reach (both Primary and Augmented Samples).

Additional, group-specific measures were performed, as described below.

Parkinson's disease. Parkinson's patients referred into the study were assessed with the Useful Field of View Subtest 2, Rapid Pace Walk, Rey-Osterrieth Complex Figure Test (ROCT), and Functional Reach measures, based on studies that have examined the usefulness of screening tools for predicting driving performance in people with Parkinson's disease (Classen et al., 2011). The Classen study also demonstrated the importance of the Unified Parkinson's Disease Rating Scale (UPDRS) Part 3 (motor subscale: UPDRS–Part 3; Fahn & Elton, 1987) including a specification of the *on* medication state (i.e., 1 hour after medication intake) and *off* medication state (i.e., at least 12 hr since the last PD medication). As part of the referral process for Parkinson's, the referring physician was asked to include the most recent UPDRS if available. An effort was made to recruit patients from physician practices that used the UPDRS.

COPD. The referring physicians provided descriptions of each COPD patient's condition and severity of symptoms. Participants who used walking aids or supplemental oxygen described where they stored the devices when driving and if (and how) the devices were secured during transit.

AMD. The referring ophthalmologist provided descriptions of each AMD patient's condition and severity of symptoms.

On-Road Driving Performance Data Collection

The same on-road driving performance data were collected for both the *Primary Sample* and the *Augmented Sample* by a CDRS affiliated with GHS. This CDRS was blind to subject group assignment. A different OT conducted the in-clinic assessment, and study group assignment was not provided to the CDRS who conducted the on-road evaluation.

Standard CDRS evaluation. The CDRS evaluated on-road driving performance on a predetermined test route in the Greenville, SC area, using a specially instrumented test vehicle owned by GHS. The 3-hour session included set-up, data collection, and feedback to the subject, as follows:

- Pre-drive vehicle set up/describing to the participant what would occur during the session, and waiting for the instrumented vehicle's computer to calibrate: 20 to30 minutes
- Normal drive time: 90 minutes
- Parking lot maneuvers: 20 minutes
- Review of clinical evaluation: 30 minutes

The route designed by the CDRS for this evaluation included situations and maneuvers where recent crash analyses have shown older drivers to be at highest risk. These included:

- *Left turns across traffic where cross-traffic does not stop*. The driving route included two unprotected left turns where drivers were required to cross two lanes of traffic to enter a parking lot, park the vehicle, back out of the parking space, pull out of the parking lot, and cross two lanes of traffic.
- *Unprotected left turns at traffic light controlled intersections.* The driving route included one left turn without a turn arrow and three left turns with turn arrows.
- Two *merges onto a controlled access highway from a ramp/acceleration lane* that required drivers to yield to through traffic.
- *Multiple lane changes on multi-lane roadways*.

A copy of the CDRS On-Road Evaluation scoring protocol and scoring template are provided in Appendix E.

Behaviorally Anchored Rating Scale (BARS). The CDRS completed the BARS evaluation following the drive by watching video recorded during the Standard CDRS evaluation. Six on-board cameras provided full motion video (30 frames per second) views of the driver's face and vehicle interior as well as forward and rear views of traffic/road conditions. The BARS scoring protocol (also included in Appendix E and explained in more detail in the Results section) was developed to avoid heads-down paperwork tasks for the CDRS during the drive.

Driving Exposure and Performance Measurement Results

Sample Characteristics

Primary sample. Two subjects were initially enrolled that met the inclusion criteria for the Parkinson's group. One of these candidates subsequently declined to participate; the other was dropped from the study due to an incompatibility between the exposure data acquisition system and the participant's vehicle. The Primary Sample therefore included only healthy older controls, plus drivers with COPD, AMD, and diabetic peripheral neuropathy (simply designated as the Neuropathy subgroup).

Age and sex. The 27 drivers who completed participation in this study ranged in age from 61 to 82 with an average age of 71. Drivers in the CMC group (with its COPD, AMD, and Neuropathy subgroups) averaged almost five years younger than those in the control group (see Table 2). There was a fairly even distribution of males and females across groups, aside from a higher ratio of females in the CMC group than in the control group (see Table 3).

*Table 2. Primary Sample Participant Age**

Group	N	Min	Max	Average	Standard Deviation
Control	**19**	**63**	**82**	**72.47**	**5.37**
Medical Condition	**8**	**61**	**75**	**67.75**	**5.01**
COPD	4	61	75	67.00	6.06
AMD	2	62	69	65.50	4.95
Neuropathy	2	71	72	71.50	0.71
Total	**27**	**61**	**82**	**71.07**	**5.62**

*Age at time of consent

Table 3. Primary Sample Sex Distribution

Group	N	Female (%)	Male (%)
Control	**19**	**37%**	**63%**
Medical Condition	**8**	**63%**	**37%**
COPD	4	75%	25%
AMD	2	50%	50%
Neuropathy	2	50%	50%
Total	**27**	**44%**	**56%**

Tables of descriptive statistics characterizing the Primary Sample with respect to the included clinical measures of visual, physical/psychomotor, and perceptual/cognitive function are presented in Appendix F as the control and CMC groups *did not differ significantly on any of these measures*. Performance on each measure is summarized below.

Visual measures. The study sample had, on average, approximately 20/30 far bilateral *acuity*. Bilateral *contrast sensitivity* (log) ranged from 1.35 to 1.95 among the study sample with an overall average of 1.81.

Physical/psychomotor measures. Among controls, *plantar threshold* (target force) averaged 0.74 grams, indicating normal to diminished light touch plantar threshold. Among participants in the CMC group, target force averaged 4.58 grams. Target force in grams for the plantar threshold test does not represent a linear scale, so target force was converted to milligrams using a $\log_{10}$ transform to perform statistical analysis. While the maximum target force (lowest sensitivity) was—as expected—demonstrated by the drivers with diabetic neuropathy, there were too few of these drivers to support an independent comparison with the controls.

The measures of *simple brake reaction time* (RT) represent an average across ten trials per participant. Average brake reaction times were nearly identical across groups, ranging from 0.3 to 0.7 seconds with an average of 0.5 seconds.

Perceptual/cognitive measures. Scores for the *UFOV, Subtest 1*measure (information processing speed) were available only for 26 of the 27 study participants. Scores across groups ranged from 17 to 77 ms, and averaged 22 ms. Scores for the *UFOV, Subtest 2*, which measures information processing speed with divided attention, also were available for only 26 of the 27 study participants and ranged from 100 to 333ms with an average of 144 ms.

Functional visual scanning was measured using the *Letter Cancellation* test. Completion times ranged from 50 to 110 seconds with an average of 75 seconds.

Scores on the *Trail Making Test*, Part A, a measure of visual search, ranged from 17 to 52 seconds with an average of 32 seconds. Scores on Part B, a measure of visual search with divided attention, ranged from 43 to 184 seconds with an average of 90 seconds.

Augmented sample. The Augmented Sample included 24 additional healthy older controls and 7 additional drivers with peripheral neuropathy. The Augmented Sample size supported comparisons not only between the controls and the CMC group but also between controls and the Neuropathy subgroup. However, no UFOV data was obtained for the Augmented Sample.

Age and sex. The 58 drivers in the Augmented Sample ranged in age from 61 to 85 with an average of 72 (see Table 4). There was a higher proportion of males than females across all participants, most notably in the Neuropathy subgroup (see Table 5).

*Table 4. Augmented Sample Participant Age**

Group	N	Minimum Age	Maximum Age	Average Age	Standard Deviation
Control	**43**	**63**	**85**	**72.19**	**5.36**
Medical Condition	**15**	**61**	**83**	**70.13**	**6.91**
COPD	4	61	75	67.00	6.06
AMD	2	62	69	65.50	4.95
Neuropathy	9	61	83	72.56	7.06
Total	**58**	**61**	**85**	**71.66**	**5.81**

*Age at time of consent

Table 5. Augmented Sample Sex Distribution

Group	N	Female (%)	Male (%)
Control	**43**	**40%**	**60%**
Medical Condition	**15**	**47%**	**53%**
COPD	4	75%	25%
AMD	2	50%	50%
Neuropathy	9	33%	67%
Total	**58**	**41%**	**59%**

Descriptive statistics characterizing the Augmented Sample with respect to the included clinical measures of visual, physical/psychomotor, and perceptual/cognitive function are presented below. Except where noted, differences between the control and CMC groups, and between the control group and Neuropathy subgroup, were not significant on these measures. Appendix F includes tables of descriptive statistics on measures where there were no significant differences between groups.

Visual measures. The study sample, on average, had approximately 20/30 far bilateral *acuity*. Bilateral *contrast sensitivity* ranged from 1.05 to 2.10 (log units) across participants, with an average of 1.80.

Physical/psychomotor measures. Participants' *plantar threshold* is displayed as target force in grams in Table 6. Among controls, target force ranged from 0.07 (normal) to 2 grams and averaged 0.65 grams, indicating normal to diminished light touch plantar threshold. Among participants in the CMC group, target force ranged from 0.07 grams to 300 grams (deep pressure sensation only), with an average of 46.44. Within the Neuropathy subset of the CMC group, target force ranged from 4 to 300 grams with an average of 76.67 indicating diminished protective sensation-to-deep pressure sensation only

Since target force does not represent a linear scale, this measure was converted to milligrams using a $\log_{10}$ transform to perform statistical analyses. There were statistically significant group differences in target force between the control and CMC groups (t [15.38] = 3.7205, p = 0.002) and between the control group and the Neuropathy subgroup (t [9.204] = 7.446, p=0.001).

Table 6. Augmented Sample Plantar Threshold Target Force

Group	N	Minimum (g)	Maximum (g)	Average (g)	Standard Deviation (g)
Control	**43**	**0.07**	**2**	**0.65**	**0.56**
Medical Condition	**15**	**0.07**	**300**	**46.44**	**103.20**
COPD	4	0.07	1.4	0.62	0.57
AMD	2	0.16	4	2.08	2.72
Neuropathy	9	4	300	76.67	126.76
Total	**58**	**0.07**	**300**	**12.50**	**55.00**

Brake reaction time was a simple RT measure, averaged across 10 trials per driver. Average brake reaction times were nearly identical across groups with RTs ranging from 0.32 to 0.72 seconds and averaging 0.49 seconds.

Perceptual/cognitive measures. Functional visual scanning was measured using the *Letter Cancellation* test. Completion times ranged from 50 to 110 seconds with an average of 74 seconds).

Completion times for the *Trail Making Test*, Part A were available for 56 of the 58 participants; these ranged from 17 to 67 seconds with an average of 31 seconds. Scores on Part B, shown in Table 7, also were available for 56 of the 58 participants. On average, the control group exhibited a faster test completion time (78.7 s) than both the CMC group (108.3 s) and Neuropathy subgroup (103.6 s). Analyses showed statistically significant differences between controls and the CMC group ($t[17.69] = 2.73$, $p = 0.014$) and between controls and the Neuropathy subgroup ($t[48] = 2.60$, $p = 0.012$).

Table 7. Augmented Sample Performance for the Trail Making Test, Part B

Group	N	Minimum Score (sec.)	Maximum Score (sec.)	Average Score (sec.)	Standard Deviation (sec.)
Control	**41**	**31**	**131**	**78.66**	**23.32**
Medical Condition	**15**	**53**	**184**	**108.27**	**39.52**
COPD	4	105	164	142.00	27.26
AMD	2	61	63	62.00	1.41
Neuropathy	9	53	184	103.56	36.40
Total	**56**	**31**	**184**	**86.59**	**31.11**

SHRP2 sample (broad sample analysis). The measures used to describe the characteristics of the SHRP2 sample for the broad sample analysis (BSA) of exposure and driving performance were similar, but not identical, to those reported above for the Primary and Augmented Samples. It is also important to reiterate that four SHRP2 drivers met the inclusion criteria for *both* the Neuropathy and COPD subgroups. These drivers are included in the CMC count (74), but they are not included in the counts for either of the Neuropathy or COPD subgroups.

Age and sex. Two hundred and three drivers were selected from the SHRP2 NDS database that met the inclusion criteria for this analysis. Drivers' ages fell into 5-year groups that ranged from 65-to-69 to 95-to-99. Exact driver ages are considered personally identifying information (PII) and cannot be extracted from the SHRP2 database. Overall, the largest proportion of participants were in the 75-to-79 age group (31.0%), followed by the 65-to-69 group (25.1%) and 70-to-74 group (22.7%). A chi-square test found there was no statistically significant difference in age between the control group and the CMC group. Table 8 and Figure 9 present the number and proportion of subjects in each age group.

*Table 8. SHRP2 Sample (BSA) Distribution, Across Age Groups**

Group	N	Age Group 65-69 n	65-69 %	70-74 n	70-74 %	75-79 n	75-79 %	80-84 n	80-84 %	85-89 n	85-89 %	90-94 n	90-94 %	95-99 n	95-99 %
Control	**129**	**37**	**28.7%**	**29**	**22.5%**	**40**	**31.0%**	**16**	**12.4%**	**7**	**5.4%**	**0**	**0.0%**	**0**	**0.0%**
Medical Condition	**74**	**14**	**18.9%**	**17**	**23.0%**	**23**	**31.1%**	**14**	**18.9%**	**4**	**5.4%**	**1**	**1.4%**	**1**	**1.4%**
COPD	21	2	9.5%	8	38.1%	8	38.1%	2	9.5%	1	4.8%	0	0.0%	0	0.0%
Neuropathy	42	9	21.4%	9	21.4%	12	28.6%	8	19.0%	2	4.8%	1	2.4%	1	2.4%
Parkinson's	7	2	28.6%	0	0.0%	3	42.9%	1	14.3%	1	14.3%	0	0.0%	0	0.0%
Total	**203**	**51**	**25.1%**	**46**	**22.7%**	**63**	**31.0%**	**30**	**14.8%**	**11**	**5.4%**	**1**	**0.5%**	**1**	**0.5%**

*Age at commencement of observation period

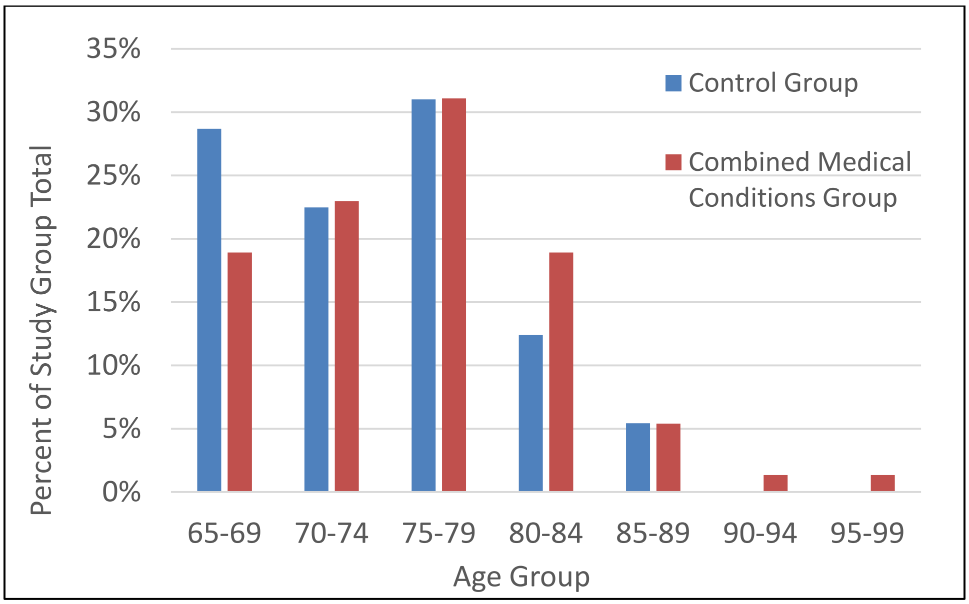

Figure 9. SHRP2 NDS sample, distribution across age groups.

Among all participants, there was a somewhat higher proportion of males (61%) than females (39%). A chi-square test found no statistically significant difference in the makeup of the groups by sex (See Table 9).

Table 9. SHRP2 Sample (BSA) Distribution of Sex by Group

Group	N	% Female	% Male
Control	**129**	**41.1%**	**58.9%**
Medical Condition	**74**	**36.5%**	**63.5%**
COPD	21	28.6%	71.4%
Neuropathy	42	38.1%	61.9%
Parkinson's	7	28.6%	71.4%
Total	**203**	**39.4%**	**60.6%**

Descriptive statistics characterizing the SHRP2 BSA sample with respect to the included clinical measures of visual, physical/psychomotor, and perceptual/cognitive function are presented below. Except where noted, differences between the control and CMC groups, and between the control group and Neuropathy subgroup, were not significant on these measures. Appendix F includes tables of descriptive statistics for measures where there were no significant differences between groups.

Visual measures. This sample, on average, had a level of *far bilateral acuity* of approximately 20/25. Contrast sensitivity (best eye) was measured using the FACT contrast sensitivity chart on the OPTEC 6500 vision tester. This instrument includes test patches at spatial frequencies of 1.5, 3, 6, 12, and 18 cycles per degree. Figures 10 and 11 present average scores by group and medical condition subgroup, respectively, as compared to population norms established by test developers (Vistech Consultants, Inc.). As seen in these figures, there was little difference in contrast sensitivity averages across groups, and all subjects fell within the normal range.

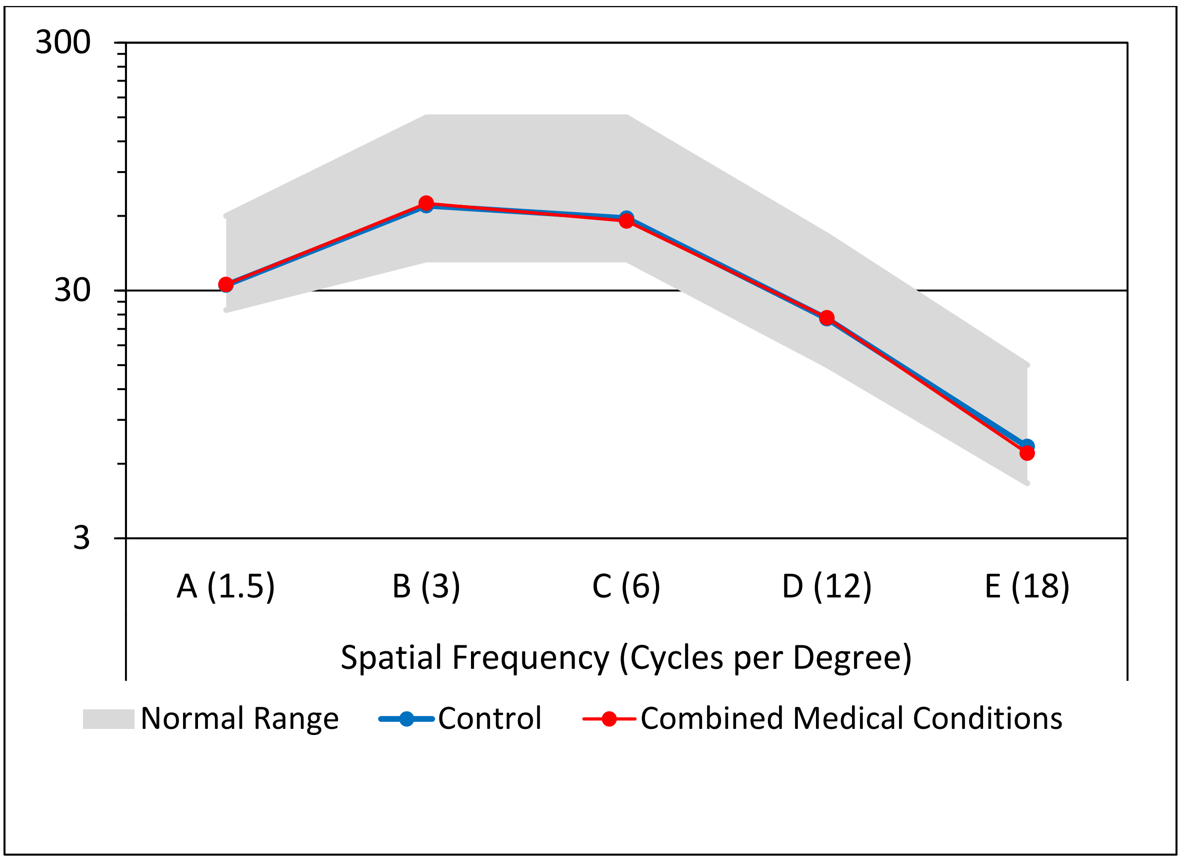

Figure 10. Average contrast sensitivity scores, by group, compared to normal range.

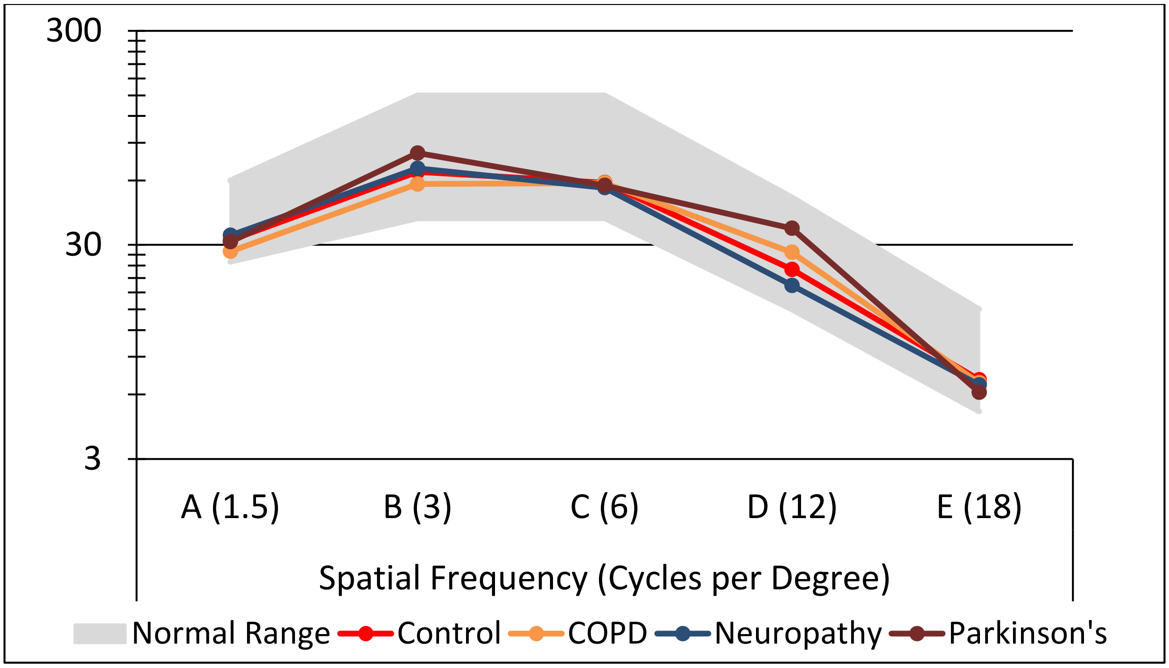

Figure 11. Average contrast sensitivity scores, by medical condition subgroup, compared to normal range.

Physical measures. *Rapid-pace walk* times were available for only 196 of the 203 drivers in the SHRP2 BSA sample. The control group completed this task significantly faster than the CMC group ($t[102.52] = 4.56$, $p = 0.001$), the Neuropathy subgroup ($t[46.6] = 4.20$, $p = 0.001$), and the COPD subgroup ($t[145] = 2.02$, $p = 0.045$) using a conventional statistical significance level of 0.05 (see Table 10).

Table 10. SHRP2 Sample (BSA) Performance for Rapid-Pace Walk Time

Group	N	Minimum Score (sec.)	Maximum Score (sec.)	Average Score (sec.)	Standard Deviation (sec.)
Control	**126**	**2.68**	**13.20**	**5.55**	**1.39**
Medical Condition	**70**	**3.76**	**15.54**	**6.84**	**2.13**
COPD	21	3.87	8.44	6.21	1.31
Neuropathy	39	4.26	15.54	7.21	2.34
Parkinson's	7	3.76	11.09	7.48	2.69
Total	**196**	**2.68**	**15.54**	**6.01**	**1.80**

Perceptual/cognitive measures. Scores on the *UFOV, Subtest 2* were available for only 196 of the 203 drivers in the SHRP2 BSA sample. Scores ranged from 100 to 500 ms with an average of 188 ms. Drivers' ability to *visualize missing information* was measured by a test protocol that mirrors the MVPT-visual closure subtest, using line drawings of symbols found on road signs. VMI results were available for only 199 of the 203 drivers in the SHRP2 BSA sample. Number of errors ranged from 0 to 10 with an average of 2.44.

For the *Trail Making Test, Part A* completion times were available for only 198 of the 203 drivers in the SHRP2 BSA sample. On average, drivers completed the test in 39 seconds. Test completion times on the *Trail Making Test, Part B* were available for only 198 of the 203 drivers in the SHRP2 BSA sample. On average, drivers completed the test in 101 seconds.

SHRP2 sample (site-specific analysis). The measures used to describe the characteristics of the SHRP2 sample used for the site-specific analysis (SSA) contrasting the behavior of older drivers with and without (self-reported) medical conditions when negotiating ramps and acceleration lanes at freeway merge locations are presented below. T-tests and Fisher's Exact tests were applied to examine the statistical significance of observed between-group differences (controls versus CMC; control versus Neuropathy; control versus COPD). Due to small cell sizes, significance testing was not carried out for controls versus the Parkinson's group, nor for age group and sex for controls versus Neuropathy or COPD groups.

Age and sex. Thirty-six drivers from the SHRP2 SSA sample traversed the designated freeway ramp coordinates. Drivers' ages fell into 5-year groups that ranged from 65-to-69 to 80-to-84. The largest proportion of participants (31%) was in the 75-to-79 age group (see Table 11 and Figure 12).

*Table 11. SHRP2 Sample (SSA) Distribution of Age Across Groups**

		Age Group							
Group	**N**	**65-69**		**70-74**		**75-79**		**80-84**	
		n	**%**	**n**	**%**	**n**	**%**	**n**	**%**
Control	**23**	**5**	**21.7%**	**6**	**26.1%**	**10**	**43.5%**	**2**	**8.7%**
Medical Condition	**13**	**5**	**38.5%**	**4**	**30.8%**	**3**	**13.0%**	**1**	**7.7%**
COPD	6	1	16.7%	3	50.0%	**2**	**8.7%**	0	0.0%
Neuropathy	6	4	66.7%	1	16.7%	**0**	**0.0%**	1	16.7%
Parkinson's	1	0	0.0%	0	0.0%	**1**	**4.3%**	0	0.0%
Total	**36**	**10**	**27.8%**	**10**	**27.8%**	**13**	**36.1%**	**3**	**8.3%**

*Age at commencement of observation period

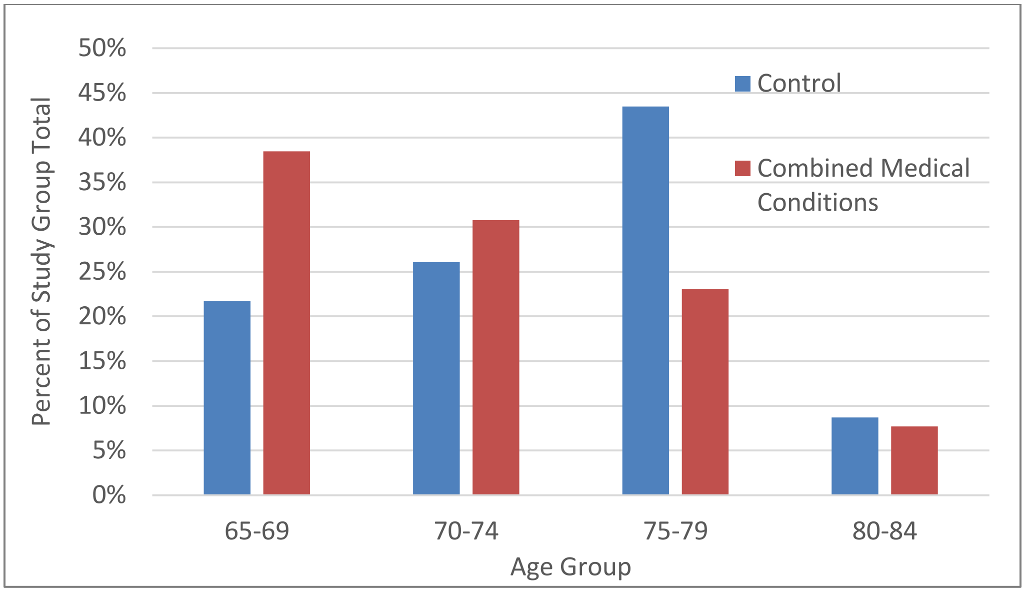

Figure 12. SHRP2 sample (SSA) distribution across age groups.

Across groups, there was a higher proportion of males than females (see Table 12).

Table 12. SHRP2 Sample (SSA) Distribution of Sex by Group

Group	Total	% Female	% Male
Control	**23**	**43.5%**	**56.5%**
Medical Condition	**13**	**38.5%**	**61.5%**
COPD	6	33.3%	66.7%
Neuropathy	6	50.0%	50.0%
Parkinson's	1	0.0%	100.0%
Total	**36**	**41.7%**	**58.3%**

Descriptive statistics characterizing the SHRP2 SSA sample with respect to the included clinical measures of visual, physical/psychomotor, and perceptual/cognitive function are presented below. Again, differences between the control and CMC groups, and between the control group and Neuropathy subgroup, were not significant on these measures unless otherwise noted. Appendix F includes tables of descriptive statistics for measures where there were no significant differences between groups.

Visual measures. The SHRP2 SSA sample, on average, had a level of *far bilateral acuity* of approximately 20/24. Figures 13 and 14 present average scores by group and medical condition subgroup as compared to population norms as established by test developers (Vistech Consultants, Inc.). There was little difference in contrast sensitivity averages across groups, and subjects generally fell within the normal range.

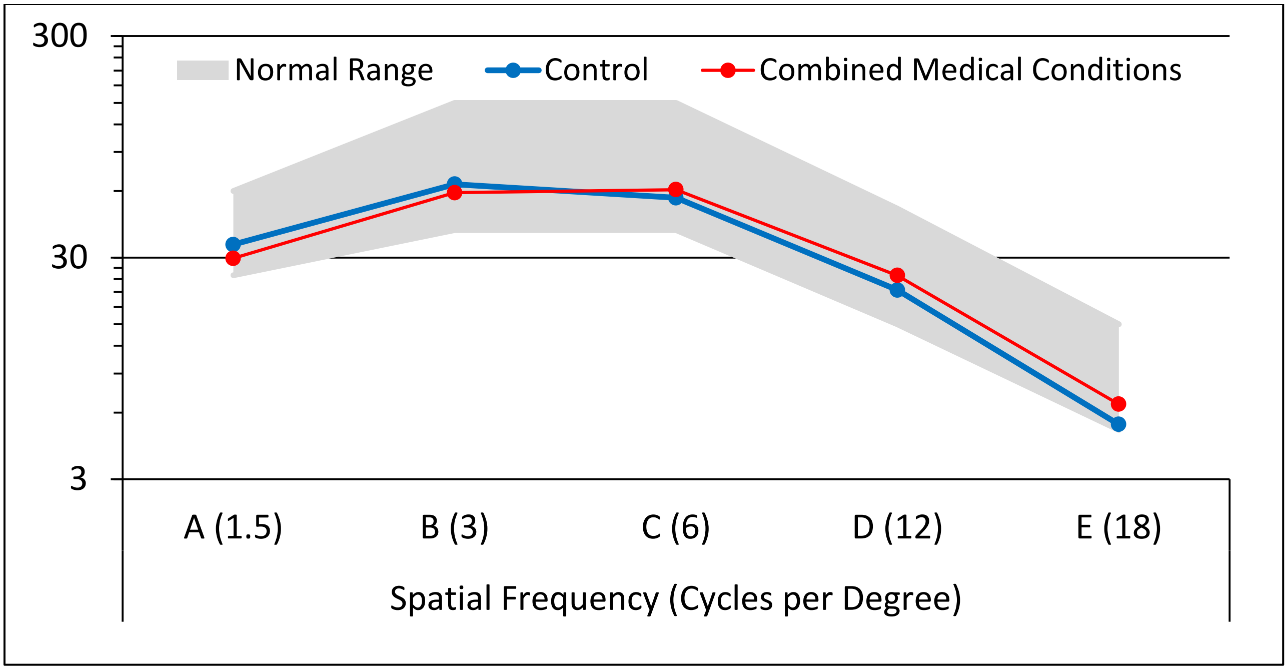

Figure 13. Average contrast sensitivity scores, by group, compared to normal range.

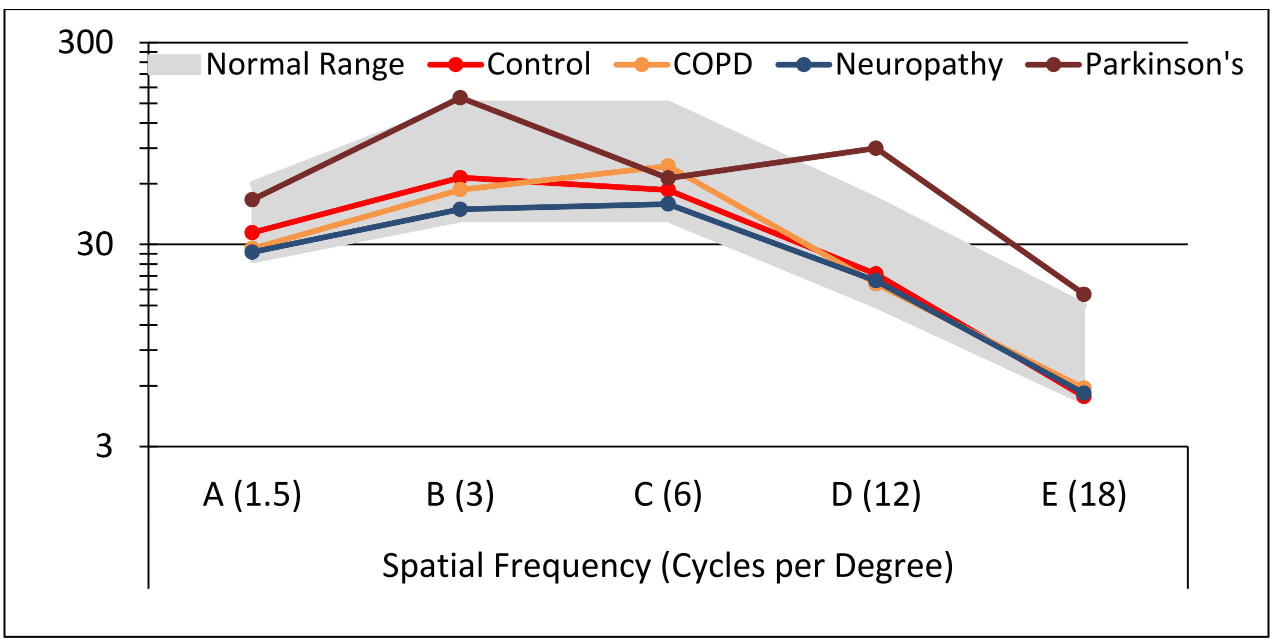

Figure 14. Average contrast sensitivity scores, by medical condition subgroup, compared to normal range.

Physical measures. *Rapid-pace walk* times were available for 35 of the 36 drivers in the SHRP2 SSA sample. This sample, on average, had an average walk time of 5.82 seconds. T-tests revealed that the CMC group had a statistically significant longer walk time than the control group (t[4.56], $p < 0.05$). The control group also displayed statistically significant faster walk times than the Neuropathy (*t*[-4.2], $p < 0.05$) and the COPD subgroups (*t*[-2.03], $p = 0.04$) (see Table 13).

Table 13. SHRP2 Sample (SSA) Performance for Rapid-Pace Walk Time

Group	N	Minimum Score (sec.)	Maximum Score (sec.)	Average Score (sec.)	Standard Deviation (sec.)
Control	**126**	**2.68**	**13.20**	**5.55**	**1.39**
Medical Condition	**70**	**3.76**	**15.54**	**6.84**	**2.13**
COPD	21	3.87	8.44	6.21	1.31
Neuropathy	39	4.26	15.54	7.21	2.34
Parkinson's	7	3.76	11.09	7.48	2.69
Total	**196**	**2.68**	**15.54**	**6.01**	**1.80**

Perceptual/cognitive measures. Scores on the *UFOV, Subtest 2* showed no statistically significant difference in scores for the CMC this test of information processing speed with divided attention and control groups (see Table 14). A *t*-test revealed a statistically significant difference between the controls and the COPD subgroup with those in the COPD group having a significantly faster average score (111.67 ms) than those in the control group (161.48 ms) (*t*[2.29], $p = 0.03$). In contrast, the test for *visualizing missing information* showed very little difference in the average number of errors between Medical Conditions and control groups.

Table 14. SHRP2 Sample (SSA) Performance for the Useful Field of View, Subtest 2

Group	N	Minimum Score (ms)	Maximum Score (ms)	Average Score (ms)	Standard Deviation (ms)
Control	**23**	**100**	**327**	**161.48**	**88.02**
Medical Condition	**13**	**100**	**360**	**155.69**	**74.99**
COPD	6	100	170	111.67	28.58
Neuropathy	6	100	360	195.67	91.20
Parkinson's	1	180	180	180.00	0.00
Total	**36**	**100**	**360**	**159.39**	**82.50**

The SHRP2 SSA sample had an average score of 36.2 seconds on the *Trail-Making Test, Part A*, with little difference between the control and CMC groups. On the *Trail-Making Test, Part B***,** this sample had an average score of 98.2 seconds overall, also with little difference between the control and CMC groups.

Driving Exposure Measures

This section reports descriptive data summaries and the results of tests for significant differences between groups for the driving exposure measures collected for the Primary Sample and extracted by VTTI for the SHRP2 NDS Sample. The measures reported for these respective data sets are similar but not identical. Exposure data were not collected for the Augmented Sample.

Primary Sample. Since the study inclusion criteria dictated that participants drive at least three times per week, only subjects with 12 or more trips (i.e., 3 trips per week over a 4-week data collection period) were included in this analysis. Three of the 27 drivers recruited in the Primary Sample failed to meet this criterion. An additional five participants who completed the driving exposure data collection could not be included in this analysis because of missing data. This resulted from limitations in the custom data logger to acquire and hold the GPS signal, which appeared to be exacerbated by very high (mid-summer) temperatures during the study period. As a result, the Primary Sample driving exposure analysis included data for a total of 19 drivers, 12 in the control group and 7 in the CMC group.

Descriptive data summaries. Table 15 shows a summary of the driving exposure results at the group level. Appendix F, Tables F26 and F27, break out these same data for individual drivers in the control and the CMC groups, respectively and Figures F1 through F7are keyed to specific driving exposure measures.

Table 15. Driving Exposure Results, Summary by Group

	Measure	Control (n=12) Average	Control (n=12) SD	Medical Conditions (n=7) Average	Medical Conditions (n=7) SD
	Age	**72.3**	5.0	**68.6**	4.8
	Total trips taken	**44**	26.1	**42**	35.4
	Average trips per day	**3.55**	0.90	**3.56**	0.59
Miles Driven	Total in observation period	**268**	144	**262**	194
	Average per day	**22.2**	10.6	**24.1**	10.7
	Min per trip	**0.66**	0.70	**0.35**	0.28
	Max per trip	**28.3**	15.8	**27.8**	18.4
Trip Duration (hrs:min:sec)	Total driving time	**9:53:00**	5:13:19	**10:33:32**	8:55:00
	Average trip length	**0:14:20**	0:03:47	**0:15:37**	0:04:00
	Min trip length	**0:02:38**	0:01:40	**0:02:19**	0:01:14
	Max trip length	**0:50:23**	0:29:57	**0:46:59**	0:19:59
% of Trips by Distance Band	<=1 mile	**9.6**	11.2	**9.2**	7.0
	>1-2.5 miles	**18.8**	11.8	**27.1**	14.8
	2.6-5 miles	**24.9**	11.0	**24.6**	6.8
	5.1-10 miles	**26.3**	16.4	**21.1**	8.4
	10.1-20 miles	**14.9**	15.0	**10.6**	7.3
	>20 miles	**5.5**	6.8	**7.4**	8.9
% of Trips by Time of Day	Before 10 AM	**20.3**	9.1	**18.7**	13.7
	10 AM - 3 PM	**47.0**	16.3	**48.5**	18.1
	3 PM - 8 PM	**28.6**	16.3	**27.6**	19.3
	After 8 PM (night)	**4.1**	7.2	**5.2**	5.7
% of Trips by Road Type	Low speed/residential	**16.1**	10.2	**16.8**	14.8
	Low speed/commercial	**17.5**	12.1	**16.8**	9.3
	Arterial/multi-lane	**30.4**	17.6	**29.9**	11.5
	2-lane rural highway	**13.2**	17.6	**19.4**	20.1
	Limited access/freeway	**22.7**	17.8	**17.2**	15.4
% of Trips	Adverse weather (rain or fog)	**5.8**	8.9	**3.5**	3.2
% of Miles Driven	common (familiar) routes	**88.2**	10.5	**82.2**	19.8
	uncommon (unfamiliar) routes	**11.8**	10.5	**19.7**	18.6

Significance testing. Student's *t*-tests (two-tailed) were used to detect statistically significant group differences for measures of driving exposure. Researchers did not analyze total, minimum, or maximum miles driven or trip duration because of the variability in number of trips among individual subjects, i.e., those with higher numbers of trips understandably reflected higher values for each of these measures. Equal variance was assumed except for the analysis of percent of trips in adverse weather conditions. Where data were characterized by unequal variance, *Welch's t-test* was used. As seen in Table 16, no significant group differences were found for any measure tested.

Analysts applied linear regression techniques to determine if there was a significant association between driver age (5-year age category), driver sex, or any of the clinical measures (brake RT, far bilateral acuity, bilateral contrast sensitivity, plantar threshold, letter cancellation test time, useful field of view, Trail-Making Test completion time, Parts A and B) and each of three measures of exposure – average trips per day, average miles driven per day, and average trip length (duration). These analyses found no statistically significant associations.

Table 16. Primary Sample Driving Exposure Analysis Results

Measure		t	df	p
	Age	1.571	17	0.14
	Avg Trips per Day	0.019	17	0.99
	Avg Trip Length	0.695	17	0.50
	Avg Miles per Day	0.383	17	0.71
% of Trips by Distance Band	<=1	0.065	17	0.95
	>1-2.5	1.346	17	0.20
	2.6-5	0.072	17	0.94
	5.1-10	0.777	17	0.45
	10.1-20	0.702	17	0.49
	>20	0.518	17	0.61
% of Trips by Time of Day	Before 10am	0.316	17	0.76
	10am-3pm	0.195	17	0.85
	3pm-8pm	0.124	17	0.90
	After 8pm	0.345	17	0.73
% of Trips by Road Type	Residential	0.111	17	0.91
	Commercial	0.147	17	0.89
	Arterial	0.071	17	0.95
	Rural Highway	0.696	17	0.50
	Freeway	0.676	17	0.51
% of Trips	Adverse weather (rain or fog)	0.802	15.1	0.44
% of Miles Driven	common (familiar) routes	0.562	17	0.40
	uncommon (unfamiliar) routes	1.194	17	0.25

SHRP2 NDS Sample

Descriptive data summary. Table 17 shows descriptive statistics for each of the driving exposure measures supported by the SHPR2 NDS data extraction for healthy older drivers (control group) and those in the CMC group.

Table 17. Driving Exposure Results: Controls and Combined Medical Conditions

		Control (n=129)		Combined Medical Conditions (n=74)	
	SHRP 2 NDS Sample	Average	SD	Average	SD
	Total trips taken	1678	1197	1341	926
	Average trips per day	4.7	1.3	4.0	1.1
Miles Driven	Total in observation period	9508	8368	7294	5673
	Average per day	19.7	12.9	15.9	11.2
	Min per trip	0.7	2.5	0.6	1.8
	Max per trip	265.7	187.2	222.6	183.4
Trip Duration (hh:mm:ss)	Total driving time	359:42:56	279:25:02	299:20:50	217:57:32
	Average trip duration	0:12:56	0:04:10	0:13:38	0:04:30
	Min trip duration	0:01:03	0:00:19	0:01:03	0:00:10
	Max trip duration	2:32:20	1:08:07	2:10:50	1:08:10
% of Trips by Distance Band	<=1 mile	25.5	17.7	24.7	14.7
	>1-2.5 miles	23.1	11.9	23.7	11.9
	2.6-5.5 miles	24.7	12.6	24.7	11.1
	5.6-10.5 miles	14.4	8.6	13.9	9.4
	10.6-20 miles	7.2	6.1	8.2	8.8
	>20 miles	5.1	5.4	4.8	5.9
% of Trips by Time of Day	Before 10 AM	15.5	9.4	13.6	9.0
	10 AM - 3 PM	48.5	12.2	49.9	13.4
	3 PM - 8 PM	29.7	11.3	31.0	13.2
	After 8 PM (night)	6.3	7.2	5.5	5.2
% of Trip Duration (by Road Type	Rural Freeway	0.5	0.7	0.4	0.7
	Rural 2-Lane	8.5	10.0	8.2	12.7
	Urban Freeway	2.4	3.1	2.1	2.5
	Urban 2-Lane	24.8	9.1	25.0	11.3
	< 35 mph Speed Limit	25.9	18.6	30.9	22.7
	40-50 mph Speed Limit	30.6	19.9	31.6	18.6
	55+ mph Speed Limit	43.5	24.7	37.5	23.5
% of Miles Driven by Miles per Hour	< = 20 mph	10.2	9.4	11.0	7.1
	20-30 mph	14.5	8.5	15.4	8.9
	30-40 mph	22.2	8.6	23.1	9.9
	40-50 mph	18.4	9.4	18.3	8.9
	50-60 mph	13.7	7.9	13.5	9.2
	60-70 mph	14.9	10.4	12.1	9.4
	70+ mph	6.1	8.3	6.5	9.7
% of Trip Duration by Miles per Hour	< = 20 mph	37.9	12.1	42.2	12.5
	20-30 mph	13.3	5.4	12.5	4.5
	30-40 mph	15.5	5.3	14.6	5.3
	40-50 mph	10.8	6.1	9.9	5.4
	50-60 mph	6.9	5.1	6.5	5.7
	60-70 mph	6.7	5.8	5.2	5.0
	70+ mph	2.6	3.8	2.7	4.7
% of Trips – Other	Seat Belt Used at least 90% of trip	93.9	8.9	85.6	20.3

Table 18 shows descriptive statistics for each of the driving exposure measures supported by the SHPR2 NDS data extraction for healthy controls and for those in each medical condition subgroup.

Table 18. Driving Exposure Results: Controls and Medical Condition Subgroups

		Control (n=129)		Neuropathy (n = 42)		Parkinson's (n = 7)		COPD (n = 21)	
	SHRP 2 NDS Sample	**Average**	**SD**	**Average**	**SD**	**Average**	**SD**	**Average**	**SD**
	Total trips taken	1678	1197	1490	961	1104	871	1253	893
	Average trips per day	4.7	1.3	4.2	1.1	3.9	1.3	3.8	1.0
Miles Driven	Total in obs period	9508	8368	7668	5547	6368	4706	7134	5284
	Average per day	19.7	12.9	16.8	11.5	15.7	13.0	15.7	11.3
	Min per trip	0.7	2.5	0.6	0.8	0.8	1.2	0.9	3.2
	Max per trip	265.7	187.2	208.9	168.0	224.1	188.2	282.2	219.9
Trip Duration (hh:mm:ss)	Total driving time	359:42:56	279:25:02	325:27:53	0:04:00	280:01:41	0:06:34	284:31:07	0:05:14
	Avg trip duration	0:12:56	0:04:10	0:13:15	0:00:06	0:14:30	0:00:27	0:14:22	0:00:06
	Min trip duration	0:01:03	0:00:19	0:01:02	1:01:08	0:01:11	1:50:03	0:01:03	1:06:47
	Max trip duration	2:32:20	1:08:07	2:00:01	0:00:00	2:47:27	0:00:00	2:28:27	0:00:00
% of Trips by Distance Band	<=1 mile	25.5	17.7	22.5	13.6	28.1	16.1	27.2	18.1
	>1-2.5 miles	23.1	11.9	24.7	13.5	27.4	11.1	19.9	9.3
	2.6-5.5 miles	24.7	12.6	26.1	11.4	22.9	10.6	25.2	11.8
	5.6-10.5 miles	14.4	8.7	15.5	10.8	10.6	6.7	13.7	8.1
	10.6-20 miles	7.2	6.1	6.9	7.1	4.7	5.0	8.1	8.8
	>20 miles	5.1	5.4	4.4	6.3	6.5	7.6	6.0	5.1
% of Trips by Time of Day	Before 10 AM	15.5	9.4	13.0	9.6	11.8	6.2	14.9	8.4
	10 AM - 3 PM	48.5	12.2	47.1	11.1	59.9	14.6	50.2	13.8
	3 PM - 8 PM	29.7	11.3	34.0	12.3	24.8	10.5	28.8	13.8
	After 8 PM (night)	6.3	7.2	5.9	5.4	3.5	4.9	6.1	5.6
% of Trip Duration by Road Type	Rural Freeway	0.5	0.8	0.4	0.5	0.8	1.5	0.6	0.7
	Rural 2-Lane	8.5	10.0	7.6	11.8	7.2	10.1	9.1	15.4
	Urban Freeway	2.4	3.1	2.5	2.9	1.1	1.3	2.0	2.1
	Urban 2-Lane	24.8	9.1	25.9	12.2	24.3	12.6	21.5	10.2
	< 35 mph Spd Lmt	25.9	18.6	33.4	24.1	26.1	31.1	26.0	20.2
	40-50 mph Spd Lmt	30.6	19.9	30.9	19.9	37.8	24.1	31.7	16.6
	55+ mph Spd Lmt	43.5	24.7	35.7	24.4	36.1	30.1	42.3	24.3
% of Miles Driven by Miles per Hour	< = 20 mph	10.2	9.4	11.8	7.7	13.0	9.6	8.4	3.7
	20-30 mph	14.5	8.5	16.6	8.8	16.2	13.1	11.7	6.2
	30-40 mph	22.2	8.6	24.4	9.2	18.7	8.8	22.4	11.8
	40-50 mph	18.4	9.4	18.7	9.5	15.67	9.3	18.2	8.2
	50-60 mph	13.7	7.9	12.1	7.2	15.6	15.6	14.9	9. 4
	60-70 mph	14.9	10.4	11.3	8.9	11.6	12.1	15.0	9.7
	70+ mph	6.1	8.3	5.1	9.1	9.2	11.5	9.4	10.5
% of Trip Duration by Miles per Hour	< = 20 mph	37.9	12.1	43.3	9.8	48.0	19.5	37.6	13.4
	20-30 mph	13.3	5.4	13.4	4.4	11.5	5.8	10.2	3.4
	30-40 mph	15.5	5.3	15.5	5.3	10.5	2.6	14.2	5.5
	40-50 mph	10.8	6.1	10.0	5.7	7.9	5.6	10.3	5.0
	50-60 mph	6.9	5.1	5.5	3.9	7.9	8.5	7.4	6.6
	60-70 mph	6.7	5.8	4.6	4.2	5.4	7.4	6.7	5.7
	70+ mph	2.6	3.8	2.1	4.5	3.7	5.4	4.0	5.2
% of Trips – Other	Seat Belt Used at least 90% of trip	93.9	8.9	84.0	24.2	75.1	22.2	91.7	10.3

Significance testing. Student's *t*-tests (two-tailed) were used to determine which, if any, of the exposure measures extracted for the SHRP2 NDS Sample showed statistically significant group differences. Separate analyses were performed comparing control group drivers to drivers in the CMC group, and to drivers in each of the medical conditions subgroups. Table 19 presents the analysis results for all exposure measures, highlighting comparisons where groups differed significantly. Figures 15-18 graphically contrast exposure results for on measures on which groups differed significantly. Appendix F, Figures F8 through F14 depict exposure results for the remaining measures.

Drivers in the control group averaged more total trips ($p = 0.04$) and more trips per day ($p = 0.01$) than the CMC group. The control group also took more trips per day than the Neuropathy ($p = 0.05$) and the COPD ($p = 0.01$) subgroups, but they did not differ from the Parkinson's subgroup (see figure 15). The control group drivers averaged longer maximum trip duration than drivers in the CMC group ($p = 0.04$) and the Neuropathy subgroup ($p = 0.01$) (see Figure 16).

Drivers in the control group averaged a lower percentage of trips driven between the hours of 3 p.m. and 8 p.m. than the Neuropathy subgroup ($p = 0.04$), and a lower percentage of trips driven between the hours of 10 a.m. and 3 p.m. than the Parkinson's subgroup ($p = 0.02$) (see Figure 17). In other words, control group drivers were more likely to drive during the morning rush hours or at night than drivers with these particular medical conditions. The control group drivers also drove a higher percentage of trips on urban freeways than drivers with Parkinson's ($p = 0.04$), although in both cases this percentage is small (see Figure 18).

Drivers in the control group averaged a *higher* proportion of *miles* driven at 60-70 mph than the Neuropathy group ($p = 0.04$), and they averaged a *lower* percentage of *time* spent driving at the lowest speeds (20 mph or less) when compared to the CMC group ($p = 0.02$) and to the Neuropathy subgroup ($p = 0.01$). Drivers in the control group averaged a *higher* percentage of time spend driving at speeds of 20-30 mph compared to the COPD subgroup ($p = 0.01$), at speeds of 30 to 40 mph compared to the Parkinson's subgroup ($p = 0.01$), and at speeds of 60 to 70 mph compared to the Neuropathy subgroup ($p = 0.01$) (see Figure 19).

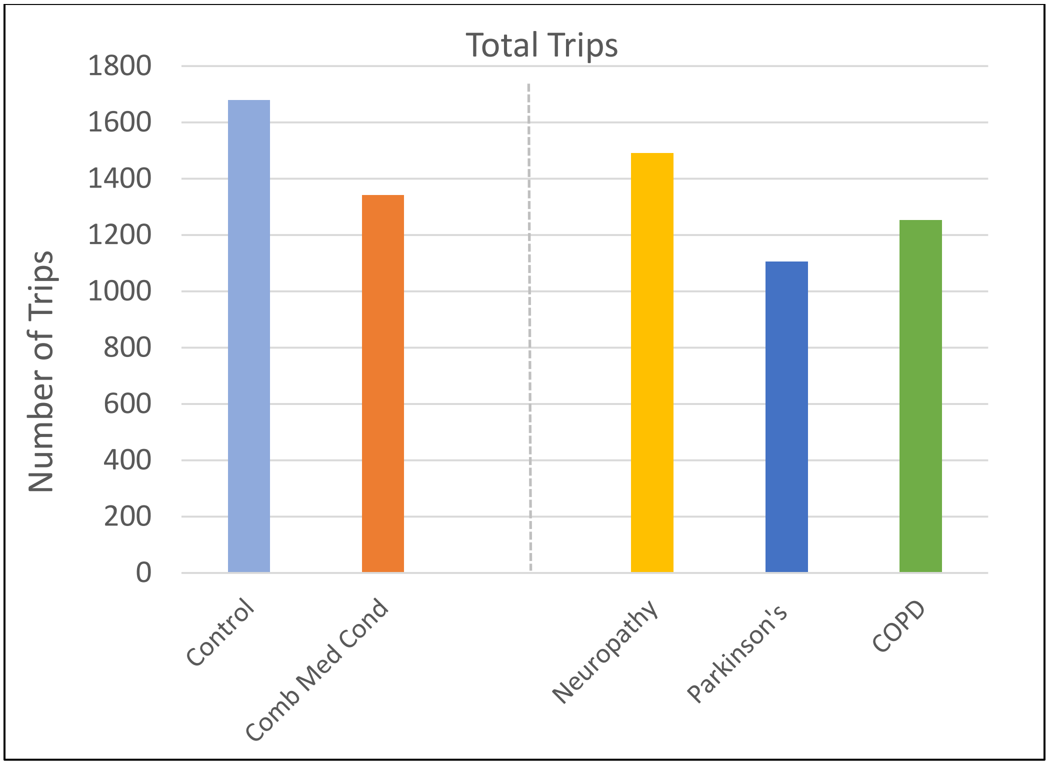

*Figure 15***.** Total number of trips, group average – SHRP2 NDS sample.

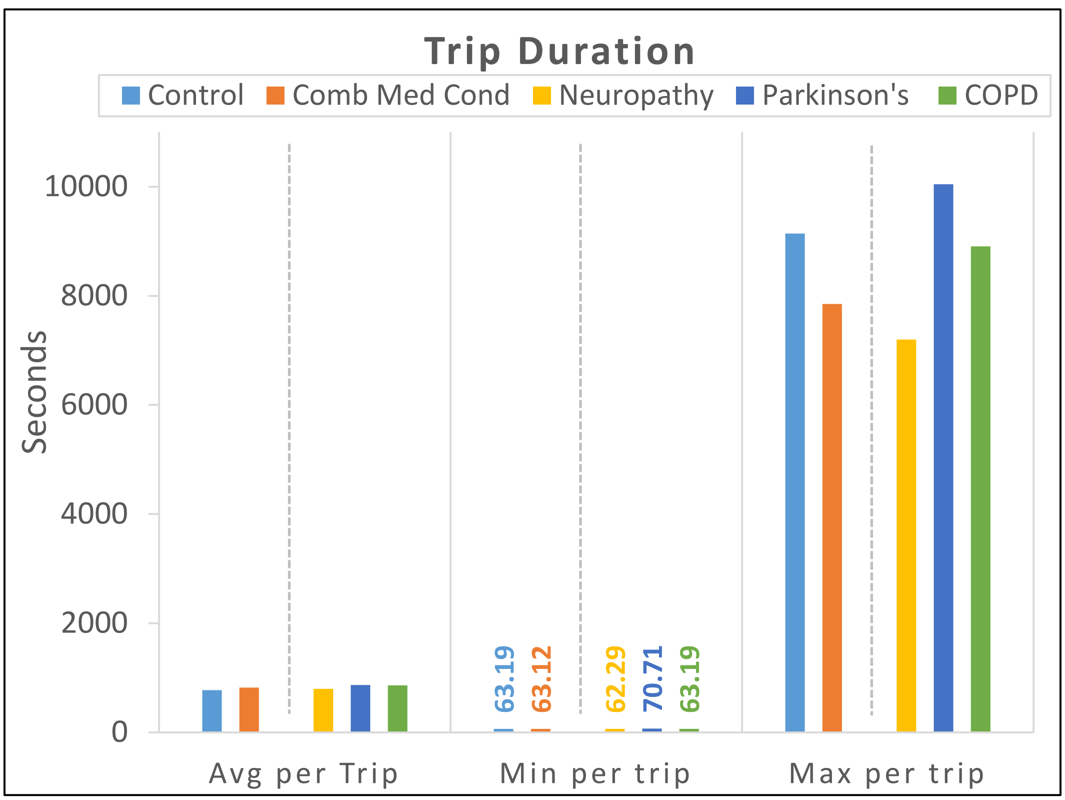

*Figure 16***.** Trip duration, group averages – SHRP2 NDS sample.

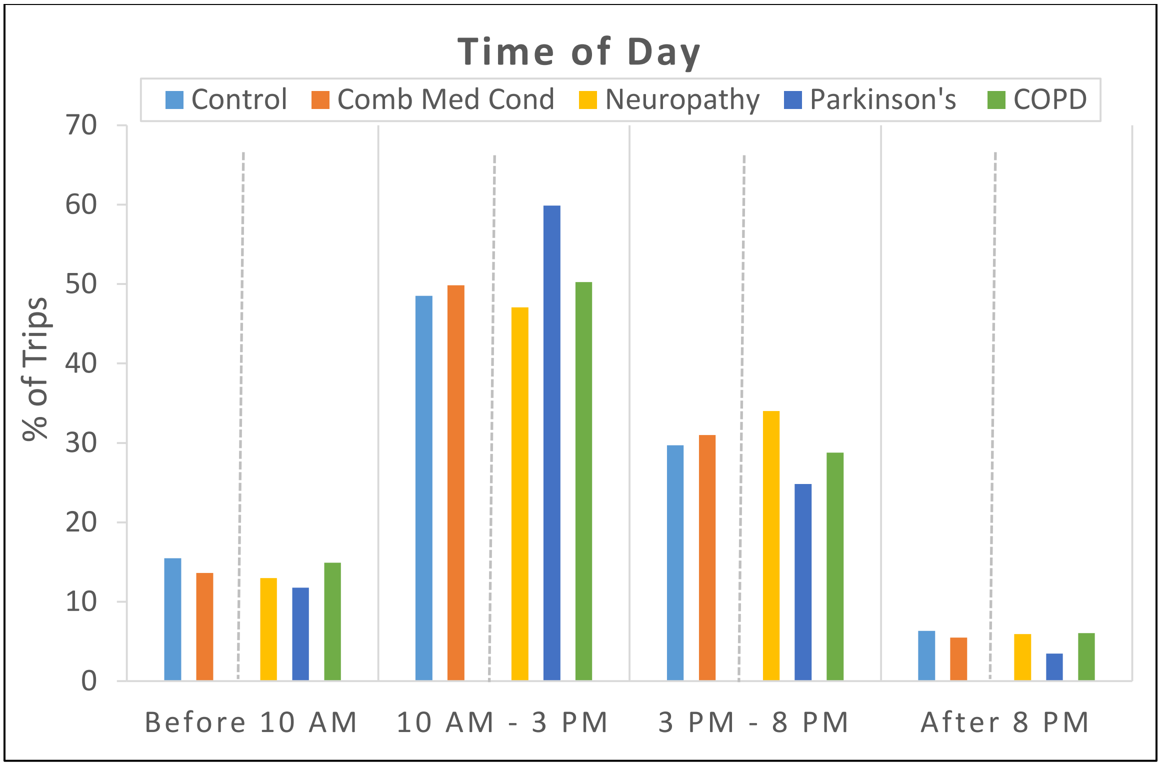

Figure 17. Percent of trips by time of day, group averages – SHRP 2 NDS sample.

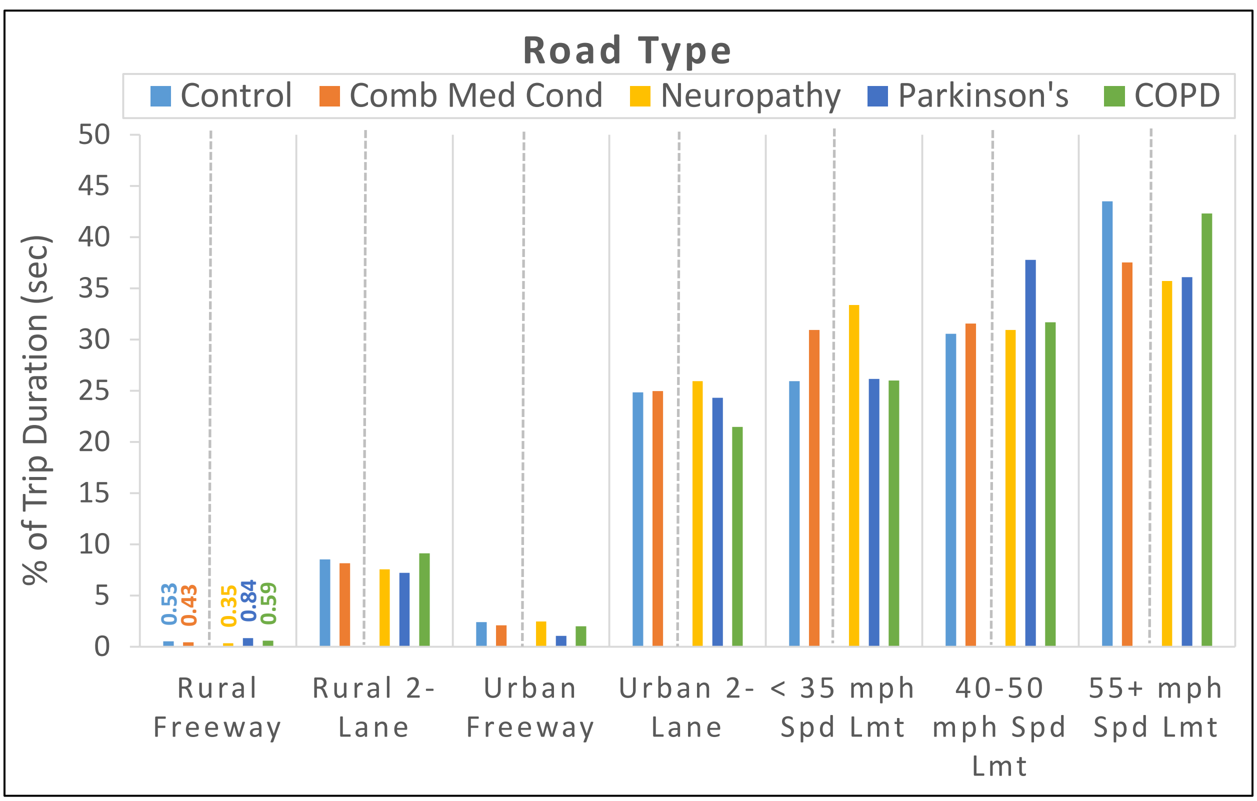

Figure 18. Percent of trip duration by road type, group averages – SHRP2 NDS sample

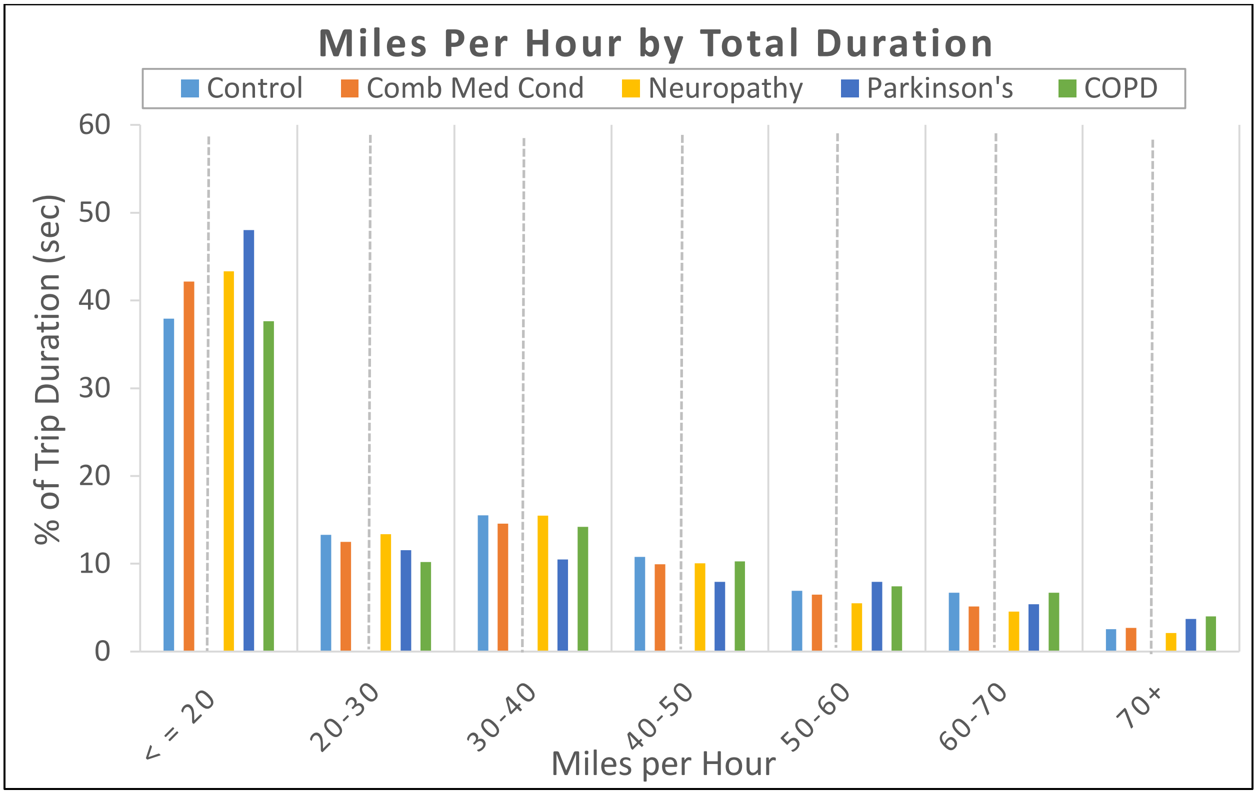

Figure 19. Percent of total duration by speed, group averages – SHPR2 NDS sample.

Table 19. SHRP2 NDS Sample Driving Exposure Analysis Results

		Control vs. Medical Condition			Control vs. Neuropathy			Control vs. Parkinson's			Control vs. COPD		
Measure		t	df	*p*	t	df	*p*	t	df	*p*	t	df	*p*
	Total trips taken	2.111	183.43	**0.036**	0.928	169	0.355	1.248	134	0.214	1.554	148	0.122
	Average trips per day	3.593	200	**0.001**	1.988	168	**0.048**	1.613	134	0.109	2.942	148	**0.004**
Miles Driven	Average per day	2.008	200	**0.046**	1.302	168	0.195	0.808	134	0.421	1.348	148	0.180
	Min per trip	0.105	185.17	0.917	0.503	167.4	0.616	-0.171	134	0.865	-0.338	148	0.736
	Max per trip	1.403	200	0.162	1.733	168	0.085	0.573	134	0.568	-0.364	148	0.716
Trip Duration (sec)	Avg trip duration	-1.169	200	0.244	-0.433	168	0.666	-0.941	134	0.348	-1.408	148	0.161
	Min trip duration	-0.036	197.74	0.971	0.463	167.55	0.644	-0.980	134	0.329	-0.002	103.86	0.998
	Max trip duration	2.021	200	**0.045**	2.711	168	**0.007**	-0.360	6.25	0.731	0.244	148	0.808
% of Trips by Distance Band	<=1 mile	0.388	200	0.698	1.019	168	0.310	-0.370	134	0.712	-0.396	148	0.693
	>1-2.5 miles	-0.306	200	0.760	-0.723	168	0.471	-0.933	134	0.352	1.176	148	0.242
	2.6-5.5 miles	-0.237	200	0.813	-0.651	168	0.516	0.367	134	0.714	-0.193	148	0.847
	5.6-10.5 miles	0.215	200	0.830	-0.632	168	0.529	1.164	134	0.245	0.377	148	0.707
	10.6-20 miles	-0.385	116.89	0.701	0.284	168	0.776	1.093	134	0.276	-0.428	23.2	0.675
	>20 miles	0.175	200	0.861	0.677	168	0.499	-0.644	134	0.521	-0.708	148	0.480
% of Trips by Time of Day	Before 10 AM	1.419	200	0.158	1.471	168	0.143	1.020	134	0.310	0.252	148	0.801
	10 AM - 3 PM	-0.605	200	0.546	0.674	168	0.502	-2.384	134	**0.019**	-0.597	148	0.552
	3 PM - 8 PM	-0.878	200	0.381	-2.098	168	**0.037**	1.117	134	0.266	0.337	148	0.737

	After 8 PM (night)	0.813	186.19	0.417	0.369	88.72	0.713	1.035	134	0.303	0.165	148	0.869
% of Trip Duration (sec) by Road Type	Rural Freeway	0.735	200	0.463	1.654	93.49	0.102	-0.569	6.19	0.589	-0.339	148	0.735
	Rural 2-Lane	0.270	123.23	0.788	0.522	168	0.602	0.343	134	0.732	-0.164	22.86	0.871
	Urban Freeway	0.679	200	0.498	-0.085	168	0.932	2.330	9.82	**0.043**	0.594	148	0.553
	Urban 2-Lane	0.084	123.76	0.934	-0.530	54.9	0.598	0.143	134	0.886	1.541	148	0.126
	< 35 mph Spd Lmt	-1.495	125.06	0.138	-1.811	56.1	0.075	-0.018	6.24	0.987	-0.014	148	0.989
	40-50 mph Spd Lmt	-0.393	200	0.695	-0.099	168	0.921	-0.925	134	0.357	-0.246	148	0.809
	55+ mph Spd Lmt	1.634	200	0.104	1.764	168	0.080	0.765	134	0.446	0.202	148	0.840
% of Miles Driven by Miles per Hour	< = 20 mph	-0.690	184.24	0.491	-0.098	168	0.328	-0.758	134	0.450	1.560	71.76	0.123
	20-30 mph	-0.724	200	0.440	-1.399	168	0.166	-0.525	134	0.601	1.406	148	0.162
	30-40 mph	-0.724	200	0.470	-1.426	168	0.156	1.047	134	0.297	-0.068	23.595	0.947
	40-50 mph	0.106	200	0.915	-0.167	168	0.868	0.763	134	0.447	0.107	148	0.915
	50-60 mph	0.154	200	0.878	1.155	168	0.250	-0.323	6.17	0.757	-0.605	148	0.546
	60-70 mph	1.905	200	***0.058***	2.019	168	**0.045**	0.806	134	0.422	-0.047	148	0.963
	70+ mph	-0.297	200	0.766	0.657	168	0.512	-0.935	134	0.351	-1.638	148	0.104
% of Trip Duration by Miles per Hour	< = 20 mph	-2.349	200	**0.020**	-2.587	168	**0.011**	-1.351	6.25	0.224	0.109	148	0.913
	20-30 mph	1.062	200	0.290	-0.054	168	0.957	0.837	134	0.404	3.524	39	**0.001**
	30-40 mph	1.226	200	0.222	0.522	168	0.959	2.470	134	**0.015**	1.029	148	0.305
	40-50 mph	0.975	200	0.331	0.680	168	0.498	1.199	134	0.233	0.362	148	0.718
	50-60 mph	0.569	200	0.570	1.665	168	0.098	-0.318	6.23	0.761	-0.404	148	0.687
	60-70 mph	1.907	200	***0.058***	2.547	91.8	**0.013**	0.570	134	0.570	-0.002	148	0.998
	70+ mph	-0.237	126.02	0.813	0.601	168	0.549	-0.765	134	0.446	-1.219	23.66	0.235
% of Trips – Other	Seat Belt Worn at least 90% of trip	1.938	24.505	***0.063***	1.389	12.04	0.190	1.679	3.1116	0.188	0.534	39	0.597

Highlighting indicates significant findings at $p < 0.05$; ***bold italics*** indicates differences that narrowly missed this criterion

On-Road Driving Performance

Primary sample.

Standard CDRS scoring protocol. The CDRS evaluated each driver's on-road performance after the exposure data collection period was complete. This section presents results of these evaluations.

The CDRS directed each driver to proceed along a common, preplanned 27-mile route through the community that required participants to navigate a mix of residential, arterial, and interstate traffic conditions, so it exposed them to a broad range of roadway types, speeds, and types of intersection control. The drive included intersections with stop signs and traffic signals, and left- and right-turn maneuvers—situations that required the driver to shift from the accelerator to the brake in response to other traffic.

The standard CDRS evaluation consisted of a scoring scale from 0 to 4. These scores were used to indicate competence on specific subscales within four domains of driving performance under both low-speed and high-speed traffic conditions. These domains fell under three *tactical* sets and one *strategic* set of driving skills. A driver who had the opportunity to demonstrate the skill/behavior in question but never did so received a score of 0. A score of 1 indicated that the driver demonstrated the skill/behavior in question on roughly 25% of the opportunities afforded during the on-road evaluation; a score of 2 on roughly 50%; and a score of 3 on roughly 75% of his/her opportunities. A score of 4 indicated that a driver consistently performed the skill/behavior in question when presented with the opportunity.

It is important to note that these scores represent only ordinal, not interval, level data. Although the CDRS used fixed evaluation routes, normal variability in traffic conditions across time of day, day of week, and weather condition produced different numbers of opportunities to demonstrate skills/behaviors. Thus, a 4 reliably connotes better performance than a 3, a 3 than a 2, and so on; but how *much* better one score is than another varied from person to person and from drive to drive. Given the ordinal nature of the dependent variable, this report provides only descriptive statistics. Table 20 and Table 21, respectively, show the distribution of performance scores across groups, expressed as the numbers and percentages of drivers scoring in each category.

Table 20. Counts of Drivers Scoring in Each Performance Category – Primary Sample

Skill/Behavior Evaluated	Subscale Scored by CDRS	Control (n = 19) Number of Drivers with Score of:					Control (n = 19) Total	Medical Conditions (n = 8) Number of Drivers with Score of:					Medical Conditions (n = 8) Total
		4	3	2	1	0		4	3	2	1	0	
Tactical Skills: Visual Search and Scanning Tasks	Mirror checks Low-Speed Traffic	19					19	7		1			8
	Mirror Checks High-Speed Traffic	19					19	7		1			8
	Scans Environment Low-Speed Traffic	19					19	6	2				8
	Scans Environment High-Speed Traffic	19					19	7	1				8
	Blind Spot Checks Low-Speed Traffic	18	1				19	7	1				8
	Blind Spot Checks High speed traffic	18	1				19	7	1				8
	Identifies Signage Low-Speed Traffic	19					19	7		1			8
	Identifies Signage High-Speed Traffic	19					19	8					8
	Checks Cross Traffic Low-Speed Traffic	19					19	8					8
	Checks Cross traffic High-Speed Traffic	19					19	8					8
Tactical Skills: Vehicle Positioning Tasks	Gap Selection Low-Speed Traffic	17	2				19	7		1			8
	Gap Selection High-Speed Traffic	17	2				19	7		1			8
	Following/Stopping Distance Low-Speed Traffic	14	4	1			19	6	1	1			8
	Following/Stopping Distance High-Speed Traffic	16	2	1			19	7		1			8
	Lane Usage/Position Low-Speed Traffic	19					19	7		1			8
	Lane Usage/ Position High-Speed Traffic	18	1				19	7		1			8
	Turns into Proper Lane Low-Speed Traffic	18	1				19	8					8
	Turns into Proper lane High-Speed Traffic	18	1				19	8					8
	Lane Changes Low-Speed Traffic	18	1				19	7		1			8
	Lane Changes High-Speed Traffic	18	1				19	7		1			8
Tactical Skills: Vehicle Handling Tasks	Appropriate Speed Low-Speed Traffic	18	1				19	6	1	1			8
	Appropriate Speed High-Speed Traffic	18	1				19	7		1			8
	Smooth Steering Low-Speed Traffic	18		1			19	7	1				8
	Smooth Steering High-Speed Traffic	18		1			19	7	1				8
	Smooth Acceleration Low-Speed Traffic	18	1				19	8					8
	Smooth Acceleration High-Speed Traffic	18	1				19	8					8
	Smooth Braking Low-Speed Traffic	19					19	8					8
	Smooth Braking High-Speed Traffic	19					19	8					8
	Complete Stops Low-Speed Traffic	19					19	8					8
	Complete Stops High-Speed Traffic	19					19	8					8
	Turns Low-Speed Traffic	19					19	8					8
	Turns High-Speed Traffic	19					19	8					8
	Yields Right of Way Low-Speed Traffic	19					19	7	1				8
	Yields Right of Way High-Speed Traffic	19					19	7	1				8
	Turn Signals Low-Speed Traffic	19					19	8					8
	Turn Signals High-Speed Traffic	19					19	8					8
	Speed Maintenance Low-Speed Traffic	19					19	8					8
	Speed Maintenance High-Speed Traffic	19					19	8					8
Strategic Skills: Cognitive and Executive Function Tasks	Divided Attention Low-Speed Traffic	18	1				19	6	1	1			8
	Divided Attention High-Speed Traffic	18	1				19	6	1	1			8
	Anticipates Hazards Low-Speed Traffic	19					19	6	2				8
	Anticipates Hazards High-Speed Traffic	19					19	8					8
	Plans Ahead Low-Speed Traffic	18	1				19	7		1			8
	Plans Ahead High-Speed Traffic	18	1				19	7		1			8
	Decision Making Low-Speed Traffic	18	1				19	7		1			8
	Decision Making High Speed traffic	18	1				19	7	1				8
	Memory Low-Speed Traffic	19					19	7		1			8
	Memory High-Speed Traffic	19					19	7		1			8
	Following Directions Low-Speed Traffic	19					19	6	1	1			8
	Following Directions High-Speed Traffic	19					19	7		1			8
	Speed of Processing Low-Speed Traffic	19					19	6	2				8
	Speed of Processing High-Speed Traffic	19					19	6	2				8
	Rules of the Road Low-Speed Traffic	19					19	8					8
	Rules of the Road High-Speed Traffic	19					19	8					8

Table 21. Percent of Drivers Scoring in Each Performance Category – Primary Sample

Skill/Behavior Evaluated	**Subscale Scored by CDRS**	**Control**					**Medical Conditions**				
		Percent of Total with Scores of:					**Percent of Total with Scores of:**				
		4	**3**	**2**	**1**	**0**	**4**	**3**	**2**	**1**	**0**
Tactical Skills: Visual Search and Scanning Tasks	Mirror checks Low-Speed Traffic	100%					88%		13%		
	Mirror Checks High-Speed Traffic	100%					88%		13%		
	Scans Environment Low-Speed Traffic	100%					75%	25%			
	Scans Environment High-Speed Traffic	100%					88%	13%			
	Blind Spot Checks Low-Speed Traffic	95%	5%				88%	13%			
	Blind Spot Checks High speed traffic	95%	5%				88%	13%			
	Identifies Signage Low-Speed Traffic	100%					88%		13%		
	Identifies Signage High-Speed Traffic	100%					100%				
	Checks Cross Traffic Low-Speed Traffic	100%					100%				
	Checks Cross traffic High-Speed Traffic	100%					100%				
Tactical Skills: Vehicle Positioning Tasks	Gap Selection Low-Speed Traffic	89%	11%				88%		13%		
	Gap Selection High-Speed Traffic	89%	11%				88%		13%		
	Following/Stopping Distance Low-Speed Traffic	74%	21%	5%			75%	13%	13%		
	Following/Stopping Distance High-Speed Traffic	84%	11%	5%			88%		13%		
	Lane Usage/Position Low-Speed Traffic	100%					88%		13%		
	Lane Usage/ Position High-Speed Traffic	95%	5%				88%		13%		
	Turns into Proper Lane Low-Speed Traffic	95%	5%				100%		0%		
	Turns into Proper lane High-Speed Traffic	95%	5%				100%		0%		
	Lane Changes Low-Speed Traffic	95%	5%				88%		13%		
	Lane Changes High-Speed Traffic	95%	5%				88%		13%		
Tactical Skills: Vehicle Handling Tasks	Appropriate Speed Low-Speed Traffic	95%	5%				75%	13%	13%		
	Appropriate Speed High-Speed Traffic	95%	5%				88%		13%		
	Smooth Steering Low-Speed Traffic	95%		5%			88%	13%			
	Smooth Steering High-Speed Traffic	95%		5%			88%	13%			
	Smooth Acceleration Low-Speed Traffic	95%	5%				100%				
	Smooth Acceleration High-Speed Traffic	95%	5%				100%				
	Smooth Braking Low-Speed Traffic	100%					100%				
	Smooth Braking High-Speed Traffic	100%					100%				
	Complete Stops Low-Speed Traffic	100%					100%				
	Complete Stops High-Speed Traffic	100%					100%				
	Turns Low-Speed Traffic	100%					100%				
	Turns High-Speed Traffic	100%					100%				
	Yields Right of Way Low-Speed Traffic	100%					88%	13%			
	Yields Right of Way High-Speed Traffic	100%					88%	13%			
	Turn Signals Low-Speed Traffic	100%					100%				
	Turn Signals High-Speed Traffic	100%					100%				
	Speed Maintenance Low-Speed Traffic	100%					100%				
	Speed Maintenance High-Speed Traffic	100%					100%				
Strategic Skills: Cognitive and Executive Function Tasks	Divided Attention Low-Speed Traffic	95%	5%				75%	13%	13%		
	Divided Attention High-Speed Traffic	95%	5%				75%	13%	13%		
	Anticipates Hazards Low-Speed Traffic	100%					75%	25%			
	Anticipates Hazards High-Speed Traffic	100%					100%				
	Plans Ahead Low-Speed Traffic	95%	5%				88%		13%		
	Plans Ahead High-Speed Traffic	95%	5%				88%		13%		
	Decision Making Low-Speed Traffic	95%	5%				88%		13%		
	Decision Making High Speed traffic	95%	5%				88%	13%			
	Memory Low-Speed Traffic	100%					88%	0%	13%		
	Memory High-Speed Traffic	100%					88%	0%	13%		
	Following Directions Low-Speed Traffic	100%					75%	13%	13%		
	Following Directions High-Speed Traffic	100%					88%		13%		
	Speed of Processing Low-Speed Traffic	100%					75%	25%			
	Speed of Processing High-Speed Traffic	100%					75%	25%			
	Rules of the Road Low-Speed Traffic	100%					100%				
	Rules of the Road High-Speed Traffic	100%					100%				

Behaviorally Anchored Rating Scale. The BARS is a measure of on-road driving performance, scored by a CDRS, that the research team developed for this study. This measure, which complemented the traditional CDRS scoring protocol, was derived from a detailed review of a driver's behavior as recorded in an instrumented vehicle by multiple video cameras focused on the driver's head movements and gaze direction (visual scanning), control movements (e.g., turn signal activation), as well as the movements of the vehicle in relation to roadway and traffic conditions.

After the CDRS designed the test route, the research team worked with her to divide the route into a sequence of segments, each described by one or more specific maneuvers with an associated set of driving task demands. These task demands were expressed in terms of a series of required behaviors that the CDRS could observe and score.

The BARS uses a 0-t100-point scale with higher scores connoting superior performance. Each discrete behavior associated with each separate location/segment along the test route was scored as "1" (fail), "2" (acceptable), or "3" (excellent). The CDRS confirmed that the intervals between each of these scores are equal; the difference between Fail and Acceptable is the same as between Acceptable and Excellent. For each driver, these scores were summed across all behaviors for all locations/segments. This sum was divided by the maximum number of points possible for the entire test route. The resulting percentage is the BARS score.

Note that not all drivers' sums of scores are divided by the same denominator. At times, an adjustment in the maximum possible number of points for the test route was required when prevailing traffic conditions (beyond the control of the CDRS) resulted in divergent driving task demands at one or more locations. An example is a location where the driver was required to make a left turn at a signalized intersection. Two distinctly different sets of task demands were described when this maneuver was protected by a green arrow signal versus only permitted by a green ball indication. In the latter case, drivers had to judge when the gap in oncoming traffic was adequate to turn safely. Elevated task demands added to the maximum number of points that drivers could obtain for that location and consequently for the test route as a whole.

Two segments along the test route were characterized by divergent driving task demands -- a left turn at an intersection with a green arrow (lower demand) versus a green ball (higher demand); and a turn from a center, two-way-left-turn lane (TWLTL) without opposing traffic (lower demand) or with opposing traffic (higher demand). As a result, drivers were sorted into one of four brackets – each associated with a different maximum possible number of points – before calculating their BARS scores: (1) low demand conditions at both locations; (2) low demand for the TWLTL maneuver but high demand for the left turn; (3) low demand for the left turn but high demand for the TWLTL maneuver; and (4) high demand at both locations.

Finally, coders made one further adjustment, on a location-by-location basis, when (1) a driver did not perform a given behavior (or series of behaviors) because s/he did not understand an instruction from the CDRS, or (2) the driver performed the behaviors but an equipment problem prevented the CDRS from viewing and scoring them. In such cases, the behaviors were removed entirely from the list of on-road performance requirements, and the driver's maximum possible score for the test route was reduced accordingly. In contrast, if a driver clearly understood the CDRS instructions but ignored or refused to comply with an instruction, the behavior was interpreted as "Fail" and received a score of "1."

Table 22 presents summary statistics for BARS scores across study groups. BARS scores were available for 25 of the 27 drivers in the Primary Sample. Student's *t*-tests (two-tailed) revealed **no significant differences** in BARS scores between the control group and the CMC group. A frequency histogram in Figure 20 shows the distribution of BARS scores for the drivers in the control group and in the medical conditions subgroups.

Table 22. BARS On-Road Performance Scores – Primary Sample

Group	N	Minimum Score	Maximum Score	Average Score	Standard Deviation
Control	**17**	**90.83**	**100**	**97.18**	**2.61**
Medical Condition	**8**	**80.00**	**98.37**	**93.45**	**7.13**
COPD	4	85.00	98.37	93.43	6.14
AMD	2	97.50	98.20	97.85	0.49
Neuropathy	2	80.00	98.20	89.10	12.87
Total	**25**	**80.00**	**100**	**95.99**	**4.74**

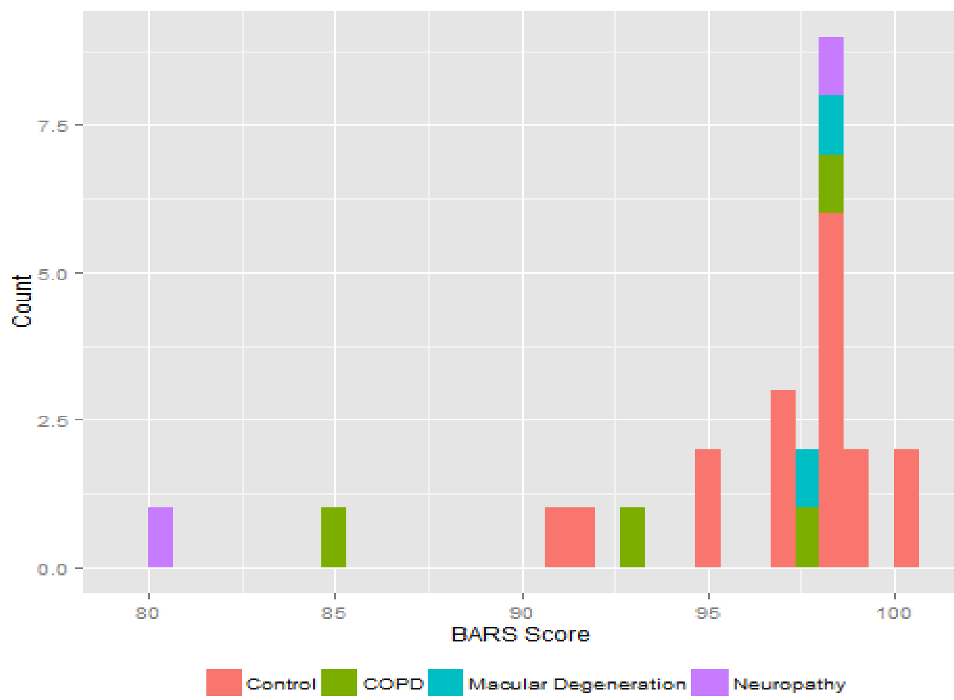

Figure 20. Histogram of BARS scores – Primary Sample.

Augmented sample.

Standard CDRS scoring protocol. Driving performance for the Augmented Sample was also evaluated using the Standard CDRS scoring protocols. Table 23 shows how performance was distributed across groups in terms of the number of drivers scoring in each category.

Table 19. Counts of Drivers Scoring in Each Performance Category – Augmented Sample

Skill/Behavior Evaluated	Subscale Scored by CDRS	Control						Medical Conditions					
		Number of Drivers with Score of:					Total	Number of Drivers with Score of:					Total
		4	3	2	1	0		4	3	2	1	0	
Tactical Skills: Visual Search and Scanning Tasks	Mirror checks Low-Speed Traffic	43					43	14		1			15
	Mirror Checks High-Speed Traffic	43					43	14		1			15
	Scans Environment Low-Speed Traffic	42	1				43	11	4				15
	Scans Environment High-Speed Traffic	42	1				43	14	1				15
	Blind Spot Checks Low-Speed Traffic	42	1				43	13	2				15
	Blind Spot Checks High speed traffic	42	1				43	14	1				15
	Identifies Signage Low-Speed Traffic	40	3				43	12	2	1			15
	Identifies Signage High-Speed Traffic	42	1				43	15	0				15
	Checks Cross Traffic Low-Speed Traffic	43	0				43	15	0				15
	Checks Cross traffic High-Speed Traffic	43	0				43	15	0				15
Tactical Skills: Vehicle Positioning Tasks	Gap Selection Low-Speed Traffic	40	3				43	13	1	1			15
	Gap Selection High-Speed Traffic	41	2				43	13	1	1			15
	Following/Stopping Distance Low-Speed Traffic	31	10	2			43	13	1	1			15
	Following/Stopping Distance High-Speed Traffic	35	7				43	14		1			15
	Lane Usage/Position Low-Speed Traffic	41	2				43	13	1	1			15
	Lane Usage/ Position High-Speed Traffic	40	3				43	14		1			15
	Turns into Proper Lane Low-Speed Traffic	39	4				43	15					15
	Turns into Proper lane High-Speed Traffic	40	3				43	15					15
	Lane Changes Low-Speed Traffic	42	1				43	14		1			15
	Lane Changes High-Speed Traffic	42	1				43	14		1			15
Tactical Skills: Vehicle Handling Tasks	Appropriate Speed Low-Speed Traffic	38	5				43	13	1	1			15
	Appropriate Speed High-Speed Traffic	39	4				43	14		1			15
	Smooth Steering Low-Speed Traffic	42		1			43	14	1				15
	Smooth Steering High-Speed Traffic	42		1			43	14	1				15
	Smooth Acceleration Low-Speed Traffic	41	2				43	14	1				15
	Smooth Acceleration High-Speed Traffic	41	2				43	14	1				15
	Smooth Braking Low-Speed Traffic	41	2				43	15					15
	Smooth Braking High-Speed Traffic	41	2				43	15					15
	Complete Stops Low-Speed Traffic	43					43	15					15
	Complete Stops High-Speed Traffic	43					43	15					15
	Turns Low-Speed Traffic	41	2				43	15					15
	Turns High-Speed Traffic	42	1				43	15					15
	Yields Right of Way Low-Speed Traffic	43					43	14					15
	Yields Right of Way High-Speed Traffic	43					43	14	1				15
	Turn Signals Low-Speed Traffic	40	2	1			43	15	0				15
	Turn Signals High-Speed Traffic	41	2				43	15	0				15
	Speed Maintenance Low-Speed Traffic	42	1				43	14	1				15
	Speed Maintenance High-Speed Traffic	42	1				43	14	1				15
Strategic Skills: Cognitive and Executive Function Tasks	Divided Attention Low-Speed Traffic	38	5				43	11	3	1			15
	Divided Attention High-Speed Traffic	39	4				43	11	3	1			15
	Anticipates Hazards Low-Speed Traffic	41	2				43	13	2				15
	Anticipates Hazards High-Speed Traffic	41	2				43	15					15
	Plans Ahead Low-Speed Traffic	39	4				43	14		1			15
	Plans Ahead High-Speed Traffic	39	4				43	14		1			15
	Decision Making Low-Speed Traffic	42	1				43	14		1			15
	Decision Making High Speed traffic	42	1				43	14	1				15
	Memory Low-Speed Traffic	41	2				43	14		1			15
	Memory High-Speed Traffic	41	2				43	14		1			15
	Following Directions Low-Speed Traffic	42	1				43	13	1	1			15
	Following Directions High-Speed Traffic	42	1				43	14		1			15
	Speed of Processing Low-Speed Traffic	39	4				43	11	4				15
	Speed of Processing High-Speed Traffic	40	3				43	11	4				15
	Rules of the Road Low-Speed Traffic	43					43	15					15
	Rules of the Road High-Speed Traffic	43					43	15					15

Behaviorally Anchored Rating Scale. BARS scores were available for 55 of the 57 drivers in the Augmented Sample. Student's *t*-tests (two-tailed) revealed **no significant differences** in BARS scores between the control group and the CMC group (see Table 24). A frequency histogram in Figure 21 shows the distribution of BARS scores for the drivers in the control group and in the medical conditions subgroups.

Table 204. BARS On-Road Performance Scores – Augmented Sample

Group	N	Minimum Score	Maximum Score	Average Score	Standard Deviation
Control	**40**	**79.63**	**100**	**95.77**	**5.00**
Medical Condition	**15**	**80.00**	**100**	**95.25**	**5.73**
COPD	4	85.00	98.37	93.43	6.14
AMD	2	97.50	98.20	97.85	0.49
Neuropathy	9	80.00	100	95.47	6.32
Total	**55**	**79.63**	**100**	**95.63**	**5.16**

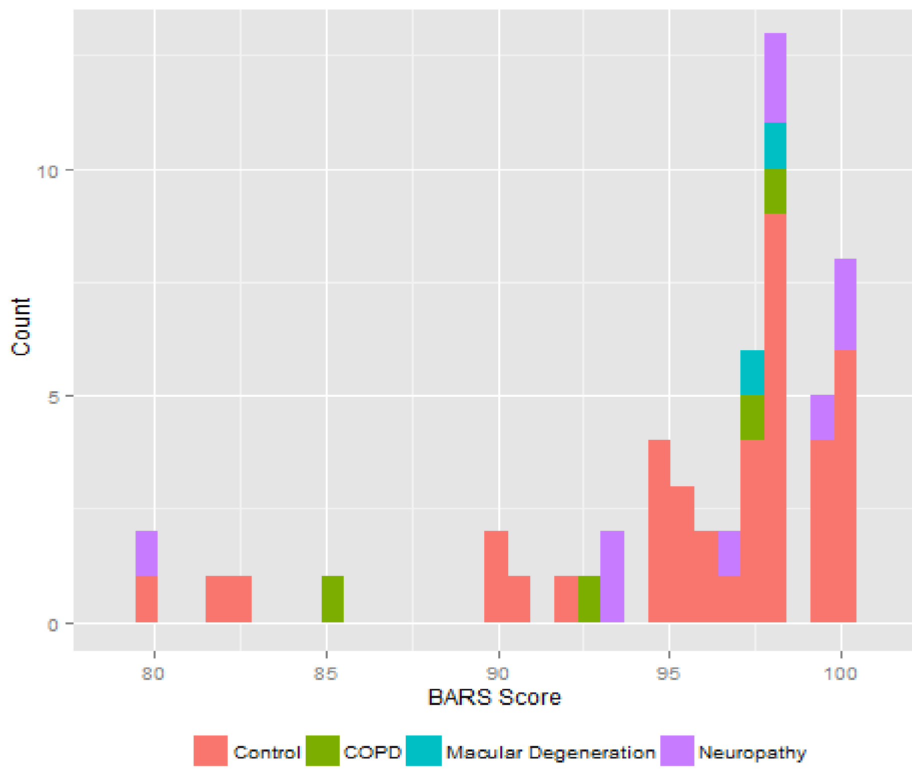

Figure 21. Histogram of BARS scores – Augmented Sample

Regression analyses were applied to determine if there was a significant association between driver age (5-year age category), driver sex, or any of the clinical measures (brake RT; far bilateral acuity; bilateral contrast sensitivity; plantar threshold; letter cancellation test time; useful field of view; Trail-Making Test completion time, Parts A and B) and BARS scores. Linear regression was used for the analysis. Backward elimination was used to remove variables that were not statistically significant, using a criterion of $p = .10$.

One measure, the Trail-Making Test, Part B score, was statistically significant ($p = .01$); a higher Trails B score (longer completion time, connoting poorer performance) was associated with a lower (poorer) BARS score. Trails B performance accounted for approximately 12 percent of the variance in the BARS metric for on-road performance. This finding is consistent with numerous studies of Trails B scores and measure of driving performance.

SHRP2 broad sample analysis. The analysis of safety-relevant performance differences between SHRP2 NDS Sample drivers in the control group and drivers with a medical condition of interest focused on involvements in crashes and near-crash events. Analysts extracted these from the SHRP2 NDS event table for all drivers in the sample including codes that denoted a level of fault assigned by a VTTI data coder. According to published coding guidelines, for a given event a driver could be designated "at fault," "not at fault," or could be identified as having exhibited some behavior that "caused or contributed to" a crash or near-crash.

Table 25 presents the number and exposure-based (per 10,000 miles traveled) rate of crashes/near crashes, both for total events and for just those events where the driver was deemed at-fault. As indicated in this table, the total event rates for the control group and the CMC group were similar, and the at-fault event rates were virtually identical. Among the medical conditions subgroups, the drivers with neuropathy evidenced higher total event and at-fault event rates than the control group drivers, while these rates for the COPD subgroup were consistently lower than for controls. Table 26 shows the number of drivers in each group/subsample with an event and with an at-fault event, along with group size (N). Chi-square tests revealed no significant differences between groups in the proportion of subjects with an event (crash or near-crash).

Table 21. Number and Rate of Total Events and At-Fault Events – SHRP2 NDS Sample

Group	Total Events*	At-Fault Events**	Total Miles Driven	Event Rate (per 10,000 miles driven)	At-Fault Event Rate (per 10,000 miles driven)
Control	**106**	**78**	**1,226,580.62**	**0.864**	**0.636**
Medical Condition	**44**	**34**	**535,229.35**	**0.822**	**0.635**
COPD	7	6	149,817.05	0.467	0.400
Neuropathy	32	25	314,400.90	1.018	0.795
Parkinson's	3	3	44,577.67	0.673	0.673
Total	**150**	**112**	**1,761,809.96**	**0.851**	**0.636**

*Crash or Near-Crash **Coded with fault or with a behavior that caused or contributed to the crash/near-crash

Table 22. Number of Drivers With Events and At-Fault Events – SHRP2 NDS Sample

Group	N	Drivers With an Event*	Drivers With No Event(s)	Drivers With an At-Fault Event**	Drivers With an Event Not At-Fault
Control	**129**	**52**	**77**	**47**	**5**
Medical Condition	**74**	**27**	**47**	**23**	**4**
COPD	21	7	14	6	1
Neuropathy	42	17	25	15	2
Parkinson's	7	2	5	2	0
Total	**203**	**79**	**124**	**70**	**9**

*Crash or Near-Crash **Coded with fault or with a behavior that caused or contributed to the crash/near-crash

Finally, regression analyses explored whether there was a significant association between driver age (5-year age category), driver sex, any of the available clinical measures (far bilateral acuity; contrast sensitivity, at each of five spatial resolution levels; rapid pace walk time; UFOV® subtest 2; Trail-Making Test completion time, Parts A and B; and Visualizing Missing Information), or a measure of driving exposure (either average trips per day, average miles driven per day, or average trip length) and counts of crashes and near crashes. Poisson regression and negative binomial regression were used for these analyses, the former when the mean and variance for the dependent were equal and the latter when the variance exceeded the mean. Backward elimination was used to remove variables that were not statistically significant, using a criterion of $p = .10$.

Number of trips per day was the only significant predictor of the more numerous "near crashes" ($p = .02$): a higher average number of trips per day was associated with a higher number of near crashes. Other results were counterintuitive. Only one independent variable, Visualizing Missing Information (VMI) was significantly associated with crash counts ($p = .04$); however, the analysis indicated that *worse* performance on this measure of spatial cognition was associated with *fewer* crashes. Similarly, examination of "at-fault" crashes showed worse performance on both VMI *and* Trails B was associated with fewer events, at a marginal level of statistical significance ($p = .057$ and $p = .064$, respectively). These findings are contrary to a large body of published literature in this area.

SHRP2 site-specific analysis. The research team hypothesized main effects of ramp design and driver group, as well as a ramp-by-group interaction, for a range of dependent measures including maximum speed, mean speed, maximum longitudinal acceleration *and* deceleration, number of brake applications, and cumulative time with headway $\geq$3.5 *and* less than 3.5 seconds. Higher speeds, higher acceleration, less deceleration, fewer brake applications, and less variability in time headway (i.e., relatively lower values for both longer and shorter headways) were predicted for the "more favorable" ramps and for the drivers without medical conditions.

An interaction of ramp by group was also hypothesized, such that performance differences on the "less favorable" versus "more favorable" ramps would be less for the control group than for the medical conditions group. In other words, the research team predicted that reducing the demand for negotiating ramps would have a greater benefit for the drivers *with* medical conditions than for drivers *without* medical conditions.

Separate ANOVA analyses were carried out for driver performance before and after traversing the reference node at the ramp gore. This was done because the variability in ramp geometry was much greater before the gore; after that node the acceleration lane geometry was more homogeneous across sites. The criterion for statistical significance was $p<.05$.

Before the node, there was a main effect of ramp design on maximum acceleration (higher for more favorable designs) (F=27.99; df=1,89), number of brake applications (more applications on less favorable designs) (F=4.53; df=1,89), and cumulative time headway $\geq$3.5 sec (more for less favorable designs) (F=8.09; df= 1,89). There was one main effect of group: medical conditions drivers exhibited a significantly higher cumulative time headway $\geq$3.5 sec than drivers without medical conditions (*F*=5.70; *df*=1,89). After the node, the only main effect was ramp design on maximum speed (higher for more favorable designs) (*F*=5.37; *df*=1,89). There were no significant group-by-ramp interactions, either before or after drivers passed the node at the tip of the gore.

Subsequent analyses revealed that the groups with and without self-reported medical conditions did *not* differ significantly on any of the available functional measures – visual acuity (bilateral), contrast sensitivity, rapid pace walk, Trail-Making, useful field of view, and visual closure. This helps explain the pattern of findings above.

Panel Discussion on Aging, Independence, and Driving Transitions

A meeting was conducted on November 16, 2015, at NHTSA headquarters in Washington, DC, to gain insight from staff at continuing care retirement communities (CCRCs) about their experience with residents who have manifested driving difficulties that place themselves and others at risk. The transition from independent living to assisted living, with a concomitant reduction and cessation of driving, provided a broad framework for the panel discussion. Ten staff members from six different CCRCs participated; these facilities varied in size from as few as 50 independent living residents to as many as 1,900 independent living residents and represented both stand-alone and networked organizations. The participants in this panel discussion included three CCRC administrators, three social service workers, two registered nurses, and one nurse practitioner and program coordinator, each. All were identified as key staff at their respective facilities who held responsibility for interacting with residents and their families – and intervening as appropriate – when driving difficulties became apparent.

The all-day meeting covered an agenda distributed in advance to all panelists (see Appendix G). The discussion, facilitated by the study Principal Investigator, sought input from each of the CCRC representatives about the full range of topics included in the agenda. The meeting was recorded by a professional transcription service.

A list of CCRCs in the Washington metro area was compiled from the internet; this was subsequently expanded as far as southeastern Pennsylvania. CCRCs of all sizes were included. Telephone contacts were made by study staff to identify who at each CCRC was the "go to" person (or persons) for driving-related issues and to gauge their interest in meeting participation. A follow-up contact via email to CCRC representatives initially expressing interest in the meeting provided full details about meeting logistics and travel arrangements and offered a $250 honorarium for committing a full day.

Responses to the telephone solicitations varied considerably. Initial contacts revealed (1) facilities that have proactive policies and programs in place that are designed to address issues of aging and safe driving; (2) facilities without such programs or policies but with a clear recognition of the importance of the issue and a sense of responsibility to address it; and (3) facilities whose representatives adamantly, and sometimes with irritation, insisted that this issue was "not our problem" and that it was up to families or to law enforcement to step in if a resident demonstrated driving difficulties. Based on the small sample, it is difficult to estimate what percentage of CCRCs fall into each of these groups.

Panelists' Responses to Discussion Topics on Meeting Agenda

Identifying residents at-risk for driving. Residents who may be high-risk drivers are brought to the attention of the CCRC representatives in a number of ways - most often through direct observation or complaints from other residents. Meeting participants often observed residents unintentionally driving too fast around the community, residents driving in the center of the road, wavy bumpers or dents in cars, cars parked sideways or in the grass, or rental cars in the community parking lots (because the resident had damaged their vehicle). Other residents often complained that someone was an unsafe driver, brought attention to dents in residents' vehicles, and/or made casual comments regarding lack of comfort as a passenger when a particular resident was driving. Occasionally, residents with issues that could potentially affect their driving were brought to their attention through reports from other departments (e.g., servers in the dining room).

Several of the panelists stated that when they see residents struggling with physical limitations (turning, walking, raising head and neck), and this causes question regarding safe driving ability. Other panelists had concerns about safe driving ability in relation to cognitive issues, such as when residents constantly repeat themselves, ask security where their car is parked, or become lost on their way home from a familiar location.

Some of the CCRCs represented in this meeting conducted annual assessments among all residents that included a short survey form with the question "are you still driving?"; or among residents with chronic medical conditions who received yearly cognitive testing (e.g., MoCA). This permitted changes to be monitored from year to year.

Panelists noted that, on occasion, adult children or other family members raised the issue of driving safety directly with the CCRC, or made comments such as "mom seems to be slowing down" that raised flags. And finally, some residents brought up the topic independently, particularly in those organizations that had a driving assessment-type program in place.

Panelists reported that medical doctors *rarely* raised the issue of safe driving with their residents or with CCRC staff. On-site physicians were sometimes the exception, but this too was rare. Medical doctors also did not often address how the medications they prescribed could affect driving. Panelists speculated that the medical doctors' main focus was treating a condition and that doctors found the issue of driving (or a holistic approach to a resident's health) to be "time consuming" and something they "don't get paid for."

Panelists stressed that because of the nature of an independent living community, it was not always possible to know who was and who was not driving, particularly among the residents who were not involved in community social engagements. Residents could cease driving without intervention from, or the notice of, the CCRC administration.

Frequency of identification and internal management of high-risk drivers. Panelists noted that one to five residents with driving-related issues were brought to their attention each month, depending on the size of the CCRC and the age distribution of the community. All of the CCRCs represented at the meeting had a resident "watch list" which, at any given time, included three to five residents with potential driving issues. Keepers of this "watch list" were usually in the social work or wellness department. Most of the CCRCs held regular meetings (daily, weekly, bi-weekly, or monthly, depending on facility) where they coordinated between departments or management regarding residents about whom they were concerned. Most often these meetings were interdisciplinary (e.g., medical, security, housekeeping, dining, social work), but sometimes they related only to medical status. Topics of concern did not always address driving directly, but they could include issues related to driving such as physical and/or cognitive deterioration.

Steps taken to address the issue of driving with high-risk residents. Some panelists emphasized that they could only have a conversation with a resident about driving if there had been a major event (e.g., a crash with injuries or significant property damage). Others proceeded after observing behaviors suggesting driving difficulties. In all cases, the CCRC representatives noted that they were required to "build a case" about why a resident was at risk for driving before the issue could be addressed. This was a multi-step process.

***Step 1: The conversation*.** While most of the CCRCs represented did not have a formal policy on how to address driving issues, they all followed the same basic course of action, which started by confronting high-risk residents and having a conversation with them about their driving. This could happen several times before taking the next step. In these conversations, residents were encouraged to make the decision to stop driving on their own. The conversation could include asking residents about their perception of their own driving ability, highlighting the ways they could save money by not driving anymore and the alternative transportation options available to them in the community. Often, however, residents saw these transportation services offered by the CCRC as being for others, not for them. These conversations were said to frequently "fall on deaf ears," with reactions almost always being adverse, often evoking the "fight or flight" instinct. Sometimes, albeit rarely, residents were actually relieved to have this conversation because they had recognized and accepted that there may be an issue with their driving. Most panelists stated that they tried to have at least one other CCRC staff member present for this conversation.

Panelists noted that residents with physical impairment were often more receptive because they were aware of their limitations and found driving physically challenging and exhausting. Conversely, residents with cognitive issues were generally less receptive because they were often not aware there was a problem or forgot that they were having difficulty driving.

When queried about a gender disparity in residents' reactions to the idea of limiting or ceasing driving, the CCRC representatives stated that it really depended on the dynamic of the community and that resident reaction relied more on individual characteristics than on gender. For example, if the community had a larger proportion of females, or tended to have independent and educated women, then the females were resistant to driving cessation, whereas in communities with females who were generally less independent (e.g., communities housing retired military), the females were more compliant.

***Step 2: Issue a formal letter to the resident*.** Panelists reported that if after one or more conversations as described above, a resident continued driving unsafely, and policy permitted, the CCRC issued a formal letter to the resident. This letter reiterated why they had been deemed an unsafe driver (e.g., car observed parked sideways, neighbor reported them driving over curb) and, depending on the CCRC policy (if any), the letter *recommended* they stop driving all together; *revoked* their "on campus" driving privileges; or *asked* that they remove their car from campus. One CCRC represented at the meeting issued this type of letter stating that campus driving privileges were revoked until the resident received a driving evaluation from a CDRS (at the resident's expense) but noted that almost all of the residents who were recommended to take this evaluation did not pass.

Step 3: Issue a formal letter to the State DMV. Panelists reported that, if driving safety was still a concern and all other options had been exhausted, the final step was to issue a letter to the DMV. This letter was either issued through administration or the medical department, and in some cases physicians issued this letter if they had good cause. However, it was a common notion among panelists that residents often appealed to the DMV and had their licenses reinstated. Depending on State regulations, residents may be required to pass a DMV driving test, but there was a broad lack of confidence among meeting panelists that this measure, or any other DMV measure/policy (e.g., mandatory physician referral), was effective at deterring those at highest risk from continuing to drive.

What about appealing to the resident's family? All panelists agreed that it was their goal to empower and support the family in acting on their concerns. They often offered to "be the bad guy" as sometimes family members contacted them with a driving-related concern but did not want to address it directly with their parent or grandparent. However, the CCRC representatives found that family support tended to be the exception. While this made the conversation with a resident about driving safety more difficult, they typically did not seek out family support before initiating this conversation for a number of reasons. First and foremost, there were issues of resident privacy that must be considered, and many residents became angry if the CCRC contacted their family without permission. Also, panelists have found that family members were often in denial and/or became defensive, possibly because they felt like the CCRC's message was that family had not noticed or had chosen to ignore the problem. The CCRC representatives noted that much revolved around family dynamics because families "have their own baggage" and nothing "happens in isolation." In other words, the decision to stop driving does not just impact the resident's life, but it impacts the lives of the family members as well.

Barriers to confronting a resident about their unsafe driving. Panelists noted a number of personal, organizational, and other barriers to confronting a resident about their unsafe driving and stated that they are never totally comfortable addressing this issue. All CCRC representatives agreed that their personal relationships with residents heavily influenced the interaction. Specifically, they stated it was especially hard when they had a relationship of trust with the resident because the resident often felt betrayed; and at the same time, it was difficult when the resident did not care for them or thought they were being punitive because then their concerns were not taken seriously. Panelists stated that when approaching this topic, they must always question whether they had exhausted all other possibilities, but they also stressed that no matter how hard, the conversation still needed to happen.

There are many organizational barriers that CCRCs may face in their interactions with a potentially unsafe resident driver. Panelists noted that these barriers can make it difficult to proceed when they identify an at-risk driver and/or can cause "feet to drag" within the organization regarding next steps to be taken. The following organizational barriers were identified by panelists:

- Resident confidentiality and rights in the community;
- Length of residency, board membership, or resident influence in community;
- Lack of support from other departments (e.g., administration) or conflicting opinions from other departments (e.g., hospitality versus medical);

- Administrative layers or “red tape”;
- Resistance from marketing departments;
- Business reputation;
- Legal issues;
- Lack of policy and/or regulation (i.e., no established mechanisms);
- Objective tools/resources are unavailable (e.g., screening tools, educational information);
- Financial costs to resident (e.g., driving evaluation, adaptive equipment);
- Financial costs to organization (e.g., lower income CCRCs have less oversight, especially among independent living residents); and
- Lack of alternative transportation options at the CCRC.

Other barriers to effective oversight and control of CCRC residents with driving difficulties were also noted. These included the absence of a formal scale or national standard that would serve as an objective measure in identifying a potentially unsafe driver. Federal action was suggested by many panelists. A simple lack of awareness regarding the issue was also seen as a barrier. Panelists noted that throughout their professional community, the topic of driving is somewhat passé; two CCRC representatives stated that their proposal to give a presentation at a high-profile conference on the issue of older driver safety and what they do to address it at their community was rejected two years in a row.

Existing policies on how to address unsafe driving. None of the CCRCs represented in this discussion had a formal, written policy on how to address the issue of unsafe driving with a resident (e.g., who has the conversation and what can or can’t be said). Nearly all of the CCRCs followed the same process − build case, have conversation, send formal letter to resident, contact DMV as last resort, but this was largely informal and not an explicit organizational policy. Just one CCRC had language in their resident contract that allowed them to take action, stating “*the Community reserves the right to revoke this [on-campus] motor-vehicle registration and resident driving privileges on campus.”* This line was recently added to the contract because a resident who was asked not to drive on campus took legal action against them.

Along with revoking driving privileges, this statement also allowed the CCRC to *ask* that the vehicle be removed from campus property. It is important to note that none of the CCRCs represented in this discussion legally had the right to physically remove residents’ cars or to physically tamper with them in any way (e.g., remove battery) to prevent them from driving it (nor does law enforcement). All meeting participants were in support of having such a statement in their contracts, but they acknowledged that there are various organizational barriers to adding it (e.g., administrative red tape, approval from resident board members, resistance from the marketing department, etc.).

Adaptive equipment and alternative transportation options. Panelists had reservations about recommending the use of in-vehicle adaptive equipment (e.g., pedal extenders, hand controls) to residents who are at-risk drivers. Concerns primarily were related to financial cost to the resident and the ease and safety of learning to use this new equipment at an advanced age.

The CCRC representatives also noted that alternative transportation was not always convenient or available to residents, particularly when they needed to travel off campus. Some CCRCs represented in this discussion offered alternative transportation options to the residents, including scheduled shuttles on- and off-campus. However, it was noted that residents did not always like to take advantage of this service and saw as it being for others (the "old people"), not for them. One smaller CCRC had no alternative transportation options, which was problematic for residents who did not drive. The campus was too large for them to walk to the community center for meals and activities, which caused increased isolation for the residents who did not drive.

Transitioning from independent to assisted living. According to panelists, driving cessation was usually a part of the transition to assisted living. The CCRC representatives stated this transition was usually a trigger to the resident and their family, and it made conversations about driving much easier because the resident's whole system of living was changing. Panelists stated that it was rare for a resident to drive after the transition to assisted living.

Other considerations affecting driving-related policies. The CCRC representatives were all in agreement that their organizations were businesses and that, *"Honestly, ... residents rule. They are tough to replace. They are few and far between. We are fighting for occupancy."* Because of the financial requirements for admittance, CCRCs had a very small target population. Having a reputation for "taking the keys" or having restrictive language in their residential contracts could deter potential applicants.

Financial constraints were cited as a possible barrier to increasing awareness and driving safety among the CCRC community, and many panelists noted that lower income CCRCs were particularly disadvantaged in this respect. The lower-income communities had less oversight because they did not have the funds to employ social workers; in fact, independent living social workers were seen as a luxury even among the higher-income CCRCs represented at the meeting. It was also noted that educational information was less likely to reach these lower-income communities unless there was demand triggered by a major incident.

The CCRC representatives observed that due to the economic recession several years ago, many older adults were unable to move into independent living communities at a younger age and are entering now at more advanced stages of decline. According to panelists, nationally, independent living now looks more like assisted living. However, the definitions and levels-of-care for independent living vary from CCRC to CCRC, and there is diversity among centers at what level of care residents enter the community. This is further impacted by the type of contract under which a resident enters a CCRC: a *life care* contract, which requires a heavier entrance fee but offers whatever level of care a resident needs throughout his/her lifetime with a standard monthly fee; versus a *fee for service* contract, which offers a lower entrance fee but has variable monthly rates depending on the level of care needed. Life care communities have a model built on the fact that residents will be independent for a number of years, so they may be better able to implement some sort of screening at admission to at least establish baseline measures or identify potentially unsafe drivers to put on a "watch list."

Steps Moving Forward

Panelists all agreed that increasing awareness of the issue of aging and safe driving among staff, residents, and the greater community was a high priority. Some of the participating CCRCs were proactive in this area, offering programs that included voluntary wellness screenings, occasional presentations to educate and raise awareness, and frequent (and well-attended) town meetings. One CCRC reported that it hosted AARP driving courses twice a year, but representatives noted that they did not attend these events to preserve resident privacy.

Notably, the CCRC that conducted voluntary wellness programs that included driver functional screening had no policy on dealing with unsafe drivers, and the administration had *never* (in the 17 or 18 years known to the representative) told a resident they could not drive on campus. Another CCRC representative stated this was also the case at their organization (no policy, never revoked driving privilege on campus); but this particular CCRC did not have any proactive program in place.

The CCRC representatives were generally not aware of some of the most widely available tools discussed at the meeting (AMA/AGS physicians' guide to assessing and counseling older drivers; AAA *Roadwise Review* and *Roadwise Rx*). Two of the CCRCs represented at the meeting had previously hosted CarFit events, one through local law enforcement and fire department and the other through an on-staff trained OT.

The CCRC representatives also suggested several methods they thought may be effective in increasing awareness of aging and driving safety issues. These are listed below as internal actions that the CCRCs could initiate on their own. Various institutions within the greater aging community that are recognized as potential resources and partners for distributing information and creating awareness were also identified.

Potential internal actions include:

- Putting in place a team of trainers to present the topic yearly to the organization with educational material and implementation ideas;
- Installing miniature tracking/recording instruments in at-risk drivers' cars (e.g., DriveCam, Progressive Snapshot);
- Safety demonstrations (e.g., CarFit events);
- Informational seminars with entertainment and food;
- Creating a resident group on driving and aging;
- Incorporating safe driving into the community health and wellness group; and
- Providing data to residents such as how many people their age no longer drive and how many residents give up driving after a set amount of years in the community.

External institutions identified as potential resources/partners include:

- American Geriatric Society;
- AMDA – The Society for Post-Acute and Long-Term Care Medicine;
- Leading Age (high-profile advocacy group);
- CARF-CCAC (Commission on Accreditation of Rehabilitation Facilities-Continuing Care Accreditation Commission);

- Department of Social Services;
- Department of Aging;
- Department of Transportation – provide information with license renewal; and
- Gerontological Advanced Practice Nurse's Association.

Discussion and Conclusions

The broad objectives of this study were to explore the effects of selected medical conditions common among older adults on their ability to drive safely and to learn how these conditions may affect when, where, and how much people drive (exposure). To meet these objectives, the research design relied on comparisons between each of four groups of older drivers who were characterized by a particular medical condition of interest—prioritized by an expert panel consisting of physicians/geriatricians and driver rehabilitation specialists— and an age-matched group of healthy older drivers.

From the outset, the research team faced formidable challenges to participant recruitment. First, the goal was to enroll older drivers in the study with a diagnosed medical condition of interest but without any *other* conditions (co-morbidities) severe enough to potentially impact driving performance. Further, while the medical conditions to be studied must of necessity have presented with symptoms sufficient to merit a diagnosis, they could not have progressed to a level where they would elicit a physician's recommendation to limit or refrain from driving. Finally, in language included in both the IRB-approved informed consent form and in a certificate of confidentiality obtained on behalf of the Greenville Health System from the National Institutes of Health, prospective study participants were advised that they could be reported to appropriate authorities if they were observed performing unsafe driving behaviors by the researchers.

Even with the active involvement of physicians in the Greenville Health System referring patients to this study, the research team succeeded only in recruiting a study sample limited to fewer than five individuals each for three out of the four targeted medical conditions—COPD, AMD, and diabetes-related peripheral neuropathy—and *no* older drivers with the other medical condition of interest, Parkinson's disease. This led to several adaptations in the technical approach for this work.

Planned analyses to examine exposure and performance differences between the comparison group of healthy older drivers and each of the medical conditions groups were refocused upon a comparison of healthy older drivers and a "CMC" group. Such analyses were carried out for the *Primary Sample* of 27 older drivers, which included eight in the CMC group and 19 healthy, age-matched controls.

Next, an *Augmented Sample* was defined through the inclusion of drivers recruited in another, concurrent NHTSA study[8] also being carried out at RCPHospital, that assessed drivers using the same clinical and on-road evaluation techniques by the same staff comprising the research team for this project. This strategy increased the sample size to 58, including 15 older drivers in the CMC group (though still none with Parkinson's disease) and 43 healthy, age-

[8] "Older Drivers' Foot Movements," NHTSA Contract DTNH22-11-D-00223, Task Order 2.

matched controls. The Augmented Sample included nine older drivers with a single medical condition of interest, peripheral neuropathy; thus, it was possible to perform inferential statistical tests on the differences between this single subgroup and the healthy controls.

In a more radical shift in technical approach, the project mined data in the SHRP2 NDS database. Self-reported medical conditions, including Parkinson's disease, peripheral neuropathy, and COPD, were documented for a large majority of the more than 3,000 drivers participating in the SHRP2 study. In addition, SHRP2 drivers' cars were instrumented with cameras, radar, and other sensors that recorded performance and exposure information and could be analyzed to address many variables of interest in this research. All SHRP2 study participants were administered tests assessing a range of physical, cognitive, and psychomotor functional abilities in common with those measured by the staff in the clinic at RCP. These attributes of the NDS database permitted the research team to examine many of the same relationships specified in the original research design with sample sizes sufficient to contrast drivers manifesting three of the four medical conditions initially targeted for data collection in this project in relation to age-matched controls.

Together, this diversity of data sources yielded a pattern of results that can best be described as unremarkable – except, perhaps, for the absence of expected differences.

Differences in driving exposure were one exception. The SHRP2 broad sample analysis found that healthy older drivers averaged more total trips and a higher average number of trips per day than the CMC group. These controls also had a higher average number of trips per day when compared specifically to the Neuropathy and to the COPD (but not the Parkinson's) subgroups. The healthy older drivers also averaged longer maximum trip duration than those in the CMC group and the Neuropathy subgroup.

There were also differences between groups with respect to the times and conditions of driving exposure. The healthy older drivers averaged a lower percentage of trips from 3 p.m. to 8 p.m. than the Neuropathy subgroup and a lower percentage of trips driven from 10 a.m. to 3 p.m. than the Parkinson's subgroup. This suggests the healthy drivers may have been more comfortable with driving during the morning rush hours and/or at night than drivers with these particular medical conditions. Similarly, the healthy drivers averaged a significantly higher proportion of *miles* driven at 60- to 70 mph than the Neuropathy subgroup, and a significantly lower percentage of *time* spent driving at the lowest speeds (20 mph or less) when compared to the CMC group and to the Neuropathy subgroup. They also averaged a significantly higher percentage of trips driven on urban freeways than drivers with Parkinson's, although for both groups this percentage was small.

Unfortunately, exposure data for the Primary Sample recruited at RCP Hospital were obtained for only 19 drivers, seven in the CMC group and 12 healthy, age-matched controls. Analyses showed no reliable between-groups differences for any exposure measure. In addition, regression analyses showed no significant associations for driver age (5-year age category), driver sex, and the various clinical measures of functional status (brake RT, far bilateral acuity, bilateral contrast sensitivity, plantar threshold, letter cancellation test time, useful field of view, Trail-Making Test completion time for Parts A and B) and each of three measures of exposure: average trips per day, average miles driven per day, and average trip length (duration).

It is the results of the driver performance analyses that most clearly draw attention to the absence of differences between older drivers with and without identified medical conditions. This equivalence was apparent in the ordinal data describing the CDRS on-road evaluations for both the Primary and Augmented Samples, and in the scores on the behaviorally anchored rating scale – devised in part to yield interval data to support more rigorous comparisons of the medical conditions group with the healthy, age-matched controls – for both of these samples recruited through physician referral.

With the much larger SHRP2 naturalistic driving study to draw upon, performance analyses initially focused on the involvement of older drivers with and without (self-reported) medical conditions in crashes and near-crashes. Rates were calculated for these event types, for both total counts and where the driver was at-fault, on both an absolute and an exposure basis. The total event rates for the healthy older drivers and the CMC group were similar, and the at-fault event rates were virtually identical. Among the medical conditions subgroups, the drivers with neuropathy evidenced higher total event and at-fault event rates than the controls, the rates for the COPD subgroup were lower, and there were too few Parkinson's drivers for a meaningful comparison. Still, tests revealed no statistically significant differences between groups in the proportion of drivers with a crash or near-crash event.

When the performance of older SHRP2 drivers with and without medical conditions was compared in freeway merge situations involving ramp/acceleration lane geometries that were classified as "less favorable" versus "more favorable" by a road safety engineer, it was hypothesized that the medical conditions group would drive slower (maximum and average speed), with greater speed variance (more brake applications), and would allow longer headways to a lead vehicle. It was also hypothesized that reducing the demand for negotiating ramps would have a greater benefit for the older drivers *with* medical conditions than for drivers *without* medical conditions. While a number of differences were found on these performance measures as a function of ramp design, the only statistically significant difference between groups was that medical conditions drivers exhibited a higher cumulative time headway $\geq$3.5 seconds than drivers without medical conditions, and only before reaching the ramp gore.

What conclusions can be drawn from these results? By design, this investigation relied upon assignment to study groups based on diagnosed medical conditions. Even for analyses of groups defined through self-reported conditions, it must be assumed that the included drivers checked only those boxes consistent with what they had been told by their physicians. Yet, for the study participants recruited at a rehabilitation hospital as well as for those who were part of the SHRP2 study, available clinical measures of functional status did not provide any sharp delineation between groups. Thus, it seems reasonable to conclude that the *diagnosed* medical conditions prevalent among older drivers that were the focus in this project do not necessarily support an expectation of performance (or safety) deficits.

Another outcome in this research is the evidence from the SHRP2 broad sample analysis that people with medical conditions accorded the highest priority by driving safety professionals appear to be self-restricting their exposure, not only in terms of total trips taken but also trip duration (shorter), time of day (less during peak traffic periods), and speed (driving more on lower speed roads).

The panel of CCRC representatives provided a window into the implications of functional deficits that impair driving safety for older drivers for the communities in which many older adults live. Panelists discussed ways their communities identified risky drivers as well as a variety of barriers to addressing these safety concerns. Panelists indicated that, when a risky driver was brought to their attention, they generally responded by discussing concerns with the driver and following up with a letter if necessary. If the driver continued to pose a risk, some of the CCRCs would relay their concerns to the driver licensing agency. The panelists pointed out that dealing with unsafe drivers was a sensitive issue as their organizations were in the business of meeting the needs of their residents. Given the necessity to attract older adults to their communities, CCRCs did not want to acquire a reputation for taking away residents' car keys.

There are certain qualifications to the conclusions stated above. Sample size limitations have already been acknowledged. Also, among those with diagnosed medical conditions of interest in this research, those who were directly solicited at the rehabilitation hospital and agreed to join the study were the rare exceptions; most did not. A selection bias in the results for the Primary and Augmented Samples cannot be discounted. Nor can the reader assume that the drivers recruited into the SHRP2 research are representative of the older driver population in the United States.

Left unexamined but also worthy of mention are those community dwelling older drivers with potentially impairing medical conditions who were *not* captured by the referral/recruitment methods that yielded the present analysis samples and who for various reasons were excluded as candidate study participants. Not all drivers have access to the resources of the RCP Rehabilitation Hospital, for example. Or they may have been previously captured and diagnosed but were not compliant with physicians' directives, and again, would not have been among those participating in this study. Given that groups classified on the basis of medical condition in this research were not significantly different in terms of their functional status – even while acknowledging this study's potential biases and limitations – this omission suggests caution. It is demographically inevitable that there will be increasing numbers of drivers with age-related functional impairments, cognitive and otherwise, in the decades ahead.

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Appendix A. Driving Safety Panel Meeting Agenda and Panelists

8:00-8:30	Breakfast
8:30-8:45	Panel Member Introductions
8:45-9:00	Project Description and Purpose of Panel
9:00-9:30	DISCUSSION: Panel Member Feedback/Update on Literature Review
9:30-10:15	DISCUSSION: Identification of Hazardous Errors Associated with Each Candidate Condition, with Rank Ordering of Candidates Using This Criterion
10:15-10:30	Break
10:30-11:15	DISCUSSION: Availability and Effectiveness of Countermeasures for Each Candidate Condition, with Rank Ordering of Candidates Using This Criterion
11:15-12:00	DISCUSSION: Current and Anticipated Prevalence (next 10-20 years) of Each Candidate Condition, with Rank Ordering of Candidates Using This Criterion
12:00-1:30	Lunch
1:30-2:00	Project Staff Presentation: Summary of Panelist Rankings (Composite)
2:00-3:00	DISCUSSION: How to Weight Each Decision Factor to Determine Top Medical Conditions for Further Study
3:00-3:15	Break
3:15-4:30	DISCUSSION: Identify Challenges and Potential Solutions Regarding Subject Recruitment and Data Collection for Each of the Top Medical Conditions
4:30	Adjourn Meeting

The following professionals participated in this project activity:

Leah Belle, CDRS, Driver Rehabilitation Coordinator, Roger C. Peace Rehabilitation Hospital, OT Department, Greenville, SC.

Jamie Dow, MBA, M.D., Medical Advisor on Road Safety, Societe de l'Assurance Automobile du Quebec.

Nathalie Drouin, Occupational Therapist, Roger C. Peace Rehabilitation Hospital, OT Department, Greenville, SC.

Judith Goldstein, OD, FAAO, Director of Vision Rehabilitation Services, Assistant Professor of Ophthalmology and Rehabilitation, Wilmer Eye Institute Johns Hopkins Univ.

Tom Kalina, OTR, CDRS, Bryn Mawr Rehab Hospital, Malvern, PA.

Richard Marottoli, M.D., MPH, Associate Professor of Medicine, Yale University, Member of the Connecticut DMV Medical Advisory Board.

Miriam Monahan, MS, OTR/L, CDRS, Driver Rehabilitation Institute, Gainesville FL.

Germaine Odenheimer, M.D., Associate Professor, Donald W. Reynolds Department of Geriatric Medicine, University of Oklahoma College of Medicine.

Susan Pierce, OTR/L, CDRS, SCDM, Adaptive Mobility Services, Inc., Orlando, FL.

Elin Schold-Davis, OTR/L, CDRS, AOTA Older Driver Initiative, Sister Kenny Rehabilitation Institute, Minneapolis, MN

Donna Stressel, OTR/L, CDI, CDRS, Sunnyview Rehab Hospital, Schenectady, NY.

Carl Soderstrom, M.D., F.A.C.S., Chief, Medical Advisory Board, Maryland Motor Vehicle Administration.

Appendix B: Specifications of SHRP 2 NDS Variables Requested

Specification of Exposure Variables

- **Total distance driven, average miles/day driven, min/max miles/day driven during data collection interval**
  - SHRP 2 Variable(s)
    - Trip Distance
      - Missing = TDIST_MIS (Column BI)
    - Trip Day Number in Study
  - Calculation(s)
    - Total distance of all trips
      - TA variable name = TDIST (Column B)
        - Add the value of all Trip Distance
    - Average distance of trips per day
      - TA variable name = ADIST (Column C)
        - Divide TDIST by the maximum Trip Day Number in Study
    - Median distance traveled per day
      - TA variable name = TDIST_MEDIAN (Column D)
        - Combine the Trip Distance of trips which occurred on identical Trip Day Number to get a figure which tells you the distance of all trips that occurred per day
        - Determine the median value based on this calculation
    - Minimum distance traveled per day
      - TA variable name = MINDIST (Column E)
        - Combine the Trip Distance of trips which occurred on identical Trip Day Number to get a figure which tells you the distance of all trips that occurred per day
        - Identify the lowest value based on this calculation
    - Maximum distance traveled per day
      - TA variable name = MAXDIST (Column F)
        - Combine the Trip Distance of trips which occurred on identical Trip Day Number to get a figure which tells you the distance of all trips that occurred per day
        - Identify the highest value based on this calculation

- **Total trips taken, average trips/day, min/max trips per day during data collection interval**
  - SHRP 2 Variable(s)
    - Trip ID
    - Trip Day Number in Study
  - Calculation(s)
    - Total number of trips
      - TA variable name = TTRIP (Column G)
        - Total count of all Trip ID
    - Average number of trips per day
      - TA variable name = ATRIP (Column H)
        - Divide TTRIP by the count of Trip Day Number in Study
    - Median number of trips per day

            - TA variable name = TRIP_MEDIAN (Column I)
                - Combine the number of trips which occurred on identical Trip Day Number to get a figure which tells you the number of trips that occurred per day
                - Determine the median value based on this calculation
        - Minimum number of trips per day
            - TA variable name = MINTRIP (Column J)
                - Combine the number of trips which occurred on identical Trip Day Number to get a figure which tells you the number of trips that occurred per day
                - Identify the lowest value based on this calculation
        - Maximum number of trips per day
            - TA variable name = MAXTRIP (Column K)
                - Combine the number of trips which occurred on identical Trip Day Number to get a figure which tells you the number of trips that occurred per day
                - Identify highest value in based on this calculation

- **Total duration (time) spent driving, average length of trip, min/max trip duration during data collection interval**
    - SHRP 2 Variable(s)
        - Trip Duration
        - TRIP ID
    - Calculation(s)
        - Total duration of all trips
            - TA variable name = TDUR (Column L)
                - Add all Trip Duration
        - Average duration of all trips
            - TA variable name = ADUR (Column M)
                - Divide total of all Trip Duration by TTRIP
        - Minimum duration
            - TA variable name = MINDUR (Column N)
                - Identify the lowest value Trip Duration
        - Maximum duration
            - TA variable name = MAXDUR (Column O)
                - Identify the highest value Trip Duration

- **Percent of trips in each of several "bands" of trip length, by miles: <=1, >1-2, 3-5, 6-10, 11-20, and >20**
    - SHRP 2 Variable(s)
        - Trip Distance
            - Missing = TDIST_MIS (Column BI)
        - Trip ID
    - Calculation(s)
        - Total number of trips
            - TA variable name = TTRIP (Column G)
                - Total count of all Trip ID

        - Percentage of all trips where a mile or less is traveled
            - TA variable name = MTRIP_1 (Column P)
                - Divide count of Trip Distance where the value is less than or equal to 1 by TTRIP
        - Percentage of all trips where 1-2 miles is traveled
            - TA variable name = MTRIP_2 (Column Q)
                - Divide count of Trip Distance where the value is from >1 to <=2.5 by TTRIP
        - Percentage of all trips where 2-5 miles is traveled
            - TA variable name = MTRIP_5 (Column R)
                - Divide count of Trip Distance where the value is from >2.5 to <= 5.5 by TTRIP
        - Percentage of all trips where 5-10 miles is traveled
            - TA variable name = MTRIP_10 (Column S)
                - Divide count of Trip Distance where the value is from >5.5 to <=10.5 by TTRIP
        - Percentage of all trips where 10-20 miles is traveled
            - TA variable name = MTRIP_20 (Column T)
                - Divide count of Trip Distance where the value is from >10.5 to <=20 by TTRIP
        - Percentage of all trips where more than 20 miles is traveled
            - TA variable name = MTRIP_PLUS (Column U)
                - Divide count of Trip Distance where the value is >20 by TTRIP

- **Percent of trips in each of several bands of trip length, by hours**
    - SHRP 2 Variable(s)
        - Trip Duration
        - Time at 0-10 mph
            - Missing = T10_MIS (Column BJ)
        - Time at 10-20 mph
            - Missing = T20_MIS (Column BK)
        - Time at 20-30 mph
            - Missing = T30_MIS (Column BL)
        - Time at 30-40 mph
            - Missing = T40_MIS (Column BM)
        - Time at 40-50 mph
            - Missing = T50_MIS (Column BN)
        - Time at 50-60 mph
            - Missing = T60_MIS (Column BO)
        - Time at 60-70 mph
            - Missing = T70_MIS (Column (BP)
        - Time at 70-80 mph
            - Missing = T80_MIS (Column BQ)
        - Time at > 80 mph
            - Missing = T80PLUS_MIS (Column BR)
    - Calculation(s)
        - Total duration of all trips
            - TA variable name = TDUR (Column L)

        - Add all Trip Duration
    - Percentage of the duration of all trips at 20 mph or less
        - TA variable name = HTRIP_20 (Column V)
            - Combine all Time at 0-10 mph and Time at 10-20 mph
            - Divide by TDUR
    - Percentage of the duration of all trips at 20-30 mph
        - TA variable name = HTRIP_30 (Column W)
            - Divide all Time at 20-30 mph by TDUR
    - Percentage of the duration of all trips at 30-40 mph
        - TA variable name = HTRIP_40 (Column X)
            - Divide all Time at 30-40 mph by TDUR
    - Percentage of the duration of all trips at 40-50 mph
        - TA variable name = HTRIP__50 (Column Y)
            - Divide all Time at 40-50 mph by TDUR
    - Percentage of the duration of all trips at 50-60 mph
        - TA variable name = HTRIP_60 (Column Z)
            - Divide all Time at 50-60 mph by TDUR
    - Percentage of the duration of all trips at 60-70 mph
        - TA variable name = HTRIP_70 (Column AA)
            - Divide all Time at 60-70 mph by TDUR
    - Percentage of the duration of all trips at 70 mph or greater
        - TA variable name = HTRIP_PLUS (Column AB)
            - Combine Time at 70-80 mph and Time at > 80 mph
            - Divide by TDUR

- **Percent of trips taken (begun) during various times of the day, e.g., before 10:00 am, 10 am-3:00 pm, 3:00-8:00 pm (dusk/twilight), after 8:00 pm**
    - SHRP 2 Variable(s)
        - Trip ID
        - Time Start Local Time Hour of Day
            - Missing = TSTART_MIS (Column BS)
    - Calculation(s)
        - Compute four variables out of Time Start Local Time Hour of Day
            - TA variable name = TRIP_MORN (Column AC)
                - Trips that start 6:00AM-9:59AM
            - TA variable name = TRIP_DAY (Column AD)
                - Trips that start 10:00AM-2:59PM
            - TA variable name = TRIP_AFTRN (Column AE)
                - Trips that start 3:00PM-7:59PM
            - TA variable name = TRIP_NGHT (Column AF)
                - Trips that start 8:00PM-5:59AM
        - Total number of trips
            - TA variable name = TTRIP (Column G)
                - Total count of all Trip ID
        - Percentage of all trips begun 6AM-10AM
            - TA variable name = PTRIP_MORN (Column AG)
                - Divide count of TRIP_MORN by count of TTRIP

        - Percentage of all trips begun 10AM-3PM
            - TA variable name = PTRIP_DAY (Column AH)
                - Divide count of TRIP_DAY by count of TTRIP
        - Percentage of all trips begun 3PM-8PM
            - TA variable name = PTRIP_AFTRN (Column AI)
                - Divide count of TRIP_AFTRN by count of TTRIP
        - Percentage of all trips begun 8PM-6AM
            - TA variable name = PTRIP_NIGHT (Column AJ)
                - Divide count of TRIP_NGHT by count of TTRIP

- **Percent of total miles driven in each of several speed bands (in mi/h), e.g., <25, 26-35, 36-45, 46-55, >55**
    - SHRP 2 Variable(s)
        - Trip Distance
            - Missing = TDIST_MIS (Column BI)
        - Distance at 0-10 mph
            - Missing = D10_MIS (Column BT)
        - Distance at 10-20 mph
            - Missing = D20_MIS (Column BU)
        - Distance at 20-30 mph
            - Missing = D30_MIS (Column BV)
        - Distance at 30-40 mph
            - Missing = D40_MIS (Column BW)
        - Distance at 40-50 mph
            - Missing = D50_MIS (Column BX)
        - Distance at 50-60 mph
            - Missing = D60_MIS (Column BY)
        - Distance at 60-70 mph
            - Missing = D70_MIS (Column BZ)
        - Distance at 70-80 mph
            - Missing = D80_MIS (Column CA)
        - Distance at > 80 mph
            - Missing = D80PLUS_MIS (Column CB)
    - Calculation(s)
        - Total distance of all trips
            - TA variable name = TDIST (Column B)
                - Add the value of all Trip Distance
        - Percent of all trips driven at 20 mph or less
            - TA variable name = SPD_20 (Column AK)
                - Combine all Distance at 0-10 mph and Distance at 10-20 mph
                - Divide by TDIST
        - Percentage of all trips driven at 20-30 mph
            - TA variable name = SPD_30 (Column AL)
                - Divide all Distance at 20-30 by TDIST
        - Percentage of all trips driven at 30-40 mph
            - TA variable name = SPD_40 (Column AM)
                - Divide Distance at 30-40 by TDIST

    - Percentage of all trips driven at 40-50 mph
        - TA variable name = SPD_50 (Column AN)
            - Divide Distance at 40-50 by TDIST
    - Percentage of all trips driven at 50-60 mph
        - TA variable name = SPD_60 (Column AO)
            - Divide Distance at 50-60 by TDIST
    - Percentage of all trips driven at 60-70 mph
        - TA variable name = SPD_70 (Column AP)
            - Divide Distance at 60-70 by TDIST
    - Percentage of all trips driven at 70 mph or greater
        - TA variable name = SPD_PLUS (Column AQ)
            - Combine all Distance at 70-80 mph and Distance at > 80 mph
            - Divide by TDIST

- **Percent of total driving time by roadway type (same as above)**
    - SHRP 2 Variable(s)
        - Trip Duration
        - % Rural Frwy
        - % Rural 2 Ln
        - % Urb Frwy
        - % Urb 2 Ln
        - % Spd Lim 35 or less
        - % Spd Lim 40-50
        - % Spd Lim 55-65
        - % Spd Lim 70 or greater
    - Calculation(s)
        - Total duration of all trips
            - TA variable name = TDUR (Column L)
                - Add all Trip Duration
        - Percentage of total trip duration on rural freeways
            - TA variable name = RD_RFRWY (Column AR)
                - Multiply % Rural Frwy by Trip Duration
                - Compute for each trip
                - Add all values
                - Divide by TDUR
        - Percentage of total trip duration on rural 2 lane roads
            - TA variable name = RD_R2LN (Column AS)
                - Multiply % Rural 2 Ln by Trip Duration
                - Compute for each trip
                - Add all values
                - Divide by TDUR
        - Percentage of total trip duration on urban freeways
            - TA variable name = RD_UFRWY (Column AT)
                - Multiply % Urban Frwy by Trip Duration
                - Compute for each trip
                - Add all values
                - Divide by TDUR
        - Percentage of total trip duration on urban 2 lane roads

- TA variable name = RD_U2LN (Column AU)
  - Multiply % Urb 2 Ln by Trip Duration
  - Compute for each trip
  - Add all values
  - Divide by TDUR
- Percentage of total trip duration driving on roads with speed limits of 35 mph or less
  - TA variable name = RD_Lim_35 (Column AV)
    - Multiply % Spd Lim 35 or less by Trip Duration
    - Compute for each trip
    - Add all values
    - Divide by TDUR
- Percentage of total trip duration driving on roads with speed limits of 40-50 mph
  - TA variable name = RD_Lim_50 (Column AW)
    - Multiply % Spd Lim 40-50 by Trip Duration
    - Compute for each trip
    - Add all values
    - Divide by TDUR
- Percentage of total trip duration driving on roads with speed limits of 55 mph or greater
  - TA variable name = RD_Lim70PLUS (Column AX)
    - Combine inputs % Spd Lim 55-65 and % Spd Lim 70 or greater
    - Multiply by Trip Duration
    - Compute for each trip
    - Add all values
    - Divide by TDUR

- **Percent of total miles driven by driving task demand level, where "high demand" conditions are operationally defined in terms of adverse weather (e.g., rain, fog) or night**
  - SHRP 2 Variable(s)
    - Light Usage Percentage
      - Missing = LIGHTUSE_MIS (Column CC)
    - Time Wipers Used
      - Missing = WIPER_MIS (Column CD)
    - Trip ID
    - Trip Duration
    - Trip End Local Time Hour of Day
  - Calculation(s)
    - Total trips
      - TA variable name = TTRIP (Column G)
        - Count of all Trip ID
    - Total duration of all trips
      - TA variable name = TDUR (Column L)
        - Add all Trip Duration
    - Count of trips with wiper use
      - TA variable name = WIPERS_COUNT (Column AY)
        - Total number of trips where wipers are on

- Percentage of wiper use for all trips
  - TA variable name = TWIPE (Column AZ)
    - Sum duration of all trips where wipers are on
    - Divide by duration of trips with wiper data available
- Count of trips with light use
  - TA variable name = LIGHTS_COUNT (Column BA)
    - Total number of trips where lights are on
- Percentage of light use for all trips
  - TA variable name = TLIGHT (Column BB)
    - Sum all time lights were on
    - Divide by duration of trips with light data available
- A trip ends at night [1 is night, 0 is not night]
  - TA variable = NIGHT (Column BC)
    - Value is 0 if Trip End Local Time Hour of Day is 6AM – 7:59 PM
    - Value is 1 if Trip End Local Time Hour of Day is 8PM – 5:59 AM
- Number of high demand trips [1 is high, 0 is low]
  - TA variable name = DEMAND_TRIP (Column BD)
    - For each Trip ID, value is 1 if wipers and lights are in use at least 75% of the time
    - Else, value is 0
    - Sum for all Trips where wiper and light data is available
- Percentage of all trips with a high demand
  - TA variable name = TDEMAND (Column BE)
    - Divide DEMAND_TRIP by number of trips where wiper and light data are available
- Column BF is blank

- **Belt use**
  - SHRP 2 Variable(s)
    - Seatbelt Usage Percentage
      - Missing = BELT_MIS (Column CE)
  - Calculation(s)
      - TA variable name = TTRIP (Column G)
        - Count of all Trip ID
  - The percentage of all trips where drivers wore their seatbelt more than 90% of the time
    - TA variable name = BELT_90 (Column BG)
      - Value is 1 if Seatbelt Usage Percentage >= 90%
      - Value is 0 if Seatbelt Usage Percentage < 90%
    - TA variable name = PERBELT (Column BH)
      - Count of Belt_90 = 1 for all trips, per driver
      - Divide by number of trips where seatbelt data is available

Specification of Demographic Variables

- Driver Demographic Questionnaire
  - SHRP 2 Variables
    - Gender
    - Age Group
    - Education

        - Driver Mileage Last Year
- Visual and Cognitive Tests
    - SHRP 2 Variables
        - Day Far Acuity Both Eyes
        - Day Near Acuity Both Eyes
        - Night Contrast Right Eye Row A
        - Night Contrast Right Eye Row B
        - Night Contrast Right Eye Row C
        - Night Contrast Right Eye Row D
        - Night Contrast Right Eye Row E
        - Night Contrast Left Eye Row A
        - Night Contrast Left Eye Row B
        - Night Contrast Left Eye Row C
        - Night Contrast Left Eye Row D
        - Night Contrast Left Eye Row E
        - Depth Perception
        - Day Contrast Right Eye Row A
        - Day Contrast Right Eye Row B
        - Day Contrast Right Eye Row C
        - Day Contrast Right Eye Row D
        - Day Contrast Right Eye Row E
        - Day Contrast Left Eye Row A
        - Day Contrast Left Eye Row B
        - Day Contrast Left Eye Row C
        - Day Contrast Left Eye Row D
        - Day Contrast Left Eye Row E
        - Peripheral Vision Right Eye
        - Peripheral Vision Left Eye
        - VMI Raw Score
        - Impairment Level - VMI
        - Visual Search Test A Raw Score
        - Visual Search Test B Raw Score
        - Visual Search Summary Raw Score
        - Impairment Level - Visual Search
        - VSA Age Percentile Rank
        - VSA Age-Ed Percentile Rank
        - VSB Age Percentile Rank
        - VSB Age-Ed Percentile Rank
        - Vis Search Age Percentile Rank
        - Vis Search Age-Ed Percentile Rank
        - UFOV Raw Score

        - Impairment Level - UFOV
        - UFOV Age Percentile Rank
        - UFOV Age-Ed Percentile Rank
        - Cog-Vis Assess Age Bin
        - Cog-Vis Assess Age-Ed Bin
        - Cog-Vis Assess Ed Bin
- Physical Strength
    - SHRP 2 Variables
        - Raw Walk Time

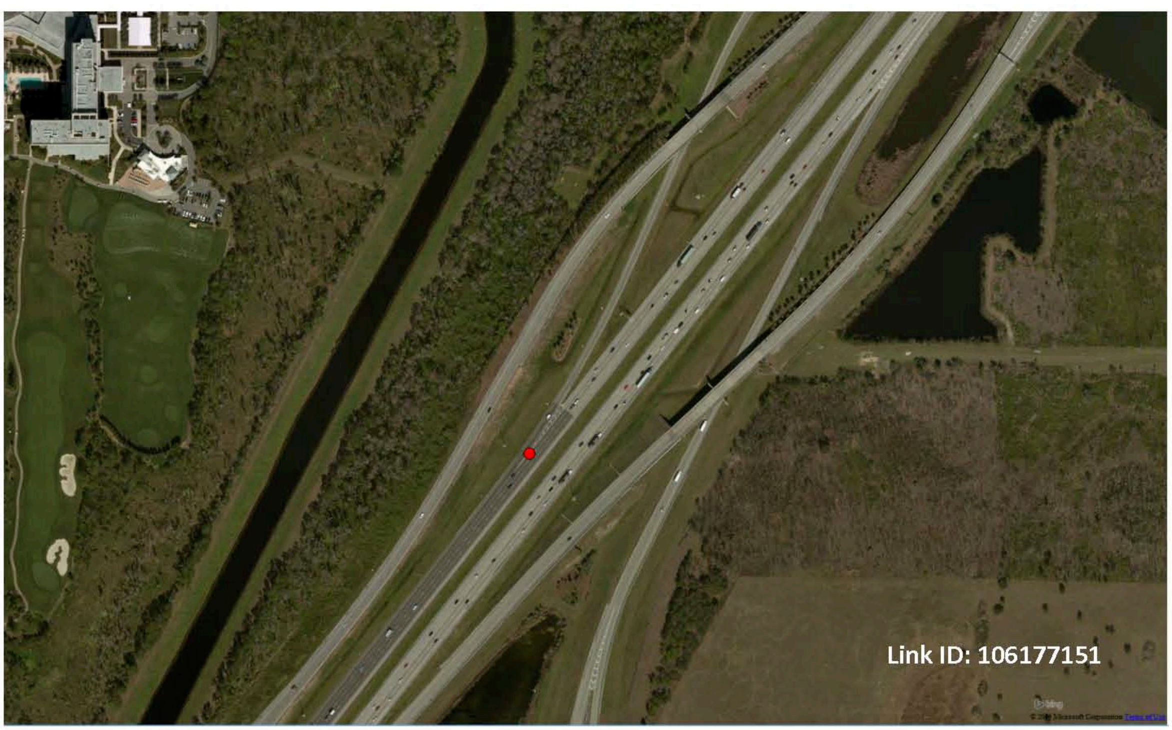
Safety and Performance Specifications

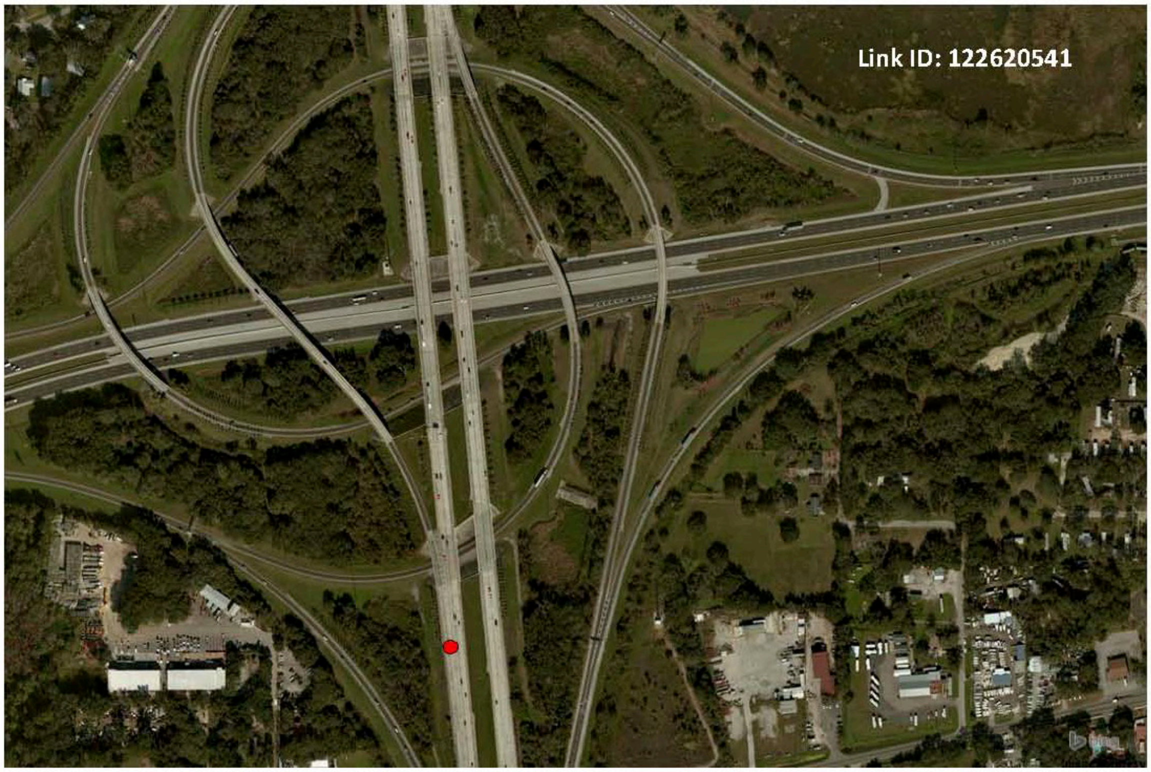
- Events Data
    - SHRP 2 Variables
        - Event ID
        - Event Severity 1
        - Event Severity 2
        - Driver Behavior 1
        - Driver Behavior 2
        - Driver Behavior 3
        - Event Nature 1
        - Event Nature 2
        - Incident Type 1
        - Incident Type 2
        - Driver Seatbelt Use
        - Driver Impairment
        - Visual Obstruction
        - Lighting Details
        - Weather
        - Fault
        - Surface Condition

Appendix C. Plan View of Ramps

Each satellite image below presents the ramp included in the analysis, the accompanying Link ID for the ramp, and the location of the ramp node (red dot).

Ramps with more favorable design:

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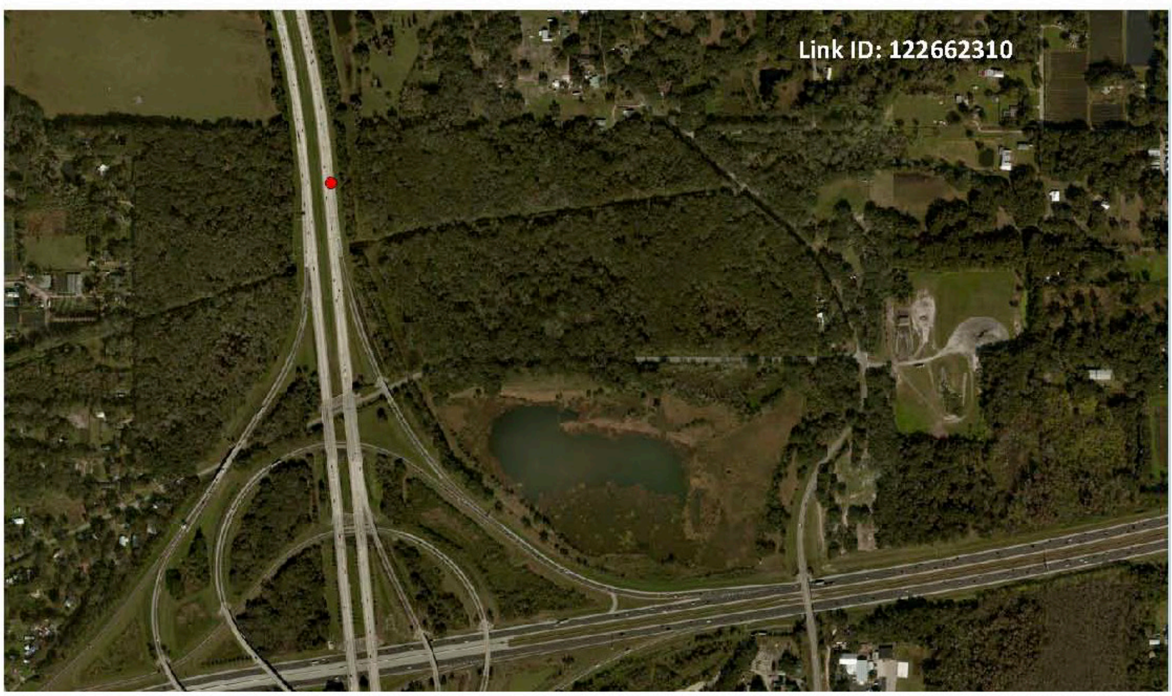
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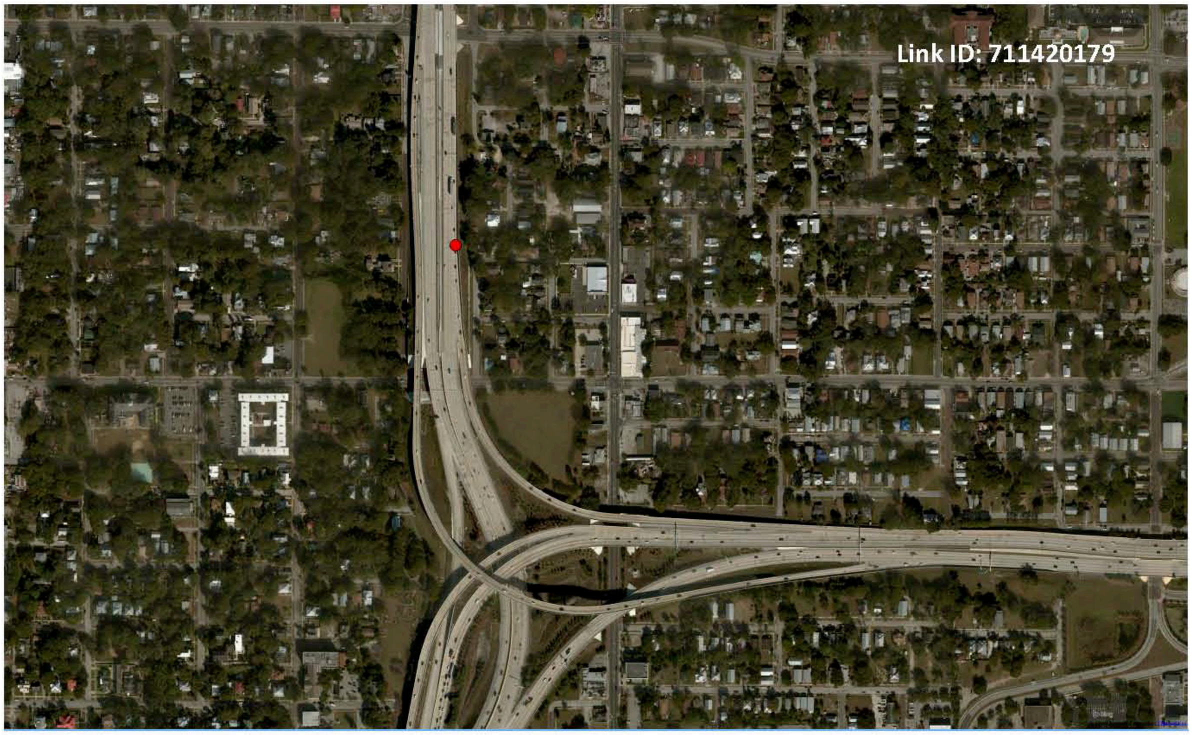
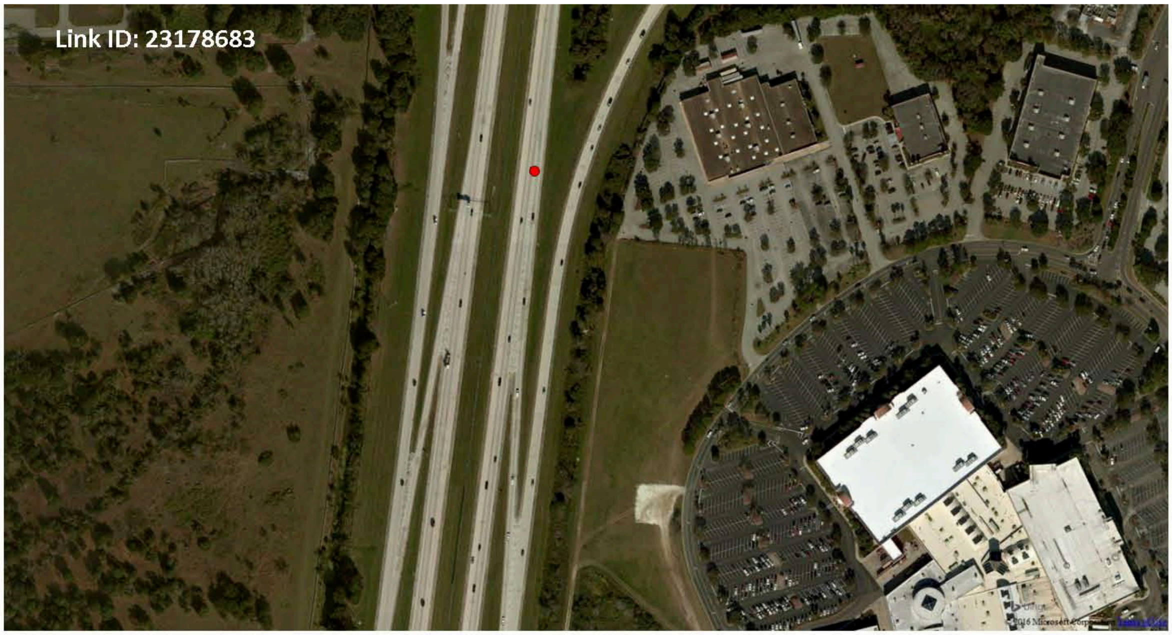
Link ID: 122662311


Link ID: 127635758


Link ID: 711420179


Link ID: 888224263

Ramps with less favorable design:

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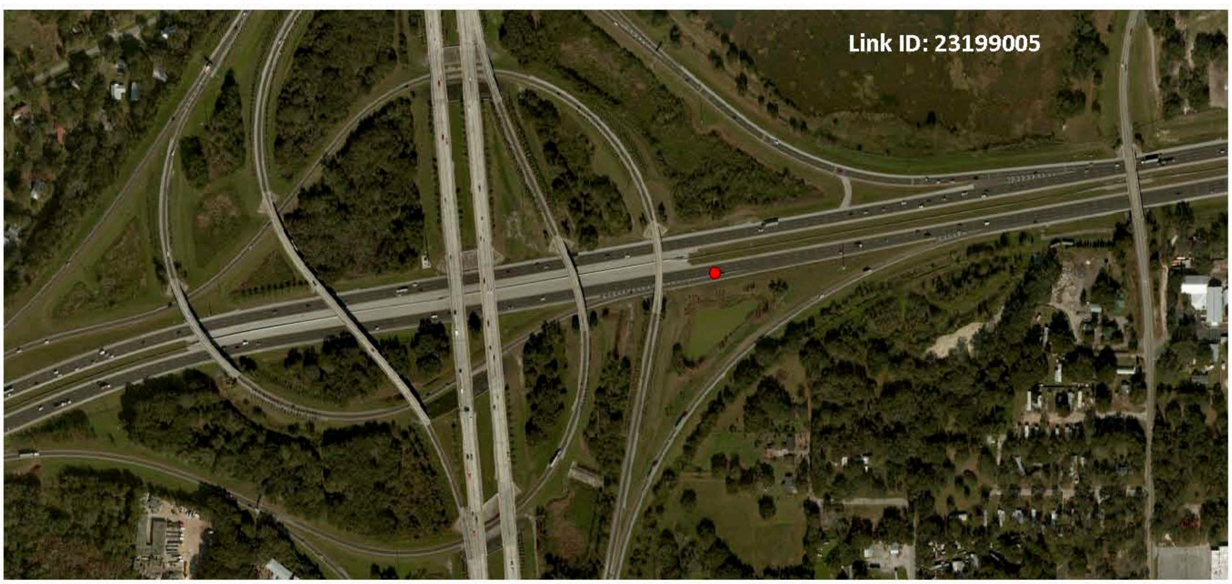
Link ID: 23199005

Appendix D. Plantar Threshold Scoring Protocol

Touch-Test™ Sensory Evaluators and Associated Foot Plantar Thresholds.

Evaluator Size	Target Force (in grams)	Representation	Hand & Dorsal Foot Thresholds	Plantar Thresholds
1.65	0.008	Green	Normal	Normal
2.36	0.02			
2.44	0.04			
2.83	0.07			
3.22	0.16	Blue	Diminished Light Touch	
3.61	0.4			
3.84	0.6	Purple	Diminished Protective Sensation	Diminished Light Touch
4.08	1			
4.17	1.4			
4.31	2			
4.56	4	Red	Loss of Protective Sensation	Diminished Protective Sensation
4.74	6			
4.93	8			
5.07	10			Loss of Protective Sensation
5.18	15			
5.46	26			
5.88	60			
6.10	100			
6.45	180			
6.65	300		Deep Pressure Sensation Only	Deep Pressure Sensation Only

Appendix E. On-Road Evaluation

Roger C. Peace Rehabilitation Hospital

Driver Rehabilitation Program: On Road Assessment

Therapist: ______________________________ Date: ______________________________

Time: __________________________________Vehicle:____________________________

Physician: ______________________________ Diagnosis: ___________________________

SUMMARY/RECOMMENDATIONS (Refer to check off for specific details):

____
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____
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____
____

____ Successful demonstration of driving skills ____ Proficient use of Adaptive Equipment

____Adequate skills in familiar areas ____Further Assess (Date___________________)

____ (_______) Training hours recommended ____Private Driving School for training or remediation

____ Unsuccessful demonstration of safe driving skills **NO DRIVING RECOMMENDED**

____Re- Assess at a later date (Date_______________________)

The recommendations noted previously are based on the medical information available at the time of this report and the client's performance during the period of the evaluation. If a patient's medical status changes, subsequent to this report, so that they may affect patient's driving status, this report is no longer valid. The recommendations, upon discharge, are valid for 1 year, however, should not be relied on as an absolute prediction of future performance. All results and recommendations have been developed based on education and experience of the evaluator and client's experience using existing equipment at Roger C. Peace Hospital.

______________________________________ ____

Driver Rehabilitation Specialist Date/ Time

Roger C. Peace Rehabilitation Hospital

Driver Rehabilitation Program: On Road Assessment

OPERATIONAL SKILLS

Adjusts Seat: Y N Adjusts Primary Controls: Y N

Adjusts Mirrors: Y N Locates Secondary Controls: Y N

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Skill Demonstrated: 0=0% 1=0-25% 2=25-50% 3=50-75% 4=75-100% No= No opportunity to observe

TACTICAL SKILLS

VISUAL SKILLS	**Speed limit 0-45 mph**	**Speed limit 45 mph and over**
Mirror checks	0 1 2 3 4 No	0 1 2 3 4 No
Scans Environment	0 1 2 3 4 No	0 1 2 3 4 No
Blind Spot Checks	0 1 2 3 4 No	0 1 2 3 4 No
Identifies Signage	0 1 2 3 4 No	0 1 2 3 4 No
Checks Cross Traffic	0 1 2 3 4 No	0 1 2 3 4 No
VEHICLE POSITION		
Gap Selection	0 1 2 3 4 No	0 1 2 3 4 No
Following/Stopping Distance	0 1 2 3 4 No	0 1 2 3 4 No
Lane Usage/ Position	0 1 2 3 4 No	0 1 2 3 4 No
Turns into Proper Lane	0 1 2 3 4 No	0 1 2 3 4 No
Lane Changes	0 1 2 3 4 No	0 1 2 3 4 No
VEHICLE HANDLING		
Appropriate Speed	0 1 2 3 4 No	0 1 2 3 4 No
Smooth Steering	0 1 2 3 4 No	0 1 2 3 4 No
Smooth Acceleration	0 1 2 3 4 No	0 1 2 3 4 No
Smooth Braking	0 1 2 3 4 No	0 1 2 3 4 No
Complete Stops	0 1 2 3 4 No	0 1 2 3 4 No
Turns	0 1 2 3 4 No	0 1 2 3 4 No
Yields Right of Way	0 1 2 3 4 No	0 1 2 3 4 No
Turn Signals	0 1 2 3 4 No	0 1 2 3 4 No
Speed Maintenance	0 1 2 3 4 No	0 1 2 3 4 No

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____________________________________ ____________________________________

Driver Rehabilitation Specialist Date/ Time

Roger C. Peace Rehabilitation Hospital

Driver Rehabilitation Program: On Road Assessment

Skill Demonstrated: 0=0% 1=0-25% 2=25-50% 3=50-75% 4=75-100% No= No opportunity to observe

STRATEGIC SKILLS

	Speed limit 0-45 mph	Speed limit 45 mph and over
Divided Attention	0 1 2 3 4 No	0 1 2 3 4 No
Anticipates Hazards	0 1 2 3 4 No	0 1 2 3 4 No
Plans Ahead	0 1 2 3 4 No	0 1 2 3 4 No
Decision Making	0 1 2 3 4 No	0 1 2 3 4 No
Memory	0 1 2 3 4 No	0 1 2 3 4 No
Following Directions	0 1 2 3 4 No	0 1 2 3 4 No
Speed of Processing	0 1 2 3 4 No	0 1 2 3 4 No
Rules of the Road	0 1 2 3 4 No	0 1 2 3 4 No

Adaptive Equipment: □HAND CONTROLS (PR, PRA, PP, R) □SPINNER KNOB □NOT APPLICABLE

□TURN SIGNAL EXTENSION □PEDAL GUARD □LEFT FOOT ACCELLERATOR

______________________________ __________________________________ Driver Rehabilitation Specialist Date/ Time

Behaviorally Anchored Rating Scale

Task	Component	Action	Fail	Acceptable	Excellent
Pleasantburg					
Lane Changes	1	Turn Signal On	Does not use turn signal	Uses turn signal at last moment (~ 1 second)	Turns on signal well before maneuver (~ 3 seconds)
Lane Changes	2	Visual search- Scans mirrors and blind spot checks	Does not check mirrors or blind spots	Checks mirrors and blind spots just prior to maneuver (~1 second)	Checks mirrors and blind spots well before maneuver (~ 3 seconds) regardless of traffic density and just prior to
Lane Changes	5	Maneuver vehicle from one lane to another (lane change) in traffic	Not able to change lanes without causing receiving lane drivers to alter speed or path of travel	Changes lanes without causing receiving lane drivers to alter speed or path of travel, but hesitates or straddles lane during maneuver	Changes lanes without hesitation, moves to center of lane, and does not cause receiving lane traffic to adjust speed or path of travel.
Lane Changes	4	Turn Signal Off	Never turns off signal		Turns off signal / signal automatically turns off

Task	Component	Action	Fail	Acceptable	Excellent
Laurens to NAPA lot					
Unprotected left against oncoming traffic (Using a TWLTL to turn left from a major roadway into a driveway or other minor roadway)	1	Turn Signal On	Does not use turn signal	Uses turn signal at last moment (~ 1 second)	Turns on signal well before maneuver (~ 3 seconds)
Unprotected left against oncoming traffic (Using a TWLTL to turn left from a major roadway into a driveway or other minor roadway)	2	Visual search- Scans mirrors and blind spot checks	Does not check mirrors or blind spots	Checks mirrors and blind spots just prior to maneuver (~1 second)	Checks mirrors and blind spots well before maneuver (~ 3 seconds) regardless of traffic density and just prior to maneuver
Unprotected left against oncoming traffic (Using a TWLTL to turn left from a major roadway into a driveway or other minor roadway)			IF THERE IS ONCOMING TRAFFIC		

Task	Component	Action	Fail	Acceptable	Excellent
Unprotected left against oncoming traffic (Using a TWLTL to turn left from a major roadway into a driveway or other minor roadway)	9	Maneuver vehicle from lane to TWLTL	Never able to move into TWLTL if another stationary opposing vehicle occupies the lane less than 5 seconds away, and/or hesitates or slows significantly (below the speed of traffic flow) before moving into TWLTL, or straddles the line	Able to move into TWLTL with or without another stationary opposing vehicle occupying the lane. Smoothly decelerates to turn location. Does not hesitate or straddle line.	Able to move into TWLTL with or without another stationary opposing vehicle occupying the lane. Can maneuver vehicle into tight gap if another vehicle occupies TWLTL. Able to determine the need to be in front of or behind the other vehicle without hesitation. Moves at or near speed of traffic flow until beginning transition into TWLTL.
Unprotected left against oncoming traffic (Using a TWLTL to turn left from a major roadway into a driveway or other minor roadway)	1	Turn Signal On	Does not use turn signal	Uses turn signal at last moment (~ 1 second)	Turns on signal well before maneuver (~ 3 seconds)
Unprotected left against oncoming traffic (Using a TWLTL to turn left from a major roadway into a driveway or other minor roadway)	4	Turn Signal Off	Does not turn off signal		Turns off signal / signal automatically turns off
Unprotected left against oncoming traffic (Using a TWLTL to turn left from a major roadway into a driveway or other minor roadway)	38	Gap judgment	Chooses a gap that requires opposing drivers to alter speed or path of travel to avoid a collision	Accepts gap where oncoming traffic reaches turning path < 3 seconds after driver completes turn	Accepts gap allowing driver to complete turn 3 seconds or more before opposing traffic crosses turning path

Task	Component	Action	Fail	Acceptable	Excellent
Unprotected left against oncoming traffic (Using a TWLTL to turn left from a major roadway into a driveway or other minor roadway)	11	Turn Movement	Driver fails to complete maneuver with vehicle properly positioned in lane or driveway.	Driver must alter speed or path during turn but ends with vehicle properly positioned in lane or driveway.	Executes turn without speed or path correction, ending with vehicle properly positioned in lane or driveway.
Unprotected left against oncoming traffic (Using a TWLTL to turn left from a major roadway into a driveway or other minor roadway)	4	Turn Signal Off	Does not turn off signal		Turns off signal / signal automatically turns off
Unprotected left against oncoming traffic (Using a TWLTL to turn left from a major roadway into a driveway or other minor roadway)			IF THERE IS NO ONCOMING TRAFFIC		

Task	Component	Action	Fail	Acceptable	Excellent
Unprotected left against oncoming traffic (Using a TWLTL to turn left from a major roadway into a driveway or other minor roadway)	11	Turn Movement	Driver fails to complete maneuver with vehicle properly positioned in lane or driveway.	Driver must alter speed or path during turn but ends with vehicle properly positioned in lane or driveway.	Executes turn without speed or path correction, ending with vehicle properly positioned in lane or driveway.
Unprotected left against oncoming traffic (Using a TWLTL to turn left from a major roadway into a driveway or other minor roadway)	4	Turn Signal Off	Does not turn off signal		Turns off signal / signal automatically turns off

Task	Component	Action	Fail	Acceptable	Excellent
NAPA to Laurens					
Unprotected left turn from driveway or other minor road into a TWLTL on a major road, then merging with same-direction traffic	1	Turn Signal On	Does not use turn signal	Uses turn signal at last moment (~ 1 second)	Turns on signal well before maneuver (~ 3 seconds)
Unprotected left turn from driveway or other minor road into a TWLTL on a major road, then merging with same-direction traffic	16	Implied stop (leaving parking lot)	Does not stop at implied stop. Proceeds on to TWLTL.	Stops only if cross traffic approaching.	Stops at implied stop regardless of cross traffic.
Unprotected left turn from driveway or other minor road into a TWLTL on a major road, then merging with same-direction traffic	19	Checks cross traffic (TWLTL maneuver)	Does not check cross traffic in both directions.		Checks cross traffic in both directions prior to moving into TWLTL.

Unprotected left turn from driveway or other minor road into a TWLTL on a major road, then merging with same-direction traffic	20	Moves into TWLTL	Does not stop in TWLTL, proceeds into lane change without slowing	Slows in TWLTL, moves vehicle into position for a lane change	Stops in TWLTL. Moves vehicle into position for a lane change.
Unprotected left turn from driveway or other minor road into a TWLTL on a major road, then merging with same-direction traffic	2	Visual search- Scans mirrors and blind spot checks	Does not check mirrors or blind spots	Checks mirrors and blind spots just prior to maneuver (~1 second)	Checks mirrors and blind spots well before maneuver (~ 3 seconds) regardless of traffic density and just prior to maneuver
Unprotected left turn from driveway or other minor road into a TWLTL on a major road, then merging with same-direction traffic	5	Maneuver vehicle from one lane to another (lane change) in traffic	Not able to change lanes without causing receiving lane drivers to alter speed or path of travel	Changes lanes without causing receiving lane drivers to alter speed or path of travel, but hesitates or straddles lane during maneuver	Changes lanes without hesitation, moves to center of lane, and does not cause receiving lane traffic to adjust speed or path of travel.
Unprotected left turn from driveway or other minor road into a TWLTL on a major road, then merging with same-direction traffic	4	Turn Signal Off	Does not turn off signal		Turns off signal / signal automatically turns off

Task	Component	Action	Fail	Acceptable	Excellent
Laurens to Washington					
Left turn at protected/permitted signal-controlled intersection	1	Turn Signal On	Does not use turn signal	Uses turn signal at last moment (~ 1 second)	Turns on signal well before maneuver (~ 3 seconds)
Left turn at protected/permitted signal-controlled intersection	12	Checks cross traffic	Does not check cross traffic	Only checks cross traffic immediately before turn	Checks cross traffic during approach to intersection and again immediately before turn
Left turn at protected/permitted signal-controlled intersection		IF SIGNAL PHASE IS PROTECTED (GREEN ARROW)			
Left turn at protected/permitted signal-controlled intersection	36	Understands right-of-way conveyed by left-turn green arrow	Stops or hesitates prior to maneuver (in the absence of a queue or lead vehicle slowing)		Proceeds into intersection on proper trajectory without hesitation
Left turn at protected/permitted signal-controlled intersection	15	Proper lane	Follows improper trajectory and/or fails to end maneuver in correct receiving lane		Follows proper trajectory to end turn in correct receiving lane.
Left turn at protected/permitted signal-controlled intersection	4	Turn Signal Off	Does not turn off signal		Turns off signal / signal automatically turns off
Left turn at protected/permitted signal-controlled intersection		IF SIGNAL PHASE IS PERMITTED (GREEN BALL)			
Left turn at protected/permitted signal-controlled intersection	37	Understands right of way conveyed by green ball	Does not slow or stop when oncoming traffic is present, or stops in the absence of oncoming traffic		Slows or stops as needed to determine safe gap if oncoming traffic is present; or proceeds without stopping (may slow) in the absence of oncoming traffic.

Task	Component	Action	Fail	Acceptable	Excellent
Left turn at protected/permitted signal-controlled intersection	38	Gap judgment	Chooses a gap that requires opposing drivers to alter speed or path of travel to avoid a collision	Accepts gap where oncoming traffic reaches turning path < 3 seconds after driver completes turn	Accepts gap allowing driver to complete turn 3 seconds or more before opposing traffic crosses turning path
Left turn at protected/permitted signal-controlled intersection	15	Proper lane	Follows improper trajectory and/or fails to end maneuver in correct receiving lane		Follows proper trajectory to end turn in correct receiving lane.
Left turn at protected/permitted signal-controlled intersection	4	Turn Signal Off	Does not turn off signal		Turns off signal / signal automatically turns off

Task	Component	Action	Fail	Acceptable	Excellent
385 to 85					
Merge	1	Turn Signal On	Does not use turn signal	Uses turn signal at last moment (~ 1 second)	Turns on signal well before maneuver (~ 3 seconds)
Merge	2	Visual search- Scans mirrors and blind spot checks	Does not check mirrors or blind spots	Checks mirrors and blind spots just prior to maneuver (~1 second)	Checks mirrors and blind spots well before maneuver (~ 3 seconds) regardless of traffic density and just prior to maneuver
Merge	3	Maneuver vehicle from one lane to another (merge) in traffic	Not able to merge without hesitating, stopping, using the shoulder, or causing receiving lane drivers to alter speed or path of travel	Completes merge without requiring receiving lane drivers to alter speed or path of travel, but hesitates due to difficulty adjusting to speed of traffic	Modulates speed according to the rate of traffic flow. Can merge without hesitation and without causing drivers in receiving lane to alter speed or path of travel.
Merge	4	Turn Signal Off	Does not turn off signal		Turns off signal / signal automatically turns off

Task	Component	Action	Fail	Acceptable	Excellent
85 to White Horse road					
Freeway exit using deceleration lane	1	Turn Signal On	Does not use turn signal	Uses turn signal at last moment (~ 1 second)	Turns on signal well before maneuver (~ 3 seconds)
Freeway exit using deceleration lane	8	Lane change onto deceleration lane	Has to make multiple lane changes to get to deceleration lane at last minute.	Is prepared in the right lane position but slows and/or does not move into deceleration lane at beginning of lane.	Has prepared to enter deceleration lane by positioning in the right lane, then moves into deceleration lane prior to reducing speed.
Freeway exit using deceleration lane	4	Turn Signal Off	Never turns off signal		Turns off signal / signal automatically turns off

Task	Component	Action	Fail	Acceptable	Excellent
85 to White Horse road					
Negotiating lane drop (pavement width transition)	1	Turn Signal On	Does not use turn signal	Uses turn signal at last moment (~ 1 second)	Turns on signal well before maneuver (~ 3 seconds)
Negotiating lane drop (pavement width transition)	2	Visual search- Scans mirrors and blind spot checks	Does not check mirrors or blind spots	Checks mirrors and blind spots just prior to maneuver (~1 second)	Checks mirrors and blind spots well before maneuver (~ 3 seconds) regardless of traffic density and just prior to maneuver
Negotiating lane drop (pavement width transition)	35	Maneuver vehicle from one lane to another to avoid physical barrier ahead (lane ends)	Not able to change lanes without causing receiving lane drivers to alter speed or path of travel, or must stop at end of lane before executing maneuver	Changes lanes without causing receiving lane drivers to alter speed or path of travel, but hesitates or straddles lane during maneuver	Changes lanes without hesitation, moves to center of lane, and does not cause receiving lane traffic to adjust speed or path of travel. Completes lane change maneuver more than 2.5 seconds before lane ends.
Negotiating lane drop (pavement width transition)	4	Turn Signal Off	Does not turn off signal		Turns off signal / signal automatically turns off

Task	Component	Action	Fail	Acceptable	Excellent
Grove to Faris					
Right with yield; no acceleration lane	1	Turn Signal On	Does not use turn signal	Uses turn signal at last moment (~ 1 second)	Turns on signal well before maneuver (~ 3 seconds)
Right with yield; no acceleration lane	2	Visual search- Scans mirrors and blind spot checks	Does not check mirrors or blind spots	Checks mirrors and blind spots just prior to maneuver (~1 second)	Checks mirrors and blind spots well before maneuver (~ 3 seconds) regardless of traffic density and just prior to maneuver
Right with yield; no acceleration lane	17	Dynamic visual search	Unable to divide attention between approaching traffic and controlling vehicle (speed and/or path) while moving into yield position. Must stop, and then check traffic.	Must significantly reduce speed to effectively divide attention, between controlling vehicle and searching for a gap on approach to yield sign.	Divides attention between vehicle control and search for gap on approach to yield sign without significantly reducing speed.
Right with yield; no acceleration lane	18	Maneuvers vehicle from yield position into lane of travel	Can not merge into receiving lane of traffic without causing other drivers to alter speed or path of travel.	Accomplishes merge without causing receiving lane drivers to alter speed or path of travel, but only under low-density conditions.	Merges into traffic at rate of flow, without causing drivers in receiving lane to alter speed or path of travel.
Right with yield; no acceleration lane	4	Turn Signal Off	Does not turn off signal		Turns off signal / signal automatically turns off

Task	Component	Action	Fail	Acceptable	Excellent
GATE ACCESS: deck					
Gate access	21	Positions car	Multiple attempts at positioning; may need to open door to successfully access pad.	Pulls up to gate, may need to reposition once to easily access pad.	Stops at appropriate position at first attempt.
Gate access	22	Reach pad	Unable to coordinate lowering window and reaching pad to swipe badge, with foot on the brake.		Able to coordinate holding brake while lowering window and using badge to swipe pad.
Gate access	23	Clears gate	Proceeds before gate clears top of vehicle or runs through gate, or moves in reverse.		Waits for gate to clear top of vehicle before proceeding forward.

Task	Component	Action	Fail	Acceptable	Excellent
PARKING LEFT: deck					
Parking, turning left into space	1	Turn Signal On	Does not use turn signal	Uses turn signal at last moment (~ 1 second)	Turns on signal well before maneuver (~ 3 seconds)
Parking, turning left into space	25	Visual search- scans mirrors, blind spots and surrounding environment (parking lot)	Never checks mirrors or blind spots. Does not scan for pedestrians or potential vehicle movement		Checks mirrors and blind spots prior to turn regardless of traffic density. Checks for potential vehicle movement/pedestrians in area surrounding parking space.
Parking, turning left into space	26	Turn	Proceeds into left turn, unable to successfully determine turn radius.	Proceeds into left turn however needs to swing wide to assist with turn radius.	Able to determine appropriate turn radius and proceeds into space without hesitation.
Parking, turning left into space	27	Spacing	Multiple attempts at aligning correctly for space, not aligned evenly despite multiple attempts to realign.	May need to realign once for centered space position.	Does not need to readjust position, evenly positioned between lines.
Parking, turning left into space	28	Stop	Speed inappropriate for smooth stopping, or impacts curb/ barrier when stopping.		Slows to an acceptable speed and comes to a smooth stop without impacting curb or parking barrier.
Parking, turning left into space	29	Shifts into park	Does not shift into park, or difficulty determining parking gear.		Shifts into park without hesitation.

Task	Component	Action	Fail	Acceptable	Excellent
BACKING: A deck					
Leaving parking space (Backing)	30	Shifts into reverse	Does not shift into reverse or difficulty determining reverse gear. Does not maintain foot on brake		Shifts into reverse without hesitation with no difficulty maintaining foot on brake.
Leaving parking space (Backing)	31	Visual search- scans mirror and over the shoulder checks (parking lot)	Does not scan mirrors or perform over the shoulder checks.	Uses mirrors primarily however would perform over the shoulder check if cued with peripheral information to verify safety.	Performs mirror checks and over the shoulder checks to verify safety.
Leaving parking space (Backing)	32	Backing into proper lane	Speed inappropriate for smooth backing or too fast for safety; or unable to back into appropriate lane to allow for forward movement into correct path of travel.		Smoothly modulates speed and backs into correct lane.
Leaving parking space (Backing)	33	Plan for forward movement	Does not shift into drive or has difficulty determining drive gear; or does not maintain foot on brake.		Shifts into drive without hesitation; maintains foot on brake without difficulty.

Task	Component	Action	Fail	Acceptable	Excellent
PARKING STRAIGHT: deck					
Parking straight	25	Visual search- scans mirrors, blind spots and surrounding environment (parking lot)	Never checks mirrors or blind spots. Does not scan for pedestrians or potential vehicle movement		Checks mirrors and blind spots regardless of traffic density and prior to turn. Checks for potential vehicle movement/pedestrians in area surrounding parking space.
Parking straight	34	Entry	Excessive speed when entering parking space (over 10 mph).		Speed appropriate for entry into parking space (10 mph or below).
Parking straight	27	Spacing	Multiple attempts at aligning correctly for space, not aligned evenly despite multiple attempts to realign.	May need to realign once for centered space position.	Does not need to readjust position, evenly positioned between lines.
Parking straight	28	Stop	Speed inappropriate for smooth stopping, or impacts curb/ barrier when stopping.		Slows to an acceptable speed and comes to a smooth stop without impacting curb or parking barrier.
Parking straight	29	Shifts into park	Does not shift into park, or difficulty determining parking gear.		Shifts into park without hesitation.

Task	Component	Action	Fail	Acceptable	Excellent
BACKING: B deck					
Leaving parking space (Backing)	30	Shifts into reverse	Does not shift into reverse or difficulty determining reverse gear. Does not maintain foot on brake		Shifts into reverse without hesitation with no difficulty maintaining foot on brake.
Leaving parking space (Backing)	31	Visual search- scans mirror and over the shoulder checks (parking lot)	Does not scan mirrors or perform over the shoulder checks.	Uses mirrors primarily however would perform over the shoulder check if cued with peripheral information to verify safety.	Performs mirror checks and over the shoulder checks to verify safety.
Leaving parking space (Backing)	32	Backing into proper lane	Speed inappropriate for smooth backing or too fast for safety; or unable to back into appropriate lane to allow for forward movement into correct path of travel.		Smoothly modulates speed and backs into correct lane.
Leaving parking space (Backing)	33	Plan for forward movement	Does not shift into drive or has difficulty determining drive gear; or does not maintain foot on brake.		Shifts into drive without hesitation; maintains foot on brake without difficulty.

Task	Component	Action	Fail	Acceptable	Excellent
GATE ACCESS: lot					
Gate access	21	Positions car	Multiple attempts at positioning; may need to open door to successfully access pad.	Pulls up to gate, may need to reposition once to easily access pad.	Stops at appropriate position at first attempt.
Gate access	22	Reach pad	Unable to coordinate lowering window and reaching pad to swipe badge, with foot on the brake.		Able to coordinate holding brake while lowering window and using badge to swipe pad.
Gate access	23	Clears gate	Proceeds before gate clears top of vehicle or runs through gate, or moves in reverse.		Waits for gate to clear top of vehicle before proceeding forward.

Task	Component	Action	Fail	Acceptable	Excellent
PARKING LEFT: lot					
Parking, turning left into space	1	Turn Signal On	Does not use turn signal	Uses turn signal at last moment (~ 1 second)	Turns on signal well before maneuver (~ 3 seconds)
Parking, turning left into space	25	Visual search- scans mirrors, blind spots and surrounding environment (parking lot)	Never checks mirrors or blind spots. Does not scan for pedestrians or potential vehicle movement		Checks mirrors and blind spots prior to turn regardless of traffic density. Checks for potential vehicle movement/pedestrians in area surrounding parking space.
Parking, turning left into space	26	Turn	Proceeds into left turn, unable to successfully determine turn radius.	Proceeds into left turn however needs to swing wide to assist with turn radius.	Able to determine appropriate turn radius and proceeds into space without hesitation.
Parking, turning left into space	27	Spacing	Multiple attempts at aligning correctly for space, not aligned evenly despite multiple attempts to realign.	May need to realign once for centered space position.	Does not need to readjust position, evenly positioned between lines.
Parking, turning left into space	28	Stop	Speed inappropriate for smooth stopping, or impacts curb/ barrier when stopping.		Slows to an acceptable speed and comes to a smooth stop without impacting curb or parking barrier.
Parking, turning left into space	29	Shifts into park	Does not shift into park, or difficulty determining parking gear.		Shifts into park without hesitation.

Task	Component	Action	Fail	Acceptable	Excellent
BACKING: A lot					
Leaving parking space (Backing)	30	Shifts into reverse	Does not shift into reverse or difficulty determining reverse gear. Does not maintain foot on brake		Shifts into reverse without hesitation with no difficulty maintaining foot on brake.
Leaving parking space (Backing)	31	Visual search- scans mirror and over the shoulder checks (parking lot)	Does not scan mirrors or perform over the shoulder checks.	Uses mirrors primarily however would perform over the shoulder check if cued with peripheral information to verify safety.	Performs mirror checks and over the shoulder checks to verify safety.
Leaving parking space (Backing)	32	Backing into proper lane	Speed inappropriate for smooth backing or too fast for safety; or unable to back into appropriate lane to allow for forward movement into correct path of travel.		Smoothly modulates speed and backs into correct lane.
Leaving parking space (Backing)	33	Plan for forward movement	Does not shift into drive or has difficulty determining drive gear; or does not maintain foot on brake.		Shifts into drive without hesitation; maintains foot on brake without difficulty.

Task	Component	Action	Fail	Acceptable	Excellent
PARKING STRAIGHT: lot					
Parking straight	25	Visual search- scans mirrors, blind spots and surrounding environment (parking lot)	Never checks mirrors or blind spots. Does not scan for pedestrians or potential vehicle movement		Checks mirrors and blind spots regardless of traffic density and prior to turn. Checks for potential vehicle movement/pedestrians in area surrounding parking space.
Parking straight	34	Entry	Excessive speed when entering parking space (over 10 mph).		Speed appropriate for entry into parking space (10 mph or below).
Parking straight	27	Spacing	Multiple attempts at aligning correctly for space, not aligned evenly despite multiple attempts to realign.	May need to realign once for centered space position.	Does not need to readjust position, evenly positioned between lines.
Parking straight	28	Stop	Speed inappropriate for smooth stopping, or impacts curb/ barrier when stopping.		Slows to an acceptable speed and comes to a smooth stop without impacting curb or parking barrier.
Parking straight	29	Shifts into park	Does not shift into park, or difficulty determining parking gear.		Shifts into park without hesitation.

Task	Component	Action	Fail	Acceptable	Excellent
BACKING: B lot					
Leaving parking space (Backing)	30	Shifts into reverse	Does not shift into reverse or difficulty determining reverse gear. Does not maintain foot on brake		Shifts into reverse without hesitation with no difficulty maintaining foot on brake.
Leaving parking space (Backing)	31	Visual search- scans mirror and over the shoulder checks (parking lot)	Does not scan mirrors or perform over the shoulder checks.	Uses mirrors primarily however would perform over the shoulder check if cued with peripheral information to verify safety.	Performs mirror checks and over the shoulder checks to verify safety.
Leaving parking space (Backing)	32	Backing into proper lane	Speed inappropriate for smooth backing or too fast for safety; or unable to back into appropriate lane to allow for forward movement into correct path of travel.		Smoothly modulates speed and backs into correct lane.
Leaving parking space (Backing)	33	Plan for forward movement	Does not shift into drive or has difficulty determining drive gear; or does not maintain foot on brake.		Shifts into drive without hesitation; maintains foot on brake without difficulty.

Appendix F. Tables and Figures Describing Non-Significant Group Differences

Clinical Measures: Primary Sample

Table F1. Primary Sample Far Bilateral Visual Acuity

Group	N	Minimum (20/_)	Maximum (20/_)	Average (20/_)	Standard Deviation
Control	**19**	**20**	**50**	**31.05**	**8.09**
Medical Condition	**8**	**20**	**40**	**30.00**	**7.56**
COPD	4	20	30	27.50	5.00
AMD	2	20	40	30.00	14.14
Neuropathy	2	30	40	35.00	7.07
Total	**27**	**20**	**50**	**30.74**	**7.81**

Table F2. Primary Sample Bilateral Contrast Sensitivity

Group	N	Minimum (log)	Maximum (log)	Average (log)	Standard Deviation (log)
Control	**19**	**1.35**	**1.95**	**1.81**	**0.20**
Medical Condition	**8**	**1.35**	**1.95**	**1.80**	**0.24**
COPD	4	1.95	1.95	1.95	0.00
AMD	2	1.5	1.95	1.73	0.32
Neuropathy	2	1.35	1.8	1.58	0.32
Total	**27**	**1.35**	**1.95**	**1.81**	**0.21**

Table F3. Primary Sample Plantar Threshold Target Force

Group	N	Minimum (g)	Maximum (g)	Average (g)	Standard Deviation (g)
Control	**19**	**0.16**	**2**	**0.74**	**0.58**
Medical Condition	**8**	**0.07**	**15**	**4.58**	**6.56**
COPD	4	0.07	1.4	0.62	0.57
AMD	2	0.16	4	2.08	2.72
Neuropathy	2	15	15	15.00	0.00
Total	**27**	**0.07**	**15**	**1.88**	**3.87**

Table F4. Primary Sample Average Brake Reaction Time

Group	N	Minimum Time (sec.)	Maximum Time (sec.)	Average (sec.)	Standard Deviation (sec.)
Control	**19**	**0.32**	**0.72**	**0.49**	**0.09**
Medical Condition	**8**	**0.39**	**0.60**	**0.50**	**0.07**
COPD	4	0.39	0.60	0.48	0.09
AMD	2	0.47	0.55	0.51	0.06
Neuropathy	2	0.45	0.58	0.52	0.09
Total	**27**	**0.32**	**0.72**	**0.49**	**0.09**

Table F5. Primary Sample Performance for Useful Field of View, Subtest 1

Group	N	Minimum Score (ms)	Maximum Score (ms)	Average (ms)	Standard Deviation (ms)
Control	**19**	**17**	**77**	**20.47**	**13.76**
Medical Condition	**7**	**17**	**77**	**25.57**	**22.68**
COPD	3	17	17	17.00	0.00
AMD	2	17	17	17.00	0.00
Neuropathy	2	17	77	47.00	42.43
Total	**26**	**17**	**77**	**21.85**	**16.28**

Table F6. Primary Sample Performance for Useful Field of View, Subtest 2

Group	N	Minimum Score (ms)	Maximum Score (ms)	Average (ms)	Standard Deviation (ms)
Control	**19**	**100**	**330**	**135.79**	**71.62**
Medical Condition	**7**	**100**	**333**	**167.14**	**92.27**
COPD	3	100	207	135.67	61.78
AMD	2	100	230	165.00	91.92
Neuropathy	2	100	333	216.50	164.76
Total	**26**	**100**	**333**	**144.23**	**77.05**

Table F7. Primary Sample Letter Cancellation Test Times

Group	n	Minimum Time (sec.)	Maximum Time (sec.)	Average Time (sec.)	Standard Deviation (sec.)
Control	**19**	**50**	**100**	**73.21**	**13.07**
Medical Condition	**8**	**56**	**110**	**79.63**	**17.74**
COPD	4	56	87	71.25	14.64
AMD	2	73	110	91.50	26.16
Diabetes with Neuropathy	2	73	96	84.50	16.26
Total	**27**	**50**	**110**	**75.11**	**14.55**

Table F8. Primary Sample Performance for the Trail Making Test, Part A

Group	N	Minimum Score (sec.)	Maximum Score (sec.)	Average (sec.)	Standard Deviation (sec.)
Control	**18**	**17**	**45**	**30.33**	**7.46**
Medical Condition	**8**	**22**	**52**	**34.50**	**9.44**
COPD	4	24	40	33.00	6.68
AMD	2	22	32	27.00	7.07
Neuropathy	2	38	52	45.00	9.90
Total	**26**	**17**	**52**	**31.52**	**8.02**

Table F9. Primary Sample Performance Summary for the Trail Making Test, Part B

Group	N	Minimum Score (sec.)	Maximum Score (sec.)	Average Score (sec.)	Standard Deviation (sec.)
Control	**18**	**43**	**131**	**78.78**	**25.62**
Medical Condition	**8**	**53**	**184**	**116.13**	**52.59**
COPD	4	105	164	142.00	27.26
AMD	2	61	63	62.00	1.41
Neuropathy	2	53	184	118.50	92.63
Total	**26**	**43**	**184**	**90.27**	**39.11**

Clinical Measures: Augmented Sample

Table F10. Augmented Sample Far Bilateral Visual Acuity

Group	n	Minimum (20/_)	Maximum (20/_)	Average (20/_)	Standard Deviation
Control	**43**	**20**	**50**	**30.47**	**9.50**
Medical Condition	**15**	**20**	**50**	**32.67**	**9.61**
COPD	4	20	30	27.50	5.00
AMD	2	20	40	30.00	14.14
Neuropathy	9	20	50	35.56	10.14
Total	**58**	**20**	**50**	**31.03**	**9.49**

Table F11. Augmented Sample Bilateral Contrast Sensitivity

Group	n	Minimum (log)	Maximum (log)	Average (log)	Standard Deviation (log)
Control	**43**	**1.05**	**1.95**	**1.81**	**0.21**
Medical Condition	**15**	**1.35**	**2.10**	**1.79**	**0.22**
COPD	4	1.95	1.95	1.95	0.00
AMD	2	1.50	1.95	1.73	0.32
Neuropathy	9	1.35	2.10	1.73	0.24
Total	**58**	**1.05**	**2.10**	**1.80**	**0.21**

Table F12. Augmented Sample Average Brake Reaction Time

Group	N	Minimum Time (sec.)	Maximum Time (sec.)	Average (sec.)	Standard Deviation (sec.)
Control	**43**	**0.32**	**0.72**	**0.48**	**0.08**
Medical Condition	**15**	**0.39**	**0.69**	**0.51**	**0.09**
COPD	4	0.39	0.60	0.48	0.09
AMD	2	0.47	0.55	0.51	0.06
Neuropathy	9	0.41	0.69	0.52	0.10
Total	**58**	**0.32**	**0.72**	**0.49**	**0.09**

Table F13. Augmented Sample Letter Cancellation Test Times

Group	n	Min (sec.)	Max (sec.)	Average (sec.)	Standard Deviation (sec.)
Control	**43**	**50**	**101**	**72.88**	**11.56**
Medical Condition	**15**	**52**	**110**	**77.93**	**18.44**
COPD	4	56	87	71.25	14.64
AMD	2	73	110	91.50	26.16
Neuropathy	9	52	108	77.89	19.00
Total	**58**	**50**	**110**	**74.19**	**13.67**

Table F14. Augmented Sample Performance for the Trail Making Test, Part A

Group	N	Minimum Score (sec.)	Maximum Score (sec.)	Average (sec.)	Standard Deviation (sec.)
Control	**41**	**17**	**67**	**30.49**	**9.12**
Medical Condition	**15**	**21**	**52**	**33.60**	**8.47**
COPD	4	24	40	33.00	6.68
AMD	2	22	32	27.00	7.07
Neuropathy	9	21	52	35.33	9.38
Total	**56**	**17**	**67**	**31.32**	**8.99**

Clinical Measures: SHRP 2 Sample (BSA)

Table F15. SHRP2 Sample (BSA) Far Bilateral Visual Acuity

Group	N	Minimum (20/__)	Maximum (20/__)	Average (20/__)	Standard Deviation (20/__)
Control	**129**	**12.5**	**50**	**24.62**	**9.14**
Medical Condition	**74**	**16**	**50**	**25.81**	**8.77**
COPD	21	16	32	22.29	4.77
Neuropathy	42	16	50	26.36	8.93
Parkinson's	7	20	50	30.29	11.21
Total	**203**	**12.5**	**50**	**25.05**	**9.00**

Table F16. SHRP2 Sample (BSA) Contrast Sensitivity (Best Eye)

		Group		Subgroup			
		Control	Medical Conditions	COPD	Neuropathy	Parkinson's	Total
Patch	N	129	74	21	42	7	203
A (1.5)	Min	13	9	13	9	13	9
	Max	100	100	50	100	50	100
	Avg	31.5	31.7	28.0	33.2	31.0	31.6
	Std Dev	15.0	16.4	10.4	19.4	14.8	15.5
B (3)	Min	20	15	29	29	15	15
	Max	160	160	114	160	160	160
	Avg	65.9	67.4	57.7	68.3	80.6	66.4
	Std Dev	31.2	36.2	24.4	36.6	59.5	33.0
C (6)	Min	0	12	12	16	12	0
	Max	180	128	128	128	128	180
	Avg	58.6	57.1	58.4	55.5	56.9	58.1
	Std Dev	30.3	29.4	29.5	27.8	37.3	29.9
D (12)	Min	0	0	8	0	0	0
	Max	120	90	90	90	90	120
	Avg	23.0	23.3	27.7	19.4	35.9	23.1
	Std Dev	18.2	20.5	22.4	14.8	38.2	19.0
E (18)	Min	0	0	0	0	0	0
	Max	33	17	17	17	17	33
	Avg	7.0	6.6	6.8	6.7	6.1	6.9
	Std Dev	7.0	6.3	6.3	6.4	6.7	6.8

Table F17. SHRP2 Sample (BSA) Performance for the Useful Field of View, Subtest 2

Group	N	Minimum Score (ms)	Maximum Score (ms)	Average Score (ms)	Standard Deviation (ms)
Control	**123**	**100**	**500**	**180.62**	**108.70**
Medical Condition	**73**	**100**	**473**	**199.32**	**104.37**
COPD	21	100	430	187.76	100.83
Neuropathy	41	100	390	200.34	96.64
Parkinson's	7	100	413	231.43	124.45
Total	**196**	**100**	**500**	**187.58**	**107.23**

Table F18. SHRP2 Sample (BSA) Performance for the Visualizing Missing Information Test

Group	N	Minimum (Errors)	Maximum (Errors)	Average (Errors)	Standard Deviation
Control	**126**	**0**	**10**	**2.29**	**2.06**
Medical Condition	**73**	**0**	**10**	**2.70**	**2.15**
COPD	21	0	10	2.90	2.53
Neuropathy	41	0	9	2.56	2.07
Parkinson's	7	0	6	3.00	2.08
Total	**199**	**0**	**10**	**2.44**	**2.10**

Table F19. SHRP2 Sample (BSA) Performance for the Trail Making Test, Part A

Group	N	Minimum Score (sec.)	Maximum Score (sec.)	Average Score (sec.)	Standard Deviation (sec.)
Control	**125**	**18.8**	**84.3**	**38.2**	**14.3**
Medical Condition	**73**	**17.2**	**86.8**	**39.8**	**12.4**
COPD	21	17.2	59.6	36.8	10.7
Neuropathy	41	21.1	86.8	41.0	13.8
Parkinson's	7	28.9	55.0	43.9	9.4
Total	**198**	**17.2**	**86.8**	**38.8**	**13.6**

Table F20. SHRP2 Sample (BSA) Performance for the Trail Making Test, Part B

Group	N	Minimum Score (sec.)	Maximum Score (sec.)	Average Score (sec.)	Standard Deviation (sec.)
Control	**126**	**36.86**	**357.99**	**98.35**	**38.83**
Medical Condition	**72**	**47.38**	**358.99**	**105.67**	**46.47**
COPD	21	47.38	210.79	108.19	43.86
Neuropathy	40	52.07	358.99	103.34	51.35
Parkinson's	7	60.09	171.90	117.24	35.20
Total	**198**	**36.86**	**358.99**	**101.01**	**41.80**

SHRP 2 Sample (SSA)

Table F21. SHRP2 Sample (SSA) Far Bilateral Visual Acuity

Group	N	Minimum (20/__)	Maximum (20/__)	Average (20/__)	Standard Deviation (20/__)
Control	**23**	**12.5**	**50**	**24.39**	**8.36**
Medical Condition	**13**	**16**	**50**	**24.77**	**9.31**
COPD	6	16	32	22.17	5.60
Neuropathy	6	16	32	23.17	6.18
Parkinson's	1	50	50	50.00	0.00
Total	**36**	**12.5**	**50**	**24.53**	**8.59**

Table F22. SHRP2 Sample (SSA) Contrast Sensitivity (Best Eye)

		Group		Subgroup			
		Control	**Medical Condition**	COPD	Neuropathy	Parkinson's	**Total**
Patch	**N**	**23**	**13**	6	6	1	**36**
A (1.5)	**Min**	**18**	**18**	25	18	50	**18**
	Max	**100**	**50**	36	36	50	**100**
	Avg	**34.4**	**29.8**	28.7	27.5	50.0	**32.72**
	Std Dev	**18.9**	**8.5**	5.7	7.1		**15.92**
B (3)	**Min**	**20**	**29**	29	29	160	**20**
	Max	**114**	**160**	80	57	160	**160**
	Avg	**64.4**	**58.9**	56.2	44.8	160.0	**62.42**
	Std Dev	**28.2**	**33.8**	16.2	13.9		**29.97**
C (6)	**Min**	**23**	**12**	12	23	64	**12**
	Max	**180**	**128**	128	64	64	**180**
	Avg	**55.9**	**60.8**	73.5	47.7	64.0	**57.67**
	Std Dev	**31.4**	**34.0**	46.3	15.3		**31.95**
D(12)	**Min**	**0**	**0**	11	0	90	**0**
	Max	**43**	**90**	30	30	90	**90**
	Avg	**21.4**	**24.9**	19.2	19.8	90.0	**22.69**
	Std Dev	**10.0**	**21.3**	6.9	11.3		**14.90**
E(18)	**Min**	**0**	**0**	0	0	17	**0**
	Max	**12**	**17**	17	17	17	**17**
	Avg	**5.3**	**6.5**	5.8	5.5	17.0	**5.75**
	Std Dev	**4.9**	**6.8**	5.8	7.3		**5.59**

Table F23. SHRP2 Sample (SSA) Performance for the Visualizing Missing Information Test

Group	N	Minimum (Errors)	Maximum (Errors)	Average (Errors)	Standard Deviation
Control	**23**	**0**	**8**	**2.74**	**2.56**
Medical Condition	**13**	**0**	**7**	**2.77**	**2.39**
COPD	6	1	6	2.33	1.97
Neuropathy	6	0	7	2.67	2.73
Parkinson's	1	6	6	6.00	0.00
Total	**36**	**0**	**8**	**2.75**	**2.47**

Table F24. SHRP2 Sample (SSA) Performance for the Trail Making Test, Part A

Group	N	Minimum Score (sec.)	Maximum Score (sec.)	Average Score (sec.)	Standard Deviation (sec.)
Control	**23**	**21.2**	**82.7**	**37.1**	**15.4**
Medical Condition	**13**	**23.7**	**45.5**	**34.8**	**6.1**
COPD	6	23.7	38.8	30.6	5.8
Neuropathy	6	34.5	45.5	38.4	4.2
Parkinson's	1	38.3	38.3	38.3	0.0
Total	**36**	**21.2**	**82.7**	**36.2**	**12.7**

Table F25. SHRP 2 Sample (SSA) Performance for the Trail Making Test, Part B

Group	N	Minimum Score (sec.)	Maximum Score (sec.)	Average Score (sec.)	Standard Deviation (sec.)
Control	**23**	**36.9**	**147.3**	**100.5**	**29.4**
Medical Condition	**13**	**65.6**	**128.9**	**94.1**	**22.0**
COPD	6	65.6	128.9	88.2	23.9
Neuropathy	6	71.1	121.4	95.6	20.1
Parkinson's	1	120.6	120.6	120.6	0.0
Total	**36**	**36.9**	**147.3**	**98.2**	**26.8**

Table F26. Driving Exposure Results, by Driver, for Control Group

PARTICIPANT NUMBER:		001	006	010	016	018	019	021	022	025	029	030	031
Age		71	71	71	72	69	71	72	81	82	63	72	72
Total trips taken		44	13	62	32	109	40	72	25	23	36	42	31
Average trips per day		3.7	2.2	2.8	4	4.2	4.4	4.2	3.1	2.9	5.3	3.2	2.6
Miles Driven	Total in observation period	202	137	488	295	325	205	586	119	309	191	214	146
	Average per day	16.9	22.9	22.2	36.9	12.5	22.7	34.5	14.8	38.6	27.2	5.1	12.2
	Min per trip	0.35	2.5	0.36	1.39	0.11	0.17	0.25	0.61	0.9	0.92	0.23	0.16
	Max per trip	30.5	24.7	16.6	26.7	22.4	16.4	39.6	27.5	57.9	55.9	14.4	7.15
Trip Duration (hrs:min:sec)	Total driving time	8:23:53	3:47:42	17:33:47	8:41:07	16:48:48	7:46:50	19:51:21	4:29:46	8:18:23	8:32:16	7:41:03	6:41:06
	Average trip length	0:11:27	0:17:31	0:17:00	0:16:17	0:09:15	0:11:50	0:16:33	0:11:20	0:22:39	0:14:14	0:10:59	0:12:56
	Min trip length	0:02:38	0:07:10	0:02:34	0:03:11	0:01:06	0:01:07	0:01:21	0:02:15	0:03:02	0:03:46	0:01:56	0:01:30
	Max trip length	0:50:02	0:43:41	0:33:54	0:58:11	0:45:52	0:31:28	0:52:00	0:40:56	1:16:08	2:11:24	0:22:06	0:18:51
% of Trips by Distance Band	<=1 mile	11.4	0	1.6	0	37.6	22.5	5.6	16	4.4	2.8	9.5	3.2
	>1-2.5 miles	38.6	7.7	6.5	9.4	34.9	15	18.1	20	8.7	36.1	21.4	9.7
	2.6-5 miles	22.7	30.8	22.6	34.4	11	0	22.2	40	26.1	36.1	23.8	29
	5.1-10 miles	22.7	7.7	30.6	25	9.2	57.5	26.4	16	17.4	16.6	28.6	58.1
	10.1-20 miles	0	46.1	38.7	15.6	4.6	5	20.8	4	21.7	5.6	16.7	0
	>20 miles	4.6	7.7	0	15.6	2.7	0	6.9	4	21.7	2.8	0	0
% of Trips by Time of Day	Before 10 AM	15.9	7.7	21	15.6	21.1	22.5	26.4	28	34.8	19.4	2.4	29
	10 AM - 3 PM	38.6	38.5	24.2	65.6	54.1	67.5	45.8	52	65.2	55.6	40.5	16.1
	3 PM - 8 PM	43.2	30.7	43.5	18.8	22	10	27.8	20	0	25	57.1	45.2
	After 8 PM (night)	2.3	23.1	11.3	0	2.8	0	0	0	0	0	0	9.7
% of Trips by Road Type	Low speed/ residential	19.7	16.5	35	33.1	12	24.2	12.4	10.9	8	9.7	11.7	0.4
	Low speed/ commercial	16.1	2.4	2.4	10.8	17.7	35.6	17.5	15.3	10.4	22.5	16	43.7
	Arterial/multi-lane	35.2	18	55.2	6.4	43.8	20	27.3	38.6	10.1	44	10.1	55.9
	2-lane rural highway	29	28.6	4.5	33.6	0	0	8.9	0	51.2	3.2	0	0
	Limited access/freeway	0	34.5	2.9	16.1	26.5	20.2	33.9	35.2	20.3	20.5	62.2	0
% of Trips	Adverse weather (rain or fog)	8.6	2.4	4.3	32.6	5.3	0	0	0	7	6.2	3.6	0
% of Miles Driven	Common/ familiar routes	100	63.6	91.6	70.8	88	93.2	97.3	90.8	89.6	87.9	94.2	91.2
	Uncommon/ unfamiliar routes	0	36.4	8.4	29.2	12	6.8	2.7	9.2	10.4	12.1	5.8	8.8

Table F27. Driving Exposure Results, by Driver, for Medical Conditions Group

PARTICIPANT NUMBER:		002	003	004	007	013	014	024
Age		64	75	69	61	72	68	71
Total trips taken		39	25	43	23	13	33	119
Average trips per day		3.3	3.6	3.6	3.3	2.6	4.1	4.4
Miles Driven	Total in observation period	274.4	304.8	113.7	183.6	75.4	218.4	661.1
	Average per day	22.9	43.5	9.5	26.2	15.1	27.3	24.5
	Min per trip	0.4	0.93	0.37	0.29	0.07	0.23	0.18
	Max per trip	21.57	48.48	8.96	28.83	13.07	57.12	16.66
Trip Duration (hrs:min:sec)	Total driving time	9:50:32	9:16:48	6:10:52	6:34:50	3:15:57	8:38:00	30:07:45
	Average trip length	0:15:09	0:22:16	0:08:37	0:17:10	0:15:04	0:15:42	0:15:19
	Min trip length	0:02:01	0:04:37	0:01:59	0:03:12	0:01:38	0:01:58	0:00:48
	Max trip length	0:28:53	1:19:00	0:26:23	0:49:53	0:29:41	1:04:09	0:50:56
% of Trips by Distance Band	<=1 mile	5.1	4	9.3	4.4	7.6	24.2	10.1
	>1-2.5 miles	33.3	24	55.8	30.4	15.4	18.2	12.6
	2.6-5 miles	18	20	27.9	21.7	30.8	18.2	35.3
	5.1-10 miles	23.1	24	7	13.1	30.8	21.2	28.6
	10.1-20 miles	7.7	4	0	21.7	15.4	12.1	13.4
	>20 miles	12.8	24	0	8.7	0	6.1	0
% of Trips by Time of Day	Before 10 AM	12.8	24	46.5	13	15.4	3	16
	10 AM - 3 PM	74.4	56	39.5	52.2	53.8	15.2	48.7
	3 PM - 8 PM	7.7	20	14	34.8	23.1	66.6	26.9
	After 8 PM (night)	5.1	0	0	0	7.7	15.2	8.4
% of Trips by Road Type	Low speed/residential	16.6	12.8	48.6	8.6	18.1	5.7	7
	Low speed/commercial	16.4	15	7.2	14.6	7.1	23.4	33.6
	Arterial/multi-lane	25.4	19.4	44.2	31.6	21.5	20	46.9
	2-lane rural highway	0	27.8	0	30.7	53.3	22.3	1.6
	Limited access/freeway	41.6	25	0	14.5	0	28.6	10.9
% of Trips	Adverse weather (rain or fog)	0	9.1	5.2	3.1	0	2.4	5
% of Miles Driven	common (familiar) routes	95.1	83.8	98.3	85	77.6	40.7	95.2
	uncommon (unfamiliar) routes	4.9	16.2	15.4	15	22.4	59.3	4.8

COPD | **Macular Degeneration** | **Diabetes with Neuropathy**

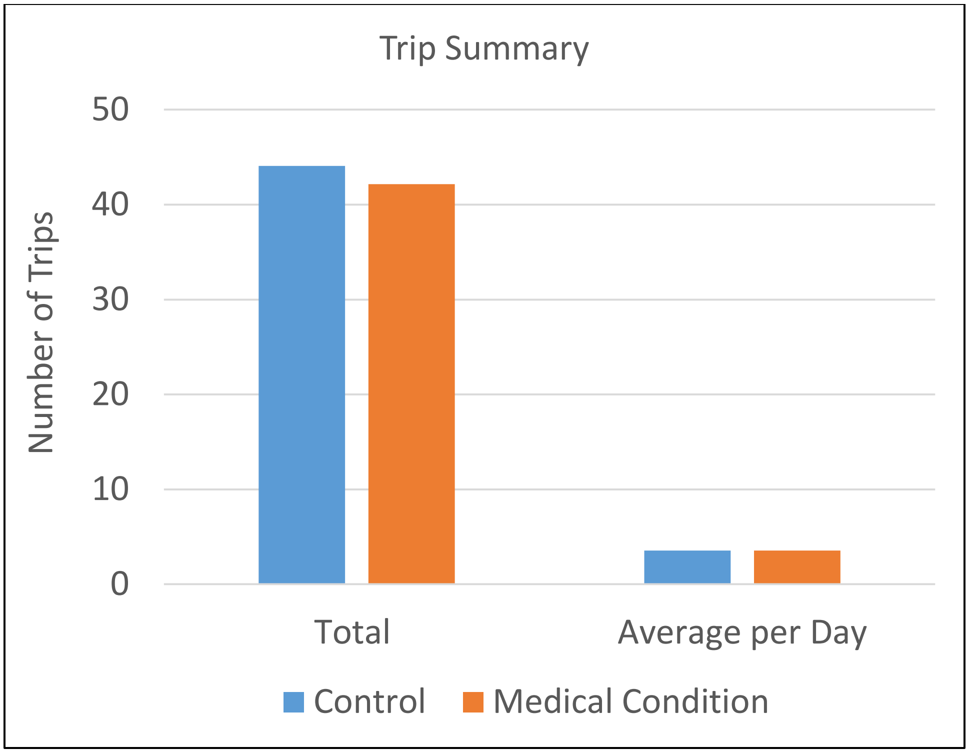

Figure F1. Trip summary, group averages – Primary Sample.

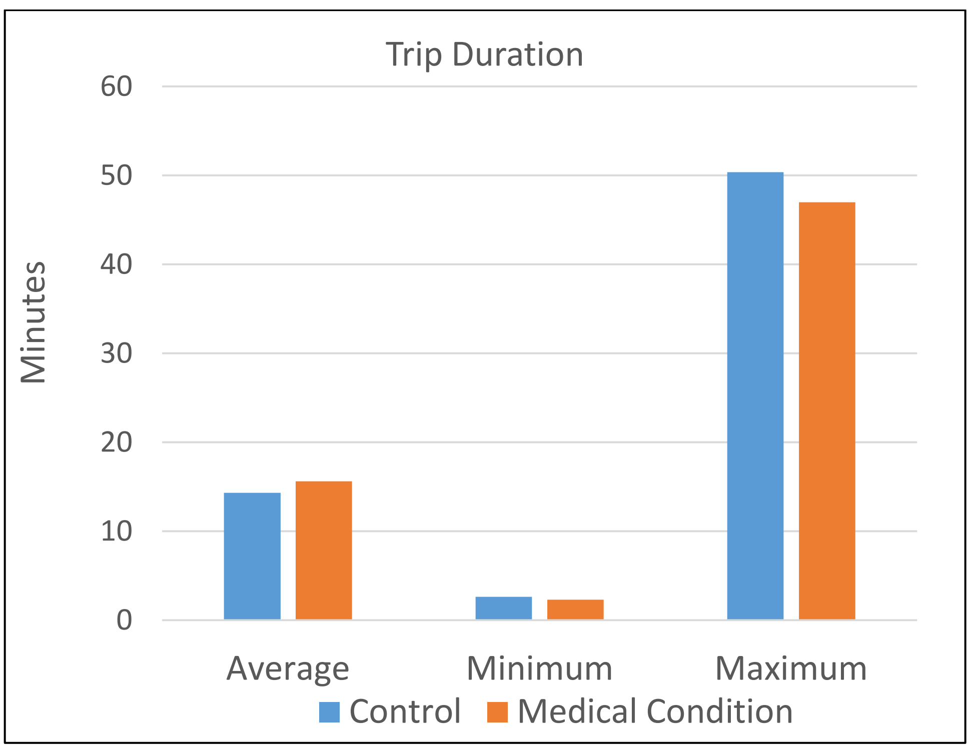

Figure F2 Trip duration, group averages – Primary Sample.

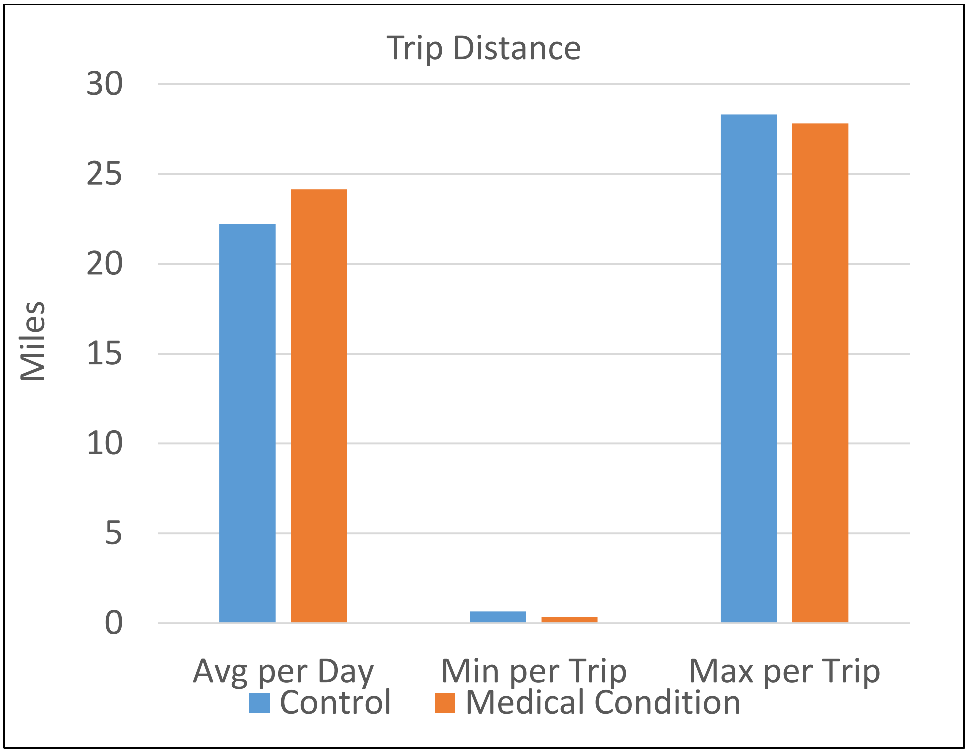

Figure F3. Trip distance, group averages – Primary Sample.

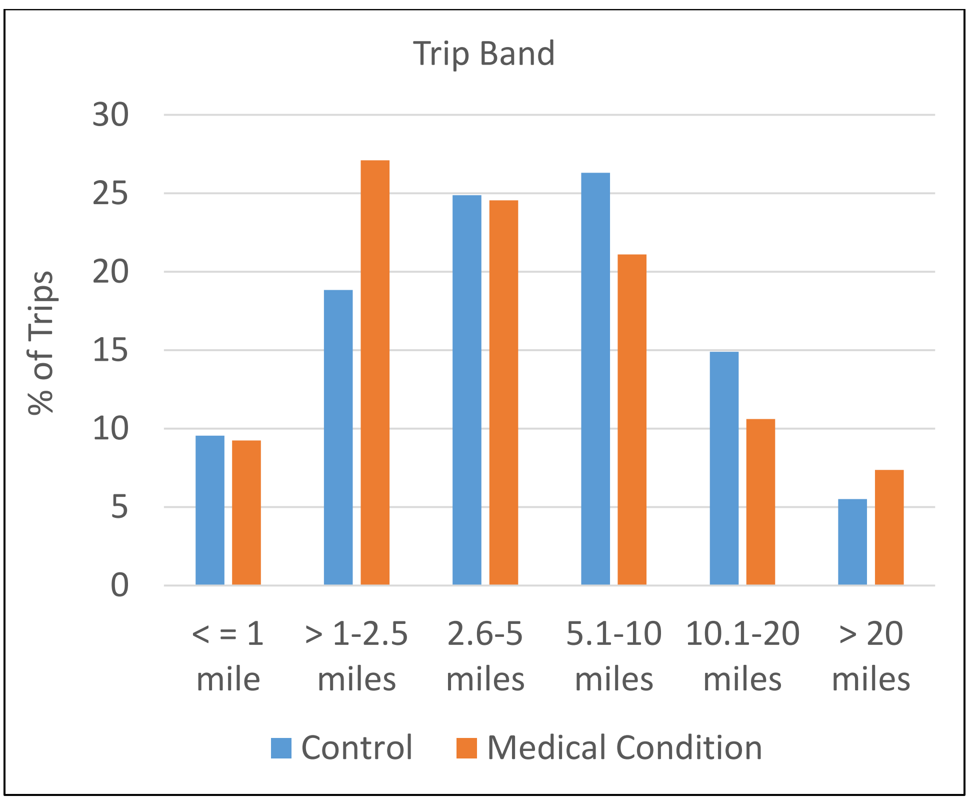

Figure F4. Percent of trips by distance band, group averages – Primary Sample.

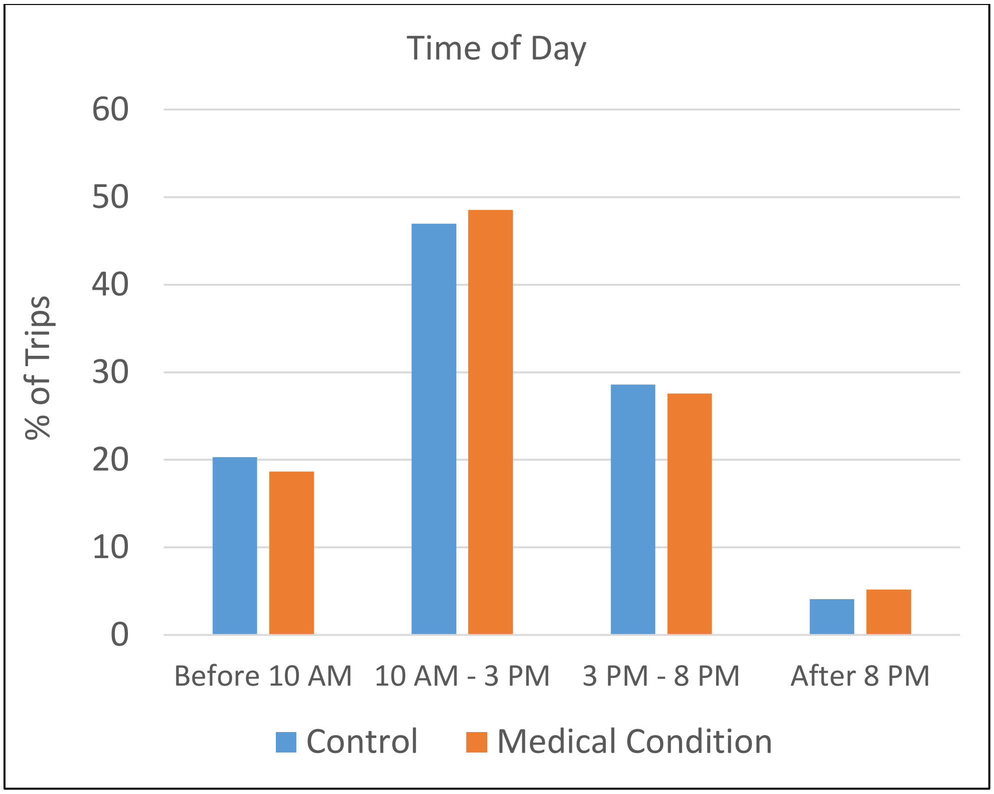

Figure F5. Percent of trips by time of day, group averages – Primary Sample.

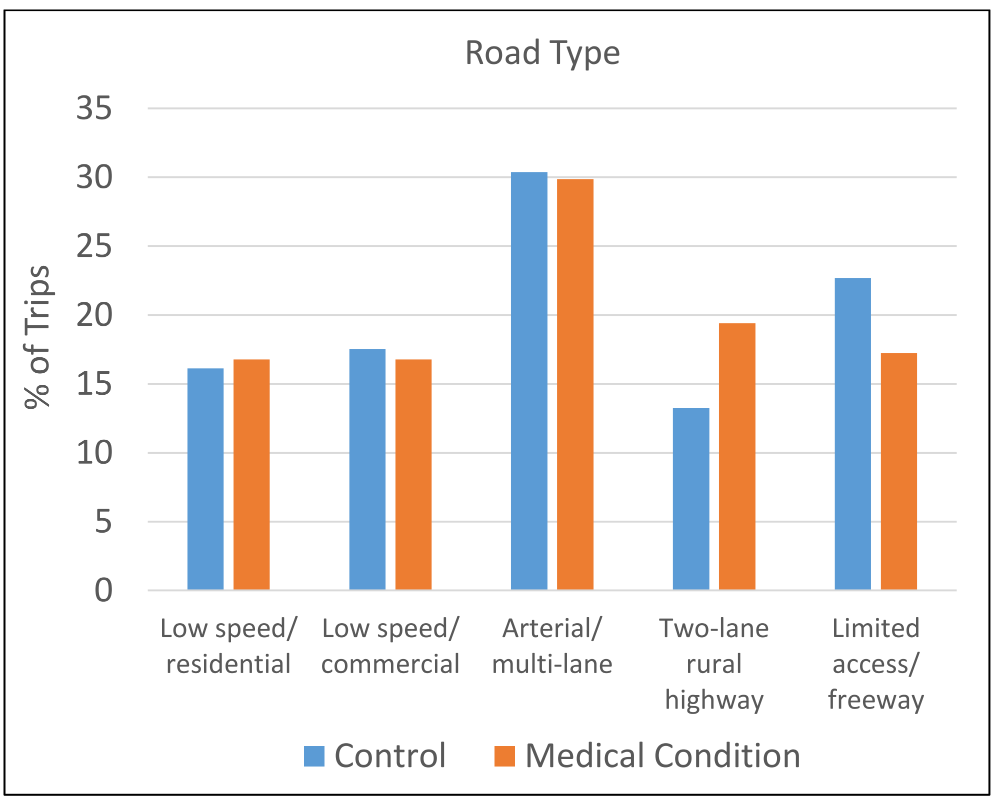

*Figure F6***.** Percent of trips by road type, group averages – Primary Sample.

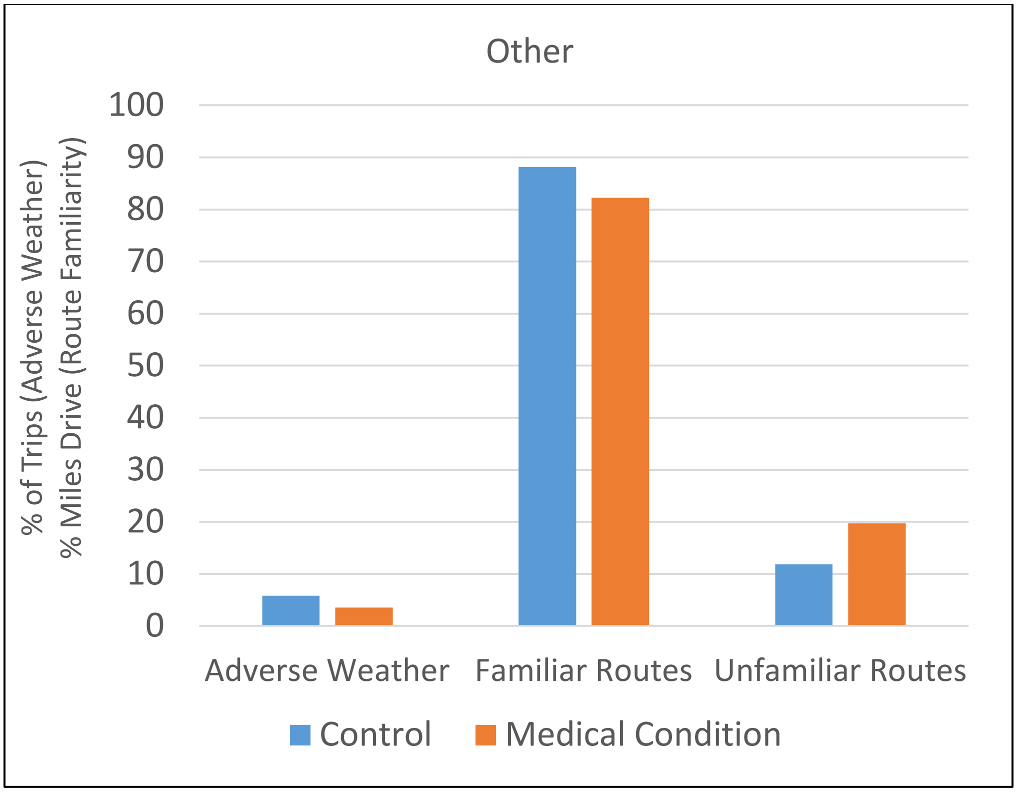

Figure F7. Percent of trips by adverse weather and percent of miles driven by route familiarity, group averages – Primary Sample.

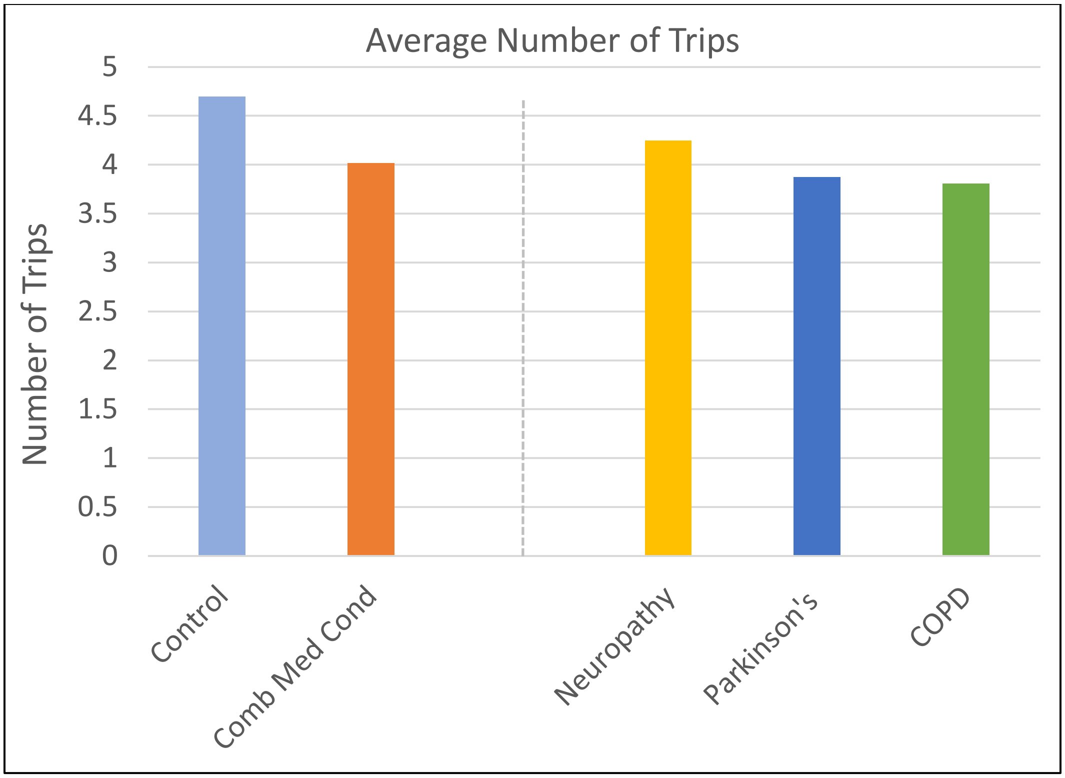

*Figure F8***.** Average number of trips, group averages – SHRP2 NDS sample.

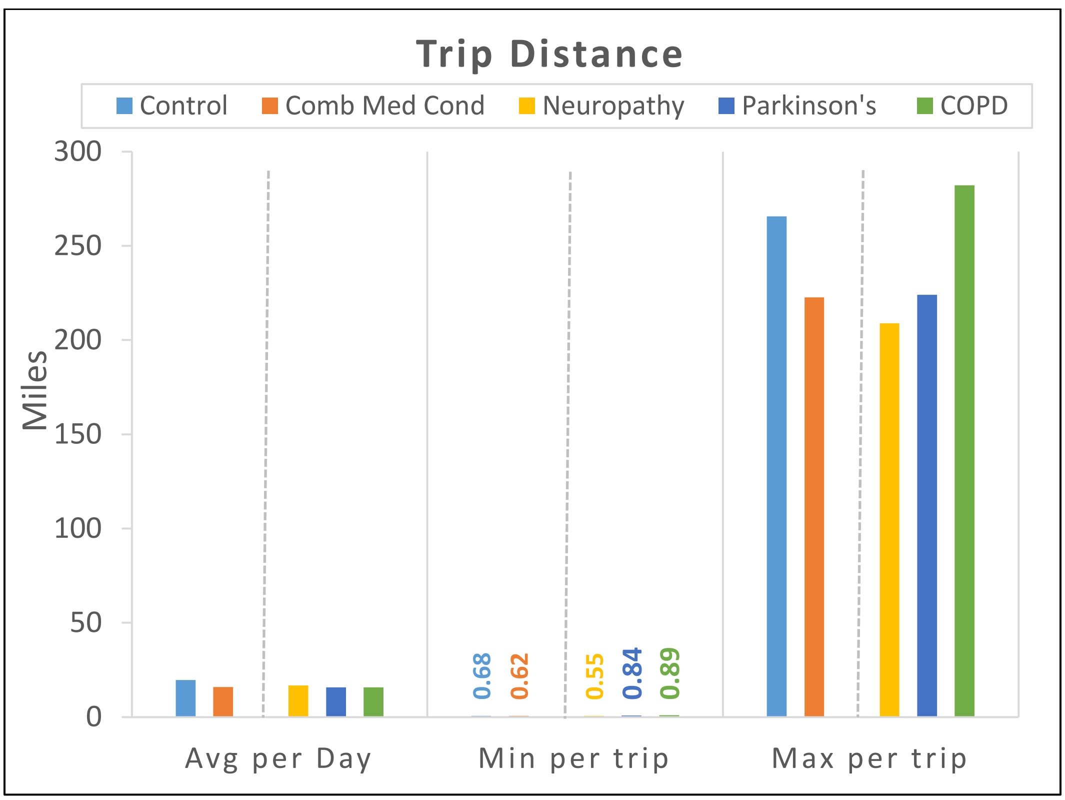

Figure F9. Trip distance, group averages – SHRP2 NDS sample.

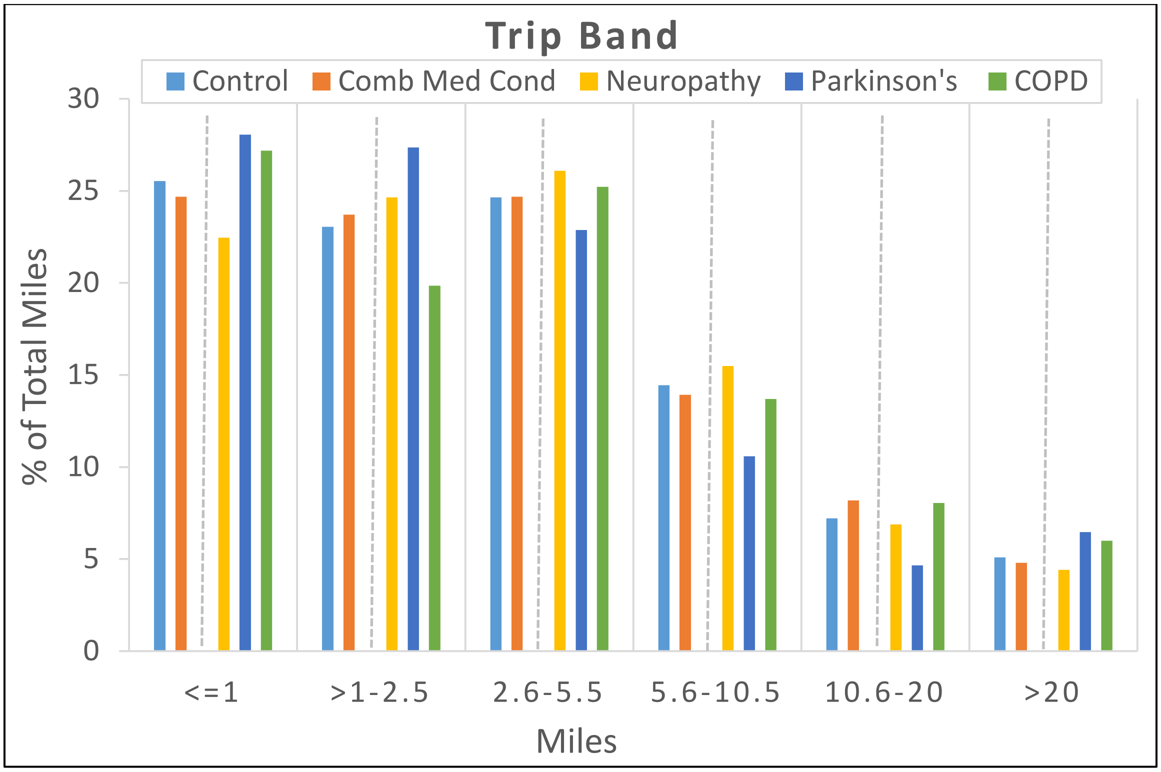

Figure F10. Percent of trips by trip band, group averages – SHRP2 NDS sample.

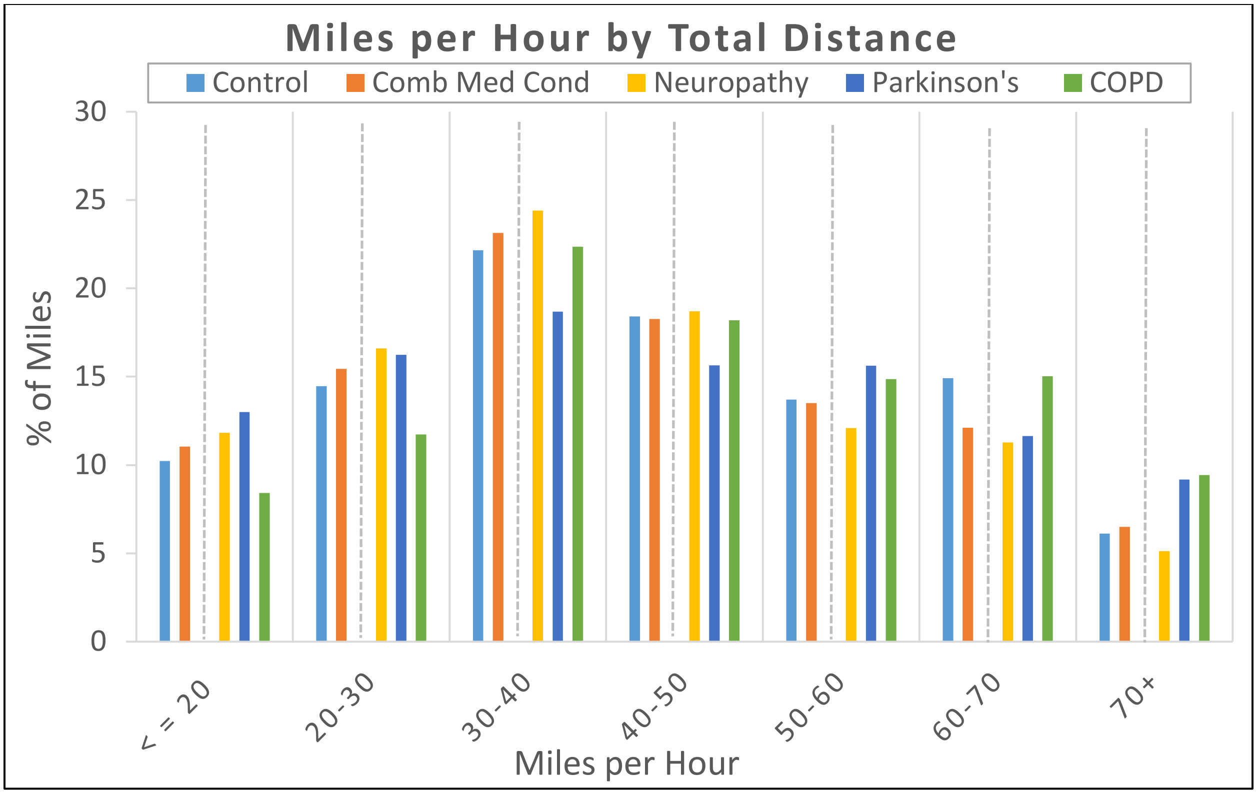

Figure F11. Percent of miles driven by speed, group averages – SHRP2 NDS sample.

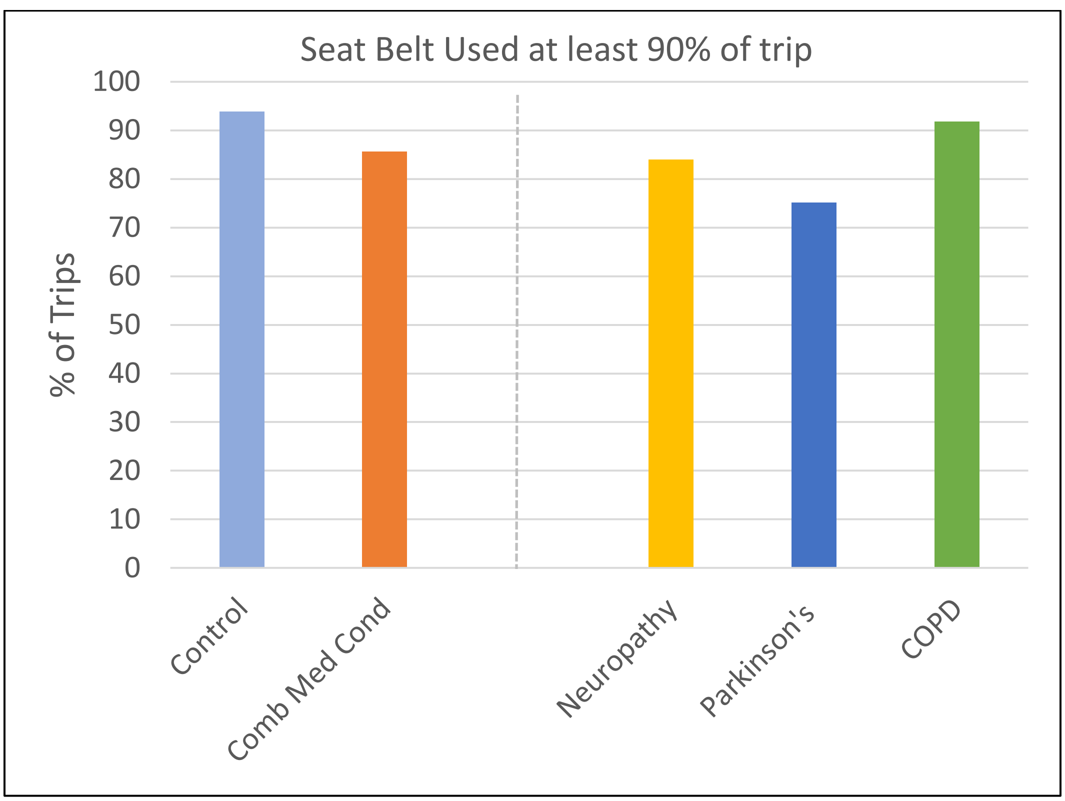

Figure F12. Seat belt use, group averages – SHRP2 NDS sample.

Appendix G. Agenda for Aging, Independence, and Driving Transitions Panel

TransAnalytics, LLC
www.transanalytics.com

NHTSA
www.nhtsa.gov

Older Driver Safety – Understanding the CCRC Perspective

November 16, 2015

U.S.DOT/NHTSA Headquarters, 1200 New Jersey Avenue SE, Washington DC 20590

AGENDA

9:00 – 9:15 am Welcome and overview of meeting purpose and goals

9:15 – 9:30 Introductions

9:30 – 10:30 Identifying residents at-risk for driving

- What most often brings to your attention that an older resident is experiencing driving difficulties that place him/her (and others) at risk (children or spouse raises concern, observations of dents in car, other residents report concerns, etc.)?
- Describe the nature of the concerns brought to your attention in the last several years.
- How many residents are brought to your attention each year?
- Do you associate other signs of decline such as memory problems, or falls, as red flags that a resident may also be experiencing difficulties with driving?

10:30 – 10:45 Break

10:45 – 12:00 Programs and procedures

- To what extent are your interactions with older drivers and their families about driving difficulties reactive, as opposed to proactively initiating conversations with residents about issues of aging and driving safety? (medical conditions, prescription drugs/polypharmacy, etc.)
- Does your CCRC communicate to residents how participation in activities such as exercise programs may help preserve critical safe driving abilities?
- Is there an explicit policy at your CCRC about who addresses driving-related issues, and what they should (or should not) say?
- What different types of staff members at your CCRC might interact with residents or their families about driving?
- Once a resident's driving difficulties have come to your attention, do you:
  - Directly advise him/her about changing driving habits to stay safe?
  - Directly advise him/her about whether it is time to give up driving?;
  - Refer him/her to a driving rehab specialist for an evaluation?
  - Refer him/her to the State DMV for an evaluation?
  - Take other action(s)?
- What most influences your course of action once a resident's driving difficulties have come to your attention?
- Have you encountered situations where something needed to be done immediately due to a driver being very high risk (e.g., dementia, LOC, severe vision loss)? What did you do?

12:00 – 1:00 pm	Lunch
1:00 – 2:15	Getting personal

- What is your comfort level in addressing this issue with residents?
- How can your personal relationships with residents influence your conversations about driving, either positively or negatively?
- What is the range of responses of residents with whom you have attempted some intervention after they have clearly demonstrated driving difficulties?
- How do responses vary according to driver characteristics and/or your approach to the subject?
- What else influences residents' responses, e.g., family dynamics?

2:15 – 2:30	Break
2:30 – 3:45	Barriers and resources

- Do you face internal barriers or constraints in identifying and effectively intervening with at-risk drivers (e.g., residents are paying customers/need to keep them happy; not enough time; insufficient resources)?
- Do you face external barriers or constraints in identifying and effectively intervening with at-risk drivers (e.g., State regulatory requirements; corporate policies or practices; other)?
- What tools/resources are you aware of that help you initiate conversations with residents and/or their families about aging and driving safety?
- Are there tools, information, or other resources that, if available to you would help you initiate conversations about aging and driving safety?

3:45 – 4:00	Travel/expense reimbursement instructions / adjourn meeting

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