THE RELATIONSHIP BETWEEN INSTRUMENTAL ACTIVITIES OF DAILY LIVING AND NATURALISTIC DRIVING PERFORMANCE: INDICATIONS FOR MILD COGNITIVE IMPAIRMENT DETECTION

by

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Rationale: A large body of literature has explored the ability of various assessment tools to determine the cognitive status of older adults, as well as the relationships between cognition and driving skills. However, few studies have linked occupational assessment tools and driving skills. Additionally, only a small selection of recent studies has explored both cognitive and driving skills using *naturalistic* driving data. Results of these studies suggest that cognitive assessments are not the strongest indicators of a person's cognitive status prior to clinical presentation. Rather, naturalistic driving performance has been implicated as a tool to predict pre-clinical dementia. Due to the established links between occupation-based assessment and standardized driving performance tests, it is plausible that similar links may exist between functional cognition, as measured by occupational assessment, and naturalistic driving performance, implicating both for application in the early detection of dementia. **Purpose:** The study sought to determine what trends and/or relationships existed amongst participants' driving aggression, amount of time driving at night, and frequency of drives based on performance in three clinical assessments (cognitive, occupational, driving). Research questions addressed included: 1) Is there a relationship between naturalistic driving performance and performance of

IADLs?, 2) Is there a relationship between naturalistic driving performance and cognitive measures?, and 3) Is there a relationship between naturalistic driving performance and standardized driving assessment? Additional research questions investigated differences between age and gender groups. **Design:** This descriptive, exploratory study collected data for analysis over the course of one year, with naturalistic data collection lasting 20 weeks for each participant. **Participants:** Participants included 40 older adult drivers (65+ years). All participants were healthy, community-living adults obtained through convenience sampling. **Methods:** Instruments included the G2 data-logging chip by Azuga Industries, which tracked participants' driving locations and velocity inside their personal vehicles. Data was computed into three "behavior" values: aggression, daylight driving, and number of trips. Other instruments included the Modified Driving Habits Questionnaire, the Assessment of Motor and Process Skills,and the Montreal Cognitive Assessment. Participants completed clinical assessment in the research lab within the 20-week driving period. Outcomes examined from the G2 chip included total instances of hard braking, total instances of speeding, weekly ratio of night to daylight driving time, and number of trips driven. **Results:** Analyses indicated that age, MoCA score, and P-Drive scores had significant relationships with one or more naturalistic driving behaviors. The distribution of aggressive driving behavior trended higher in drivers in their 60s and in drivers with low AMPS performance. **Discussion:** Naturalistic driving performance, as a single measure, was able to reflect differences in performance in all clinical assessments used. The trends in aggressive driving reflected in AMPS performance provide the only known link in the current literature between naturalistic driving and functional assessment. Therefore, the AMPS as a functional assessment may be implicated in the understanding of pre-clinical dementia.

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1 – Introduction

The population of older adults in the United States has grown exponentially in recent decades and has continued to increase its rate of growth over the last eight years. According to the most recent United States Census Bureau estimates (United States Census Bureau, 2019), the population of adults aged 65 years and older has grown at a rate of 17.39% since 2014, while the largest age group in the nation, ages 15-44, has only grown at a rate of 1.56%. Projections for population size of adults aged 70 years or older is 53 million by the year 2030 based on these rates of growth. It is clear from these rates that if our whole society is to prosper, greater preventative care and attention to our aging population is required (Insurance Institute for Highway Safety, 2022; United States Census Bureau, 2014; 2019).

Aging affects each person uniquely; however, older adults are more likely to have multiple medical conditions that further compromise their occupational engagement (Wells et al., 2016). The health care industry is often unable to extend the resources necessary for older adults to both live, and live well, because of these combined factors. Wells and colleagues (2016) found that 67% of Medicare beneficiaries have two or more chronic conditions, 50% have 3 or more, and 37% have 4 or more. These older adults were more likely to visit multiple practitioners, both primary and specialty, in a variety of locations, compromising their access to necessary care (Wells et al., 2016). The compounding of conditions leaves older adults more vulnerable to functional limitations while simultaneously requiring them to maintain access to the community to receive care. If this is not possible, these adults may make the decision to transition to retirement or long-term care facilities that can meet their needs. However, this may limit their ability to access their communities.

Rather than uproot their lives and connections, many older adults choose to "age in place", meaning they maintain their lifestyle from an independent home while making adjustments that support their health and well-being, reduce risks, and enable social relationships and role functions (Means, 2007; Lewis & Buffel, 2020). Iecovich (2016) describes aging in place as a process of multiple interrelated dimensions. It is not only the physical home, but the person's relationships and modes of connection, as well as the emotional, psychological, and cultural dimensions of the "place" in which the person lives. The physical space can be adjusted to reduce fall risk, for example, but the external "place" in which the other dimensions exist is the person's wider community. Whether they wish to age in place, or choose to transition to life in a supportive environment, all older adults are faced with the complex decision of how to access their communities despite changes in their health and abilities.

Community mobility intervention is a domain of occupational therapy services focused on enabling participation in both transportation planning and use, through either private or public means, to access the community (American Occupational Therapy Association [AOTA], 2020). This is as an important an aspect to well-being and quality of life as any other dimension of occupational engagement. Attitudes about maintaining driving independence to access the community have been found to vary in the literature. Babulal and colleagues (2019) surveyed 349 drivers, aged 65 and older, to determine participants' estimates of how many years they would continue to drive and how many years they would continue to live following driving cessation. The majority (76%) expected to live at least one year past driving cessation. However, the end-range of responses surpassed 40 years, suggesting great variation in predictions. These responses seemed to depend on the unique circumstances of each participant's experience with aging and driving. Considering the discussions provided by both Iecovich (2016) and Babulal and colleagues

(2019), it is clear that community mobility can be both a valued and daunting occupation for older adults, yet is also a dimension of aging in place that supports older adult well-being. For those adults that do value driving as a mode of community mobility, the implications of age-associated health concerns that may influence participation must be discussed.

Due to its high correlation with age, dementia is one of the most concerning health impairments for the future of our aging society (Langa, 2018). Regardless of its many forms, dementia can severely limit older adults' ability to engage in a multitude of occupations (Maresova, 2019). When the impairment is mild, the decline is often less visible to friends, family members, and the individuals themselves and disturbances in cognitive functions such as memory, processing speed, and attention may go unnoticed (Anderson, 2019; Petersen, 2004; Bruderer-Hofstetter et al., 2020; Gold, 2012; Jekel et al., 2015; Rafeedie, 2017; Ginsberg, et al., 2019; Gold, 2012; Jekel et al., 2015; Lindbergh et al., 2016). These areas of function are integral to driving ability, as illustrated by Michon's (1985) Hierarchy of Driving Behaviors.

Michon's Hierarchy of Driving Behaviors

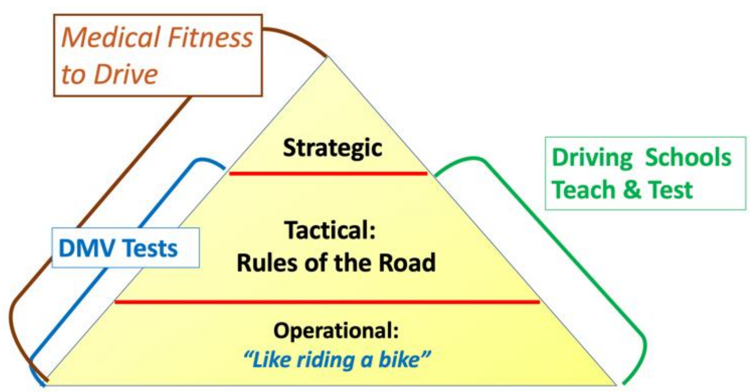


Figure 1. Hierarchy of driving behaviors.

Michon's (1985) hierarchy of driving behaviors is a three-tiered hierarchy that organizations driving into distinct levels of performance. The ***operational*** level consists of the most basic set of skills needed for driving fitness. This level is made up of highly over learned motor patterns required for use of driving mechanisms (e.g., hitting the brake or accelerator, moving the steering wheel) and is done automatically without conscious thinking. The body is able to retain these abilities despite cognitive impairments due to the intensity of neuronal encoding that has occurred over the course of years of successful driving execution. At this level, tasks that the higher-level cognitive areas cannot process or respond to, the underlying sensory-motor responses of the body can (Dickerson & Babulal, 2022).

The ***tactical*** level can be thought of as a combination of rehearsed patterns and adaptive responses that are dictated by the rules of the road. Drivers follow these rules to ensure successful performance, indicating that motor planning and rehearsal are involved in making decisions and responding to the driving environment (e.g., keeping speed limits, stopping at traffic lights, staying in channeled turns). These maneuvers become routine, especially as drivers continuously follow familiar routes, such as a daily commute to work. For this reason, the tactical level can also be executed on a sensory-motor level without higher processing due to overlearning of the habits for driving success (Dickerson & Babulal, 2022).

The ***strategic*** level is the highest level of driving behavior. Traditionally, the strategic level was considered only for pre-drive or planning activities (Michon, 1985). For example, knowing whether to walk or drive to a store down the street is a strategic decision made based on distance, time of day, and weather. However, it has been updated to include strategic decisions needed while driving (Transportation Research Board [TRB], 2016). For example, if decisions are needed to adapt a route, manage time for travel, respond to unexpected maneuvers, or navigate novel situations. Cognitive functions required for the strategic level are those first affected by dementia. Drivers with impairments in cognition will demonstrate more frequent episodes of being lost in familiar areas when there is a change to the environment, such as the passing of an emergency vehicle or a road closure. The ability of older adults to dictate their own mobility within the community is therefore influenced by their strategic cognitive abilities (Dickerson & Babulal, 2022).

Occupational therapists are required to consider a person's motor skills, process skills, social skills, unique needs, environments and supports, and their personal desires for independence when determining driving fitness. Therefore, investigating driving fitness must consider driving not only a valued occupation, but an indicator of personal freedom, making it of great importance to the general practitioner. To better understand the community mobility needs of older adults and the skills required for driving, this review will explore the underlying cognitive functions related to driving performance, including:

Attention - Attention refers to "the way in which humans allocate cognitive resources to information processing" (Frey, 2018).

Cognitive Processing Speed – Cognitive processing speed is defined as "the ability to process information rapidly" (Lichtenberger & Kaufman, 2012).

Executive Functioning – Executive functioning refers to "a multifaceted neuropsychological construct consisting of a set of higher-order neurocognitive processes that allow higher organisms to make choices and to engage in purposeful, goal-directed, and future-oriented behavior" (Suchy, 2009).

Memory – Memory is defined as "the faculty of encoding, storing, and retrieving information" (Squire, 2009).

Visual-Motor Integration – Visual motor integration refers to "the ability and extent to which visual perception and motor coordination are well coordinated with each other" (Beery & Beery, 2010).

To support access to reliable screening tools for driving, occupational therapists need to use functional assessments to determine older adults' driving fitness. One such tool, the Assessment of Motor and Process Skills (Fisher, 1995) is of particular consideration due to its strong ecological validity related to its review of a person's typical performance habits. As a tool available to generalists, administration of the AMPS to at-risk adults could potentially allow practitioners to bypass referring patients to a costly and lengthy comprehensive driving evaluation. Lastly, as an emerging method of driving assessment, naturalistic data collection of driving behaviors will be discussed in relation to formal assessments of driving ability to further understand the potential relationships investigated in the present study. The strength of these relationships may even indicate the utility of naturalistic driving data for early detection of cognitive impairment.

2 - Literature Review

Cognition

The human function of cognition has always been a domain of interest in the science of occupational therapy and is an essential skill for successful driving performance. To understand the multitude of subfunctions involved in human cognition, scientists have identified neurocognitive domains the typical individual uses for both every day and complex occupations: complex attention, executive functioning, learning and memory, language, perceptual-motor functions, and social cognition (American Psychiatric Association, 2013). These cognitive functions are also foundational constructs of process skills, which are performance areas having to do with cognition and mental processing during task execution described in the Occupational Therapy Practice Framework 4 (AOTA, 2020). These process skills are notable in that they involve not only interaction with objects and carrying out steps of a task, but also prevention of occupational error and preservation of safety during task execution (Fisher & Martella, 2019). Cognition is, therefore, integral to many instrumental activities of daily living (IADLs), driving being one of the most complex activities among them. Most significant to driving, however, are memory, executive functioning, visual-motor integration, and attention (Barco et al., 2012).

Attention

The ability to attend to one's environment is the gateway to both thought and action. The information we take in through our senses is actively absorbed using directed attention of these senses to our surroundings and to stimuli we encounter. This process of attending is primarily done using the sense of vision; the information we receive using vision gives us the most insight into our surroundings compared to any other sense (Golembiewski & Charlton, 2011). As a foundational skill of cognition, all other cognitive skills are enabled or disabled by one's ability to attend and gather information through attention. This suggests that for one to perform any complex task, one has the capacity to attend.

Driving is unquestionably a complex task that requires use of attention. The many types of attention sustained and organized in the brain are what make driving possible for human beings. Two main networks of the brain organize information for attention, known as the dorsal and ventral attention networks (Vossel et al., 2014). The dorsal network orients and maintains attention towards external stimuli relevant to one's task, including information processed using vision. The ventral network automatically processes external stimuli that are novel or unexpected, allowing the dorsal network to reorient the brain to respond (Vossel et al., 2014). These networks and their associations have shown how interactions between the brain and the environment help the driver to develop *situational awareness* (Anderson et al., 2021). This sense of awareness operates along the hierarchy of cognitive functions to help the brain accomplish three tasks: determine attributes and dynamics of an environment, determine what these attributes mean for proceeding with goal-directed behaviors, and predict future actions or needs for action based on the information given (Endsley, 2011). This indicates that more complex environments with greater amounts of information to process create higher demands on attention and may compromise the ability to develop situational awareness, which is easily translated to driving environments (Anderson et al., 2021). Without the ability to simultaneously attend to the road ahead, the goals of the journey, to other vehicles actions and reactions, and to the controls of our own vehicle, drivers may have more difficulty initiating nor sustaining any driving-related tasks. Risk of crashing is also increased when attention is impaired, and drivers with attention impairments, including Alzheimer's disease, are less likely to anticipate their crash risk on crowded roadways as a result (Vaux et al., 2010).

Divided and Selective Attention.

The ability of the neurotypical brain to attend would be an overwhelming cognitive experience without the aid of information filtering, a process known as selective attention (Hahn et al., 2008). Research on divided attention, or attending to multiple stimuli, indicates that the brain cannot concentrate on two stimuli in the same moment, but instead responds to multiple demands in quick succession while tuning out irrelevant information (Hahn et al., 2008). This process indicates how divided and selective attention work together to "task-switch" and accommodate the presence of multiple stimuli at one time. Experimentation with distracting stimuli has shown that, following exposure to dual stimuli, recall accuracy of the target stimulus was significantly lower than when only exposed to the target (Middlebrooks et al., 2017). However, interpreting these findings in relation to functional performance can be taken in many directions due to the variety of environmental stimuli present during functional tasks. In the case of driving tasks, performing multiple, simultaneous tasks, such as talking on a cell phone while driving, has been shown to reduce both attention to changes on-road and accuracy of storytelling, leading to poor outcomes in both tasks (Becic et al., 2010; Schnabel 2018). However, the ability to task-switch continues to be of great relevance not to driving failure, but to driving success, simply due to the spatial nature of the stimuli to which attention is directed (Ferlazzo et al., 2008). For example, the differentiation between divided attention leading to success versus failure has been found to be greatly influenced by whether or not the driver is attending to multiple spaces (Ferlazzo et al., 2008). Task-switching in the context of the vehicle's greater external space, rather than the internal space of the car or additional "space" of a cellphone screen, promotes successful navigation of one's environment as a driver (Ferlazzo et al., 2008). In the case of those with compromised neurological systems, divided attention may be more difficult, leading to greater driving risk.

Visual-Motor Integration

Visual-motor integration is the dynamic interaction of motor skills and visual perception of one's environment, requiring several integrative skills: environmental awareness (within the visual field), detection and discrimination of stimuli, positional responses, balance, proprioception, eye-hand and eye-foot coordination, topographical orientation, depth perception, bilateral integration, and general functional mobility and motor control (Beery & Beery, 2010; Fraker & Yatczak, 2017, Carsone et al., 2021). Visual-motor integration is often studied in relation to early childhood development, as it is a skill that enables nearly every action we produce as human beings (e.g., walking, moving objects, manipulating aspects of an environment,). In fact, recent research has found that visual-motor integration deficits can directly influence one's ability to navigate an environment as an adult following brain lesion (van der Ham & Claessen, 2017). Additionally, decline in visual-motor integration has been negatively correlated with age and may be further exacerbated by diseases of old age, with decreased adaptive responses being shown in older adult samples compared to younger adults (Kim et al., 2014; Buch et al., 2002). As a foundational human function developed in childhood and an essential process in most adult actions, these disturbances in visual-motor integration that come with age may lead to deficits in functional performance later in life.

The interrelated skills of visual-motor processing are just as relevant in driving performance as in any other functional performance. Their dynamic interactions of these skills and the speed with which they are exercised are what make basic driving tasks easy to learn and implement for most individuals. For example, it is not often that a typical individual has to think about lifting their foot from the gas pedal to the brake when approaching a red light at an intersection. This is a visual-motor reaction that pairs visual processing of the change in stimulus (red to green) with a change in motor action (gas to brake). Most importantly, visual-motor processing becomes overlearned and automatic, resulting in a persons' ability to sustain physical capabilities despite cognitive impairment. Rehearsal of the movement patterns and even basic cognitive decision-making during driving is sustained over the course of years of driving experience, resulting in the development of rote skills that are rarely processed at a conscious level. However, these rote skills must also be adaptable to environmental change. As described by Michon's hierarchy (1985), the adaptability factor of driving performance happens at the "strategic" level of driving behavior. Since older adults tend to be slower to adapt in their movements, this indicates that global decline in driving ability is to be expected in older drivers (Wolpe et al., 2020). This may be further explained by the influence of memory on automatic actions and adaptive responses.

Memory

Memory is a heavily researched domain of cognition with only a portion of its processes fully understood by modern science (Brem et al., 2013). Despite the challenge of interpreting neural pathways and the function of memory within them, types of memory have been observed and established over time. These types include: episodic memory, the knowing of one's past experiences; semantic memory, the set of learned facts and knowledge accumulated over time; procedural memory, the implicit knowing of how to perform a previously learned task, short-term memory, the storage of recently learned information; working memory, the manipulation of short-term memory information; and long-term memory, the information encoded for future retrieval (Barco et al., 2012). Arguably, all of these types of memory are used in occupational performance based on the individual's experience, environment, and client factors. Encoding information and retrieving it at opportune moments allows for adaptive responses relative to one's surroundings and circumstances (Forester et al., 2020). Memory impairment, both objectively and subjectively measured, has been shown to predict loss of functional independence in IADLs (Mansbach & Mace, 2018; Tangen et al., 2019). Impairment in IADLs has also been implicated as the first area of functional decline related to dementia (Tangen et al., 2019). As an IADL, driving should also be examined through the lens of memory functions to understand its impact on performance.

In a driving context, Barco and colleagues (2012) note that differing types of memory are applied in different driving circumstances; for example, when a driver is lost, working memory may be helpful if the driver visualizes their route to help them find their way. Long-term or episodic memory may be useful in the same scenario if a driver has a memory of a past trip to the same location. Short-term memory contributes to recall of landmarks they may have passed along the way. If a driver with memory impairment gets lost, it will therefore be more difficult for corrections to be made using memory functions (Barco et al., 2012). However, episodes of being lost are not the only instance in which intact memory is useful for driving performance. The ways in which procedural memory contributes to function are of great relevance in driving performance.

Procedural Memory

Procedural memory is the context-dependent, implicit memory of how to complete a task, allowing for automatic responses to complex environments (Barco et al., 2012; Simor et al., 2019). It is also referred to colloquially as “muscle memory” because of the widely held notion that the body initiates actions “on its own” to complete well-rehearsed tasks. This form of memory is what allows for retention and replication of previously learned behavior patterns or actions, eliminating the need for the brain to relearn actions each time they are indicated. Not only does this explain how typical adults perform daily functions without constant cognitive strain, but it also supports use of procedural memory in dementia care (Ritchie, 2007; Kirsch-Darrow & Tsao, 2021). Impairments in procedural memory are often seen in the moderate-severe and severe stages of

Alzheimer's disease progression, but intact procedural memories in very simple tasks (e.g., undressing, drinking, self-feeding) can be elicited well into these late stages to aid in the performance of daily tasks (Schultz-Krohn et al., 2017). This differentiation in procedural memory abilities between early and late stages of Alzheimer's disease is important when considering how procedural memory deficits can impair driving performance.

The process of procedural memory might explain why some functions of driving, such as steering, braking, using turn signals, are maintained into old age (i.e., operational level skills). Compared to novel movements and reactions, procedural actions are not as difficult to initiate. For example, the association between a green traffic light turning red and moving the foot to the brake pedal is reencoded thousands of times over the course of a person's driving career. Performing this action, therefore, shifts over time from intentional recall of the action steps to procedural, automatic action (Tenison & Anderson, 2015). These stages of cognitive learning are developed for many daily tasks, such as handwriting, dressing, or making a favorite meal. More complex tasks are also dominated by procedural memory, like playing a piano. All of these tasks become procedural with continued encoding of their steps and elements, and the procedural memory of how to drive within familiar driving environments relies on this same cognitive mechanism.

Cognitive Processing Speed

Cognitive processing speed is an essential component to effective working memory, motor response time, verbal action responses, and is related to higher-order cognitive abilities (Barco et al., 2012; Lichtenberger & Kaufman, 2012). Additionally, the relationship between perceptual abilities and cognitive processing speed has been shown to be reciprocal, with deficits in either affecting the other (Roberts & Allen, 2016). When considering the effects of aging on cognitive performance, it is assumed that older adults who make errors in complex cognitive testing do so because of degradation of processing speed with age (Salthouse, 1996; Salthouse & Ferrer-Caja, 2003). Age-related degradation of cognitive processing speed is very common, but can also be exacerbated by multiple pathologies such as neurodegenerative diseases, brain injury, stroke, or other pathological causes of neurological impairment (Fraker & Yatczak, 2017; McDonald, 2017).

Ebaid and colleagues (2017) studied differences between age groups in cognitive performance on standard measures of processing speed measures, involving scanning and identifying objects and symbols. The researchers accounted for the potential impact of motor impairment on the performances of the older adult group and found that, though motor reaction time was correlated with age, declines in cognitive processing speed could not be explained by declines in motor speed (Ebaid et al., 2017). This is an important finding as it suggests that the use of measures requiring motor performance have the potential to be sensitive to cognitive impairments despite the potential impact of motor impairments.

The effect of cognitive processing speed on functional performance has been highly researched (Brigman & Cherry, 2002; Wadley et al., 2008; Lassen-Greene et al., 2017; Valdes et al., 2012; Wadley et al., 2021). Strong associations have been found between daily functioning and cognitive processing speed in those with mild cognitive impairment, especially, with biomarkers for Alzheimer's disease being found in those with significantly low processing speed and functional performance (Lassen-Greene et al., 2017; Wadley et al., 2021). This relationship has also been connected to a variety of IADLs, including driving. Wadley and colleagues (2021) found that cognitive processing speed had a strong, positive association with both IADL function and driving.

These associations should be of no surprise considering the high-level processes necessary for successful driving. Driving skills require appropriately timed motor responses to a number of cues such as speed limit signs, oncoming traffic, and traffic lights, to maintain safety (i.e., tactical level skills). Speed of processing directly impacts the time it takes to respond to those cues and, if impaired, can be the difference between a smooth stop at a red light or colliding with the car in front. Drivers experiencing cognitive decline may show symptoms of slowed processing speed which may be revealed in driving errors like hard stops or late responses to road signs (Barco et al., 2012; Babulal et al., 2016; Wadley et al., 2021). This is supported by Wadley and colleagues (2021) finding that both better processing speed and younger age were significant predictors of better driving performance in an on-road evaluation.

Executive Functioning

Executive functioning is the most complex domain of cognition (Suchy, 2009). As such, there is ongoing debate amongst experts as to what skills it encompasses as a singular function of the mind (Barkley, 2012). Some sources claim it involves a multitude of subfunctions including sequencing, object selection, self-assessment of occupational errors, response inhibition, categorization, behavior organization, and even motor planning (Fraker & Yatczak, 2017; Jurado & Rosselli, 2007; Suchy, 2009). Though controversial in its definition, executive functioning is largely agreed upon to be a complex interaction of planning a task and awareness within the task and is used in nearly every complex action (Barkley, 2012).

Significant relationships have been found between executive functioning and IADL performance (Marshall et al., 2012; Nguyen et al., 2020). Ngyuen and colleagues (2020) specifically noted a direct relationship between verbal abstraction abilities of executive functioning and IADLs not otherwise studied in the literature. Impairment in shifting and abstract reasoning were shown to be the most significant subfunctions of executive functioning that contributed to IADL performance (Nguyen et al., 2020). As driving is the most complex of all IADLs, impairment in executive functioning would be evident at the strategic level of driving, as abstract reasoning is needed to problem solve a way home if lost.

When considering these skills in a driving context, the connection is clear. Due to the complex nature of problems and decision-making processes that arise while driving, executive functions are often employed. Barco and colleagues (2012) maintain the role of executive functioning as key in driving safety as it determines driver strategies and safety. Executive functions develop with growth of the frontal lobe, often not complete until the end of young adulthood (Walshe et al., 2017). By no coincidence, the research on the relationships between executive functioning and driving is heavily focused on younger drivers, as well as those with disorders impacting the frontal lobe such as attention deficit hyperactivity disorder and autism spectrum disorder (Walshe et al., 2017). However, executive functioning deficits, most commonly cognitive flexibility, inhibition, and task-switching, have been shown in older adults with mild cognitive impairment and even more so in those with dementia (Traykov et al., 2007; Junquera et al., 2020). This may indicate that the effects on driving often seen in teenagers with developing executive functions may also be seen in older adults with deteriorating executive functions. As essential as executive functioning is to driving performance, its impairment must be noted as one of the core predictors of poor driving in cognitive assessment (Anstey et al., 2005).

Of the cognitive domains reviewed, attention and executive functioning have been found to have the strongest correlation with daily, complex task performance (Sikkes et al., 2012). Therefore, as notable and impactful as these are on task performance, these domains should be considered as essential aspects of how cognition and its impairment can influence both IADL and driving abilities.

Cognitive Impairment in Older Adults

Peters and Rabins (2017) describe cognitive impairment as “unexpected deficits in neurocognitive domains” including all those previously described. These impairments and their level of influence on occupations manifest themselves differently based on the factors associated with their onset and progression. Now referred to under the umbrella term, Neurocognitive Disorders (NCDs), these impairments are the result of pathological aging (McDonough & Allen, 2019). Though normal aging can lead to decline in cognitive skills, diseases of the aging brain are major contributors to cognitive decline that leads to a lack of independence in occupations (Fraker & Yatczak, 2017, McDonough & Allen, 2019). Neurocognitive disorders can be caused by a combination of both genetic and environmental factors, but are often exacerbated by lifestyle choices including diet, exercise, smoking status, and alcohol abuse and by medical histories of head trauma, depression, and hypertension (Peters & Rabins, 2017). Neurocognitive disorders range in severity but are almost exclusively progressive, though it may take as many as 10 or more years for an NCD to lead to death (Fraker & Yatczak, 2017. McDonough & Allen, 2019).

Mild Cognitive Impairment

Mild cognitive impairment (MCI) is a deficient state of cognition typically presenting with memory, language, and executive functioning impairments (Anderson, 2019; Petersen, 2004). The typical difference between this stage and more progressive stages of cognitive dysfunction, aside from an increased impact on function and severity of symptoms, is the presence of self-awareness, though this is not exclusively true in all older adults with MCI. These individuals are still typically engaging in most to all of their daily activities (Anderson, 2019; Petersen, 2004). However, individuals with MCI are at increased risk for developing dementia or Alzheimer’s disease later in life and, like those with other NCDs, may also experience changes in mood and irritability levels or experience increased anxiety as symptoms worsen (Anderson, 2019; Petersen, 2004). MCI manifests similarly to Alzheimer's disease if it is an early-form of the diagnosis, with deposits of tau proteins and beta-amyloid plaques, or in the form of Lewy bodies leading to Lewy body dementia. More commonly though, MCI can begin after small infarcts in the brain, or ministrokes, in which blood flow is restricted in the brain at a mild rate, making these events more likely to be undetectable (Fraker & Yatczak, 2017). The influence of MCI on a person's life may or may not be noticed in the moment, but it contributes to subtle changes in function in complex occupations due to its effect on process skills like reaction time, organization, and decision making (Bruderer-Hofstetter et al., 2020; Gold, 2012; Jekel et al., 2015; Rafeedie, 2017).

The relationship between MCI and changes in IADL function has been widely studied (Ginsberg, et al., 2019; Gold, 2012; Jekel et al., 2015; Lindbergh et al., 2016). Ginsberg and colleagues (2019) evaluated 77 undiagnosed participants for MCI and assessed their IADL ability using the Lawton and Brody *Instrumental Activities of Daily Living Scale* (Lawton & Brody, 1969). Results indicated a statistically significant relationship between IADL impairment and neuropsychiatric symptoms indicative of MCI (Ginsberg et al., 2019). Lindbergh and colleagues (2016) conducted a systematic review and meta-analysis of 23 studies on functional disability (IADL restriction) in MCI. Findings produced a large effect size (g = 0.76), indicating a significant difference in IADL function between those with MCI and those with normal cognition (Lindbergh et al., 2016). A review completed by Gold (2012) found that those with multiple domains of impairment for MCI have greater functional impairments in IADLs. Gold (2012) also found that even mild IADL changes could predict future cognitive decline. These findings were repeated in a review conducted by Jekel and colleagues (2015), which also found that performance-based instruments held an advantage in detecting differences between groups compared to questionnaires. This is an important finding when considering popular measurements of cognitive decline, as it supports the use of functional performance measurement over assessment tools that are written or verbal.

Short-term memory deficits are common outward expressions of cognitive decline that has progressed past the point of MCI (DeCarli et al., 2004; Saunders & Saunders, 2012). This can become significant to health and well-being over time due to the number of ADLs and IADLs that are supported by memory functions (Hall et al., 2011). Early recognition of MCI is, therefore, essential to protecting and supporting individuals with MCI. Through early detection, practitioners with this knowledge about their patients can encourage healthy practices to maximize brain health and memory, and help them remain functionally independent for as long as possible (Nakahori et al., 2019).

Early Detection of MCI

Research has greatly illuminated the need for early recognition of MCI, specifically as it relates to Alzheimer's disease (AD), to improve the quality of life of older adults before severe cognitive impairment begins (Campbell et al, 2013; Rajan et al., 2013; Sabbagh et al., 2020). Measuring cognitive decline is typically done either by screening performance across areas of cognition, or by performing standardized assessment of one area (i.e., attention) using gold-standard assessment tools such as the *Montreal Cognitive Assessment* (MoCA) (Nasreddine et al., 2005) or the *Mini-Mental Status Exam* (MMSE) (Tombaugh et al., 1996). Results of these measures can then be used to determine the effects of cognitive deficits on occupational performance. However, this is not the only way cognitive decline can be detected, nor is it universally considered the best way by modern standards (Sabbagh et al., 2020).

A study conducted by Mancioppi and colleagues (2021) compared the use of both the *Mini-Mental Status Examination* (MMSE) and *Motor and Cognitive Dual-Tasks* (MCDT) (reference) to detect MCI in 44 older adults with a mean age of 70 years. Results indicated statistically significant correlations between dual-tasks and the MMSE screening tool, as well as an area under the curve of 0.97 for detection of MCI using the dual task involving toe-tapping (Mancioppi et al., 2021). The researchers determined that the toe-tapping dual-task could distinguish MCI in unimpaired older adults with a specificity of 63% and a sensitivity of 94%, while the dual-task involving gait specified MCI with 100% accuracy (Mancioppi et al., 2021). This study supports the use of measures for MCI detection that combine motor and cognitive skills, as these demonstrate the interactive effects MCI can have on these skills, specifically, the effect of increased cognitive load on ease of motor performance (Mancioppi et al., 2021).

Biomedical methods have emerged in the past decade as another means of detecting cognitive decline and predicting future diagnosis of dementia based on the presence of organic markers in the body (Campbell et al., 2013; Roe et al., 2017). Through inspection of cerebrospinal fluid samples, proteins indicative of cortical cell shedding will indicate loss of brain matter caused by neurodegeneration associated with dementia (Campbell et al., 2013). These markers are highly associated with the development of cognitive deficits. Campbell and colleagues (2013) studied the associations between scores on the neuropsychiatric inventory and the presence of biomarkers for Alzheimer's disease in a review of associated literature. Genetic factors are also predictors; the absence of the clusterin allele is an indicator of greater risk of progression from MCI to Alzheimer's disease (Campbell et al., 2013). The review determined that the presence of neuropsychiatric symptoms increased risk of progression towards dementia, also demonstrated in the presence of CSF biomarkers (Campbell et al., 2013).

Despite these important findings and the proactive caution they may offer to participants, the study by Wadley and colleagues (2021) found that measurable cognitive deficits show a stronger relationship with functional performance than biomarkers for Alzheimer's disease, most likely due to the stage of impairment at which participants were observed (Wadley et al., 2021). Specifically, the researchers found that genetic risk biomarkers were not significantly correlated with functional performance, but that processing speed had a more direct relationship with IADL function.

A study by Rajan and colleagues (2013) has indicated that this relationship between cognitive decline and IADL performance may not only be unidirectional, but reciprocal. Researchers examined the association of physical disability and rate of cognitive decline in older adults in a longitudinal study from 1993 to 2012. Participants included 6,678 racially diverse adults aged 65 or older at the start of the study. Participants were interviewed in 3-year installments using assessments of ADL and IADL, and scores on the Mini-Mental State Examination (Rajan et al., 2013). At the time of final evaluation, 37% of participants developed ADL disability and nearly half developed IADL disability. The mean rate of cognitive decline in participants that developed IADL disability increased by 115% immediately following onset of physical dysfunction (Rajan et al., 2013). These results illustrate both the declination of cognition over time preceding visible loss of function and the acceleration of decline following a loss of function, indicating that the quality of functional performance of IADLs may be an indicator of hidden or increasing cognitive deficits in older adults. The study concluded that cognitive function declined more rapidly following physical disability across participants and that both basic and instrumental ADL disability may act as underlying catalysts for cognitive decline (Rajan et al., 2013). Another way to consider this is, when someone has a cognitive impairment and develops a physical impairment, they no longer have the capacity to **compensate** for their physical and cognitive deficits and it becomes obvious in everyday performance.

Mild Cognitive Impairment Amongst Drivers

Based on the literature's investigation of MCI and its detection in older adults, a strong connection has been found between the presence of MCI and IADL dysfunction, (Hall et al., 2011; Campbell et al, 2013; Rajan et al., 2013; Wadley et al., 2021). Therefore driving, as an IADL, is likely influenced by cognitive decline (Connors, et al., 2017; Wadley et al., 2021). Individuals experiencing cognitive decline also demonstrate a heightened risk for driving-related injury (Pomidor, 2016; Wadley et al., 2021). Older drivers that are aware of their limitations may choose to cease driving to avoid these risks. In some cases, these drivers are forced into driving cessation following a dangerous collision.

Connors and colleagues (2017) investigated the presence of predicting factors for driving cessation in adults with MCI using a 3-year longitudinal design. Participants included 185 older adults diagnosed with MCI that provided driving status and completed measures of cognition, function, neuropsychiatric symptoms, and medication use at regular intervals. (Connors et al., 2017). The study found that age, level of impairment in cognition and function, and rate of decline were predictors for driving cessation; over half of participants were diagnosed with dementia during the study and the majority ceased driving following progression of the diagnosis (Connors et al., 2017). It is important to note that these studies did not look at specific driving behaviors, but merely driving outcomes for older adults. Researchers are finding that driving is a complex and sensitive occupation that experiences early breakdown in performance when influenced not just by Alzheimer's disease, but by emerging, mild cognitive impairment. This breakdown in performance is visible enough that normal psychological testing may fall short of the insights that driving performance can provide on pathologies of the brain.

Evaluating the IADL of Driving

A *comprehensive driving evaluation* (CDE) is a part of the rehabilitation process for individuals who wish to drive following an acute injury or exacerbation of a medical condition that may impair their driving abilities. These are administered by occupational therapists with advanced training to determine a person's fitness to drive, including reaction time, visual acuity and perceptual ability, and decision-making skills (AOTA, 2022). The CDE consists of a medical and driving history, clinical assessment of sensory–perceptual, cognitive, or psychomotor functional abilities, on-road assessment, as appropriate, an outcome summary, and recommendations for an inclusive mobility plan including transportation options (Pomidor, 2019).

Though this method has been established in the literature as a standardized one, there is no true standard set of tools within the CDE that are used by all practitioners and in all practice settings. This begs the question of whether the CDE is the most accurate method of determining fitness to drive, or simply the most common one. In addition, completing a CDE is complex , not only due to cost barriers, but to its limited availability across the country. Rather, understanding the relationships between common driving assessment tools and actual driving performance can help determine what tools are truly the most accurate and predictive of driving cessation. Following, are descriptions of some of the commonly used assessments for the purposes of performing a CDE.

Common Assessment Tools for Determining Driving Fitness

Arguably, the most important aspect of determining fitness to drive is observing actual driving behavior. The Standard On-Road Evaluation (SORE) is one such method used for structured observation and rating of driving performance, in which an evaluator observes an individual drive a vehicle with specified instructions to ensure observation of a variety of driving functions (i.e., use of turn signal, lane placement, speed, observation of regulations). However, these evaluations vary widely in how they are administered; they can be closed or open course and may or may not include a predetermined route (Odenheimer et al., 1994; Classen et al., 2012). They may also vary in the types of tasks required or external stimuli along the route (Classen et al., 2012). This variability is not conducive to true standardization, despite the value to the evaluator of observing real-time driving performance.

Enriching to many driving evaluations is the performance of ability tests regarding physical, cognitive, perceptual, and visual skills (Barco et al., 2012). A combination of assessments of these abilities are used to predict an individual's overall driving ability, as no single tool can accomplish this (Dickerson, 2014a; Dickerson et al., 2019). Physical evaluation may consider cervical ROM, upper extremity ROM, Timed Up and Go (Podsiadlo & Richardson, 1991), or other measures of functional mobility that may or may not impact driving ability. Deficits in these areas can impede ability to check blind spots, quickly adapt steering direction, or lift and press a brake pad.

Cognitive screening and tools, like the MoCA, have been used as predictive tools of driving fitness due to the connection between cognitive skills and occupational performance (Kandasamy et al., 2019). Kandasamy and colleagues (2019) determined that older adults who both scored below a 28 on the MoCA and had mobility deficits were more likely to perform poorly in a driving evaluation, indicating its value as a screening tool for relative need for driving evaluation. Importantly, Anderson and colleagues (2012) noted that use of just one of these tools in evaluation alone is not a strong enough measure to predict holistic driving ability.

Cognitive tools may be used in conjunction with motor-visual and perceptual assessments; these are better able to thoroughly investigate the effect of perceptual and cognitive issues on motor and visual task outcomes. These assessments may or may not include the Motor-Free Visual Perception Test (MVPT-4) (Colarusso & Hammill, 2015) and Comprehensive Trail-Making Test (CTMT) (Moses, 2004). The CTMT, which assesses cognitive domains through fine motor tasks like drawing, is part of the Halstead-Reitan Neuropsychological Test Battery (Springate & Fein, 2013). In the CTMT, participants are asked to use a pencil to connect numbered circles in ascending order (Trails A) and to connect alternating numbers and letters in ascending order (Trails B) (Ciolek & Lee, 2020). These are performed all while ignoring visual distractions such as empty circles or symbols. These tasks are timed and designed to assess visual and perceptual abilities as well as executive functioning and is a well-established measure for determining the need for on-road testing (Ciolek & Lee, 2020). Memory is assessed following this portion of the task by requiring participants to recall and draw the shapes and their relative positions (American Psychological Association, 2020).

Cognitive tests, including those described above, and process components of the Assessment of Motor and Process Skills (AMPS) (Fisher, 1995), have been used both within the CDE and as screening tools to identify drivers in need of further assessment. These tools have also been used to understand the relationships between driving and other areas of occupational performance (Holowaychuk et al., 2020; Dickerson et al., 2010; Dickerson et al., 2011). The AMPS is of particular interest due to its established sensitivity to changes in performance skills (Dickerson et al., 2011). As an assessment of IADLs, the AMPS is implicated as a strong screening tool for medical fitness to drive based on the established connection between cognitive impairment and deficits in IADL performance.

Assessment of Motor and Process Skills

The Assessment of Motor and Process Skills (AMPS) (Fisher, 1995) is a criterion-referenced instrument for structured observation of daily activities. These activities lie on a spectrum from simple to complex and are relevant to the participant's everyday occupations. This specific aspect of the AMPS is what supports its strong ecological validity (Bouwens et al., 2007; Robinson & Fisher, 1996) as exemplified in Glen Gillen's (2013) Eleanor Clark Slagle lecture , stating the AMPS was a "gold standard" measurement of occupational performance. Gillen argues that the ecological validity of a tool is determined by the degree of similarity between the cognitive demands of the test task and the cognitive demands of the real-world environment. In the case of the AMPS, there is no question that these demands are as similar as possible, as the activities chosen are those that the test-taker regularly performs and is encouraged, if not required, to perform in a way that is habitual.

These activities are observed and assessed with careful attention to the client's specific motor and process skills. The two score components, motor and process, are assessed at the same time with the same task performance. Motor skills performance is primarily a measure of effort. These skills include a wide range of abilities such as maintaining balance during performance, positioning oneself appropriately with respect to various workspaces, exerting appropriate amounts of effort throughout the task, enduring the physical demands of the task, lifting, transporting, and manipulating objects with ease, and coordinating use of both upper extremities to fluidly accomplish task steps. Process skills performance is primarily a measure of efficiency. These skills are also quite variable and range from the ability to pace one's performance appropriately, to sequencing and decision making, to organizing time and space both effectively and logically. This then results in two separate ADL ability measures, motor and process, which are interpreted using standard scores and percentiles in comparison to the client's assigned demographic (Robinson & Fisher, 1996). Severe outcomes may result in changes in a client's medically necessary level of assistance for daily activities. Through research, the AMPS have been shown to moderately correlate with the Functional Independence Measure (FIM) (Granger et al., 1986) and Mini-Mental Status Exam (MMSE) (Folstein et al., 1975) (r = 0.67) supporting congruent validity (Robinson & Fisher, 1996).

Detection of Impairment

Previous findings suggest that the AMPS has the ability to indicate the effects of cognitive impairment on disability in functional tasks (Robinson & Fisher, 1996). As early as 1993, researchers found the AMPS was sensitive to changes in process skills (Dickerson & Fisher, 1993). In 1997, Dickerson and Fisher compared two, community-dwelling cohorts, one comprised of young adults aged 21-41, and the other of older adults aged 59-81. The researchers administered four familiar and four unfamiliar AMPS tasks in their homes according to standardized procedure. Following their completion, participants were asked to rate their familiarity with each task on a 5-point Likert scale. Results showed that older adults performed significantly lower on the process scale than young adults, with no significant interaction effects present based on age, type of task, or level of familiarity. These results supported that age-related cognitive decline cannot be compensated for by practice or years of experience (Dickerson & Fisher, 1997).

Bouwens and colleagues (2007) investigated the relationship between the AMPS and dementia assessment outcomes to better understand the severity of dementia symptoms and its range of impacts on daily activity performance. Using a cross-sectional design of 118 participants with cognitive disorders, various assessments were administered including the AMPS. The study found that the AMPS was positively correlated with other dementia scores, increasing its reliability and validity as a measure of cognitive impairment (Bouwens et al., 2007).

The AMPS has also been used in previous research as an assessment relevant to driving (Bouwens et al. 2007; Dickerson et al., 2011). Dickerson and colleagues (2011) studied the relationship of AMPS scores to driving assessment outcomes in 55 older adults with a variety of medical diagnoses. A behind-the-wheel assessment of driving was given following a clinical observation by a licensed occupational therapist. Administration of the AMPS was completed separately by certified raters. The driving assessment gave an outcome of pass, restrict, or fail for all participants. MANCOVA analysis found that a significant difference in AMPS process scores was found between "pass" and "fail" outcome groups and between "restrict" and "fail" outcomes (Dickerson et al., 2011). Motor skills scores were not significant between outcome groups (Dickerson et al., 2011).

In surveys on the use of AMPS in clinical practice, Chard (2000) found that of the 53 occupational therapists that reported using the AMPS, 100% had found it moderately to significantly useful. Additionally, when asked if any aspects of personal clinical practice had changed since using the AMPS, 35% of occupational therapists stated that observation skills and objectivity had improved (Chard, 2000).

In a systematic review of the best tools for determining executive function's influence on driving performance, Asimakopulos and colleagues (2012) found that when using the AMPS, there were significant differences between passing and failing drivers. The cut-off value that determined a pass or fail outcome for the drivers was 1.0 logits out of a 0-2.0 scale on the process measure (Asimakopulos et al., 2012). Using these cutoff values as a guide, AMPS has the potential to determine the point at which older adults should consider their IADL performance significantly impacted. By recognizing this point early on, older adults can plan for their future of functioning and how to maintain safety and independence as long as possible, including in the occupation of driving.

Naturalistic Driving

Driving skills have typically been assessed in behind the wheel assessment, using either a simulator or a vehicle. The assessor is positioned strategically so that they can count errors or note habits according to a predetermined standard or tool (Chen et al., 2018). However, the use of naturalistic methods for driving assessment, such as participant reports, computer chips, and in-vehicle recording devices, have also been recommended through comparative studies on assessment standards and the ability to assess functional driving skills (Chen et al., 2018). During naturalistic driving observation, participants use familiar routes that are purposeful and meaningful and, therefore, a true measure of relevant driving function.

Chen and colleagues (2018) compared standard on-road evaluations and naturalistic driving observation methods with respect to common occupational therapy practice models. Results of the review indicated that naturalistic driving observation methods incorporate less interference from typical experimental controls that may affect participant skill. Self-regulatory behaviors could also be observed as another measure of participant interaction with environment and occupation (Chen et al., 2018). Schedules for naturalistic driving observation were developed by Vlahodimitrakou and colleagues (2013) without standardization of driving behavior. Researchers used inter-rater reliability, ecological validity, and a post-drive survey that indicated 100% of the sample believed assessment performance to reflect everyday performance. Results showed that a suitable naturalistic driving observation route was formulated for functional assessment and could potentially be used to monitor driving performance of an individual over time (Vlahodimitrakou et al., 2013).

Rubin and colleagues (2020) implemented naturalistic driving observation for elderly drivers in a clinical study using Chen and colleagues' (2018) methods. The purpose of the study was to compare the *naturalistic driving observation* method to the *standard on-road evaluation.* Participants included 61 older adults participating in both naturalistic and standardized assessments (Rubin et al., 2020). Notably, scores were significantly different between the two methods; scores were higher overall on the standard on-road driving evaluation measure than on the naturalistic driving observation measure of driving skill, suggesting that naturalistic driving observation may show more accuracy when scoring typical, regularly occurring errors a driver makes on the road. Results also showed a correlation between in-clinic assessments and both the naturalistic driving observation and standard on-road driving evaluation results, improving the validity of naturalistic driving observation measures for clinical use (Rubin et al., 2020).

With respect to all previously mentioned studies, the connection between detecting cognitive impairment and naturalistic driving outcomes is based on the interactions between a variety of variables: biological measures, cognitive, functional, and observations which may or may not coincide with clinical assessment and the on-road performance assessment. To explore the interaction between these factors, using cerebrospinal fluid biomarkers for Alzheimer's disease and naturalistic driving outcomes was explored by Roe and colleagues (2017). All participants were over the age of 65 with no known diagnoses of cognitive impairment. Participants were assessed for dementia and had CSF samples taken by lumbar spinal puncture. Following these measures, participants completed an on-road driving evaluation using the *Record of Driving Errors* (Roe et al., 2017). The study found that higher levels of CSF Alzheimer's disease biomarkers were correlated with higher numbers of driving errors in the on-road assessment (Roe et al., 2017). Most interestingly, the psychometric scores developed from dementia screenings were not associated with number of driving errors (Roe et al., 2017).

Knowing this relationship between CSF biomarkers and driving error existed for this sample, it is necessary to understand what this may indicate for long term function and how driving may be used as a predictive tool for Alzheimer's disease (Roe et al., 2017). In a follow-up, longitudinal study conducted by Roe and colleagues, finalized in 2019, the resilience of the relationship between cognitive decline and driving skill was clearly shown. Participants with preclinical Alzheimer's disease showed greater rates of decline than normal individuals in driving ability over 2.5 years of data collection (Roe et al., 2019). These results indicate that not only can driving be a strong indicator of mild cognitive decline, but an early predictor of Alzheimer's disease as well (Roe et al., 2019).

Current exploration of this association between driving and detection of cognitive impairment continues to support this hypothesis. Bayat and colleagues (2021) studied the ability of GPS tracking devices to identify drivers with AD. Participants included 75 cognitively typical adults, and 64 with preclinical AD, as determined by biomedical markers. Following one year of location tracking while driving, noticeable differences between the two groups were detected, with an area under the curve of 0.82 for prediction of Alzheimer's disease status solely based on driving behavior. When combined with traditional means of prediction (age and biomarker presence), the AUC grew to 0.96 for accurate prediction of AD. This study also identified driving behaviors most influential to the predictability of AD. These included average jerk (smoothness or abruptness of driving), number of night trips, radius of gyration, number of trips shorter than 1 mile, and speeding, indicating that both spatial and behavioral aspects of driving performance were significant to the prediction of Alzheimer's disease in this study (Bayat et al., 2021). Studying these key, predictive driving behaviors in comparison with occupational therapy measures of both driving performance and functional cognition may highlight functional evaluation, as performed by occupational therapists as a potential diagnostic tool for AD. Moreover, it emphasizes the distinct contribution of driving rehabilitation as a practice area for occupational therapy.

Summary

As seen throughout previously mentioned research, the interactions between functional assessment, driving assessment, and cognitive decline have been studied using a variety of tools, timelines, and populations. The aging adult population has even been shown to experience greater functional loss when cognition declines than when it is unimpaired (Maresova, 2019; Peters & Rabins, 2017; Rajan et al., 2012; Nakahori et al., 2019). Cognition, made up of multiple subfunctions of the human brain, is the foundation for many driving process skills, one such occupation that may be influenced by the cognitive decline of older adults (Fisher & Martella, 2019; Barco et al., 2012; Anstey et al., 2005; Connors et al., 2017 ; Wadley et al., 2021). Driving skills can also be assessed using a wide variety of methods, supplementary testing, and both on-road and naturalistic data collection (Chen et al., 2018; Vlahodimitrakou et al., 2013; Rubin et al., 2020). The same underlying process skills used in driving are often also assessed in the field of occupational therapy by measures of daily activity functioning, namely the AMPS (Chen et al., 2018; Vlahodimitrakou et al., 2013; Rubin et al., 2020). The AMPS, as a valid and reliable indicator of cognitive decline has also been shown to correlate with driving habits in on-road evaluations and driving simulation but has yet to be tested against naturalistic driving data : (Dickerson et al., 2011, Asimakopulos, et al., 2012).

This research provides information on the nature and strength of both driving assessments and AMPS data as predictive variables for early cognitive decline and/or pre-clinical Alzheimer’s disease. However, there is extraordinarily little literature on the relevance of naturalistic driving assessment to cognitive evaluation in older adults compared to that of monitored or simulated driving assessment. Naturalistic driving has been shown to present opportunity for broader data collection in terms of driving behavior than standard on-road driving evaluation (Chen, Gélinas, & Mazer, 2018). Its validity and reliability as a measure of driving behaviors compared to standard on-road driving evaluation have also been recently strengthened using systematic review (Rubin et al., 2020). Standard on-road driving evaluation has shown some correlation with the development of Alzheimer's disease in older adults suggesting naturalistic driving data may have a potential contribution to the early detection of Alzheimer's disease and/or MCI (Roe et al., 2017). Though AMPS scores and standard on-road driving evaluation outcomes have been compared in previous research, use of the AMPS as a predictor of naturalistic driving outcomes has not been studied (Dickerson et al., 2010).

To enrich the field's understanding of driving as an indicator of cognitive decline, and to compare the strength of cognitive screenings and performance of IADLs as two potential indicators of cognitive functioning as it relates to driving, the study explored trends in cognitive screening performance, IADL performance, and naturalistic driving performance. Additionally, the study explored the nature and strength of the relationship between performance in standardized road assessment and performance in naturalistic driving to further understand potential benefits and drawbacks of naturalistic data in driving research.

3 - Method

Design

This descriptive exploratory study used healthy, community-living older adults to examine the relationship between cognition, naturalistic driving performance, driving evaluation performance, and functional performance in IADLs. As part of a larger ongoing study, outcome measures were collected for on a group of older adults over 20 weeks. Classification of participants' naturalistic driving behavior was based on the number of adverse naturalistic driving behaviors detected, self-restricting driving behavior (i.e., no night driving, limited mileage, limited number of trips).

Variables considered for comparative analysis in this study were the clinical occupational therapy assessments, including MoCA scores, AMPS process scores, and scores from an observational driving tool. The dependent variable was naturalistic driving performance.

Research questions to be explored include: 1) *Is there a relationship between naturalistic driving performance and performance of IADLs?*, 2) *Is there a relationship between naturalistic driving performance and cognitive measures?*, and *3) Is ther a relationship between naturalistic driving performance and standardized driving assessment?*

The East Carolina University & Medical Center Institutional Review Board (UMCIRB) granted approval for this study (UMCIRB 20-000236) (see Appendix A).

Participants

The target population for this study was community-living older adult drivers in eastern North Carolina. Participants were recruited from the local community with the inclusion criteria of: 1) 65 years of age or older, 2) having a valid driver's license, 3) currently driving at least four days a week, 4) fluent in spoken and written English, and 5) having ready and immediate access to a motor vehicle. Exclusion criteria were 1) a diagnosed medical condition that clearly impacted driving ability, 2) having a vehicle older than 1996 due to the use of technology, and 3) not willing to complete all the components of the study. For some (n = 6) participants, the vehicle was shared either between two participants or with another primary driver outside of the study. In these cases, the participants were instructed to log the dates and times when they each drove the vehicle. Researchers provided a notebook for logging driving hours to any participant that required one.

Convenience sampling was used to recruit 41 participants from a variety of sources: previous research on driving outcomes, a local retirement community, and local volunteers that fit participation criteria. Participation was voluntary and confidential, and participants were treated in accordance with the *Occupational Therapy Code of Ethics* (American Occupational Therapy Association, 2015). All participants signed a consent form (see Appendix B) and received a total of $300 in incentives for completion of the clinical assessments and naturalistic data collection period (distributed over time for completion of each part of the study). Following data collection, one participant was excluded from the study due driving only once a week. The final number of participants in the study was N=40.

Table 1 describes participant demographics by gender, race, and age group. Table 2 illustrates participant driving habit descriptive derived from the *Modified Driving Habits Questionnaire* (MDHQ) organized by variables of interest including, but not limited to, amount of driving during the week, number of miles driven from home, and difficulty with driving under various conditions (i.e., nighttime, when raining).

Table 1

Participant Demographics

Participants (N=40)	M (*SD*, Range)
Age, *M (SD*, Range*)*	73.56 (*5.66*, 65-87)
Age Groups, N (%, Range)	
60-69	11 (27.5%, 65-69)
70-79	23 (57.5%, 70-79)
80-89	6 (15%, 81-87)
Gender, N (%)	
Male	14 (35%)
Female	26 (65%)
Race, N (%)	
Caucasian	34 (85%)
African American	5 (12.5%)
Asian American	1 (2.5%)

Table 2

Modified Driving Habits Questionnaire

Questionnaire Item	M (*SD*, Range)
Average miles driven from home	12.97 (*16.5*, 1-120)
Average # days driven per week	5.28 (*1.52*, 2-7)
Self -Reported Quality of Driving	Total # per group
Excellent	12
Good	22
Average	4
Difficulty Driving in Rain	
No difficulty	23
A little difficulty	12
Moderate difficulty	3
Extreme difficulty	0
Difficulty Driving at Night	
No difficulty	19
A little difficulty	9
Moderate difficulty	7
Extreme difficulty	1
Average # Accidents in Last Year	X = 1

Instrumentation

Modified Driving History Questionnaire

The *Modified Driving History Questionnaire* (MDHQ) (Owsley et al., 1999) (see Appendix C) consists of 30 questions regarding participant perceptions of driving performance, amount of driving completed in a typical week, and habits regarding driving routines (i.e., driving at night, in the rain, parallel parking, etc.) Questionnaire items concerning number and length of trips were used for comparison with GPS driving data during data analysis to support researchers in notation of anomalies in the latitudinal-longitudinal data.

Assessment of Motor and Process Skills

The *Assessment of Motor and Process Skills* (AMPS) (Fisher, 2006) (see Appendix D) consists of two scales designed to assess motor and process function during the performance of daily activities. Raw scores ranging from 4 (without error) to 1 (contributing to task breakdown) are given to each skill based on functional performance (Fisher, 2006). The ratings are also defined differently based on each skill being assessed. For example, a score of 2 in the skill “lifts” may be caused by a person sliding an item across a counter instead of lifting and placing it, whereas a 2 in the skill “endures” may be caused by a person requiring a rest break in the middle of task performance. For scores of 1 or 2, examples of potential performance deficits are provided to assist the examiner in identifying errors (Fisher, 2006). A raw score of 3 indicates questionable performance or uncertainty by the rater and are used infrequently to support reliable data collection (Fisher, 2006). The activities used for skill rating are regular and familiar to the participants and are scored by appropriately trained and calibrated raters. Using Rasch analysis, the AMPS has been indicated as a reliable tool for assessing functional performance and skills (Fisher, 1993).

Previous research indicates validity of AMPS outcomes in consistent identification of ADL and IADL deficits and reliability of outcomes for older adults (Doble et al., 1999; Fisher, 1993; Merritt, 2011). The AMPS has also been indicated as a sensitive measure of other specific deficits. Choo and colleagues (2017) found that the AMPS was more sensitive to cognitive change across three treatment groups (orthopedic, geriatric, and oncology) in comparison with the *Functional Independence Measure* (Choo et al., 2017). Additionally, the AMPS has been tested as a measure of community mobility independence. Merritt (2011) found that AMPS process scores, when used to determine community independence, had an area under the curve (AUC) of 0.84, with sensitivity of 0.80 and specificity of 0.70. These indicate acceptable cut off points for determining independence versus dependence for accessing the community (Merritt, 2011).

Research has applied this knowledge of the AMPS to driving IADLs, specifically. Dickerson and colleagues (2011) found that the AMPS was able to reliably discriminate between drivers that failed, passed, or were given restrictions following a behind-the wheel evaluation. Cutoff scores of 1.2 logits for motor scores and 1.0 logits for process scores were indicated as consistent markers (87%) of pass versus fail and further evaluation groups (Dickerson et al., 2011). The performance groups for the AMPS used in the present study were, therefore: 1) less than 1.0 logits, 2) between 1.0-3.0 logits, and 3) more than 3.0 logits.

Occupational Therapy Assessment Package

To determine total AMPS scores, the Occupational Therapy Assessment Package (OTAP) (Innovative OT Solutions, 2014) software was used. The OTAP software converts raw scores in both motor and process areas for both tasks into logit scores, z scores, standard scores, and percentile ranks. These final score areas are used to compare participants with a national database of their peers based on factors of age, gender, and diagnostic category. All participants were scored using the "well, older adult" diagnostic category.

Montreal Cognitive Assessment

The *Montreal Cognitive Assessment* (MoCA) (Nasreddine et al., 2005) (see Appendix E) is a widely used, sensitive measure for screening cognitive impairment, increasing its validity as a measure for this study (Koski, 2013). The MoCA assesses the two sensitive indicators of cognitive impairment, executive functioning and attention, using a series of visual and recall-based tasks (Garrett et al., 2004). Previous literature indicates validity of the MoCA as a wide-range tool for sensitive detection of clinically significant cognitive impairment (Koski, 2013). Longitudinal collection of MoCA scores has also indicated that its trajectories are sensitive to cognitive changes in patients with mild cognitive impairment (Salvadori et al., 2021). However, it is important to note recent discrepancies in the literature related to the MoCA's cutoff scores used for determining impairment.

As of 2013, researchers validating the MoCA for screening MCI and AD suggested an optimal cut-off of below 22 for MCI and below 17 for AD (Freitas et al., 2013). The 2020 study completed by Dautzenberg and colleagues, however, suggested that previous studies of the MoCA using healthy controls contributed to overestimations in specificity and a need for cutoff score adjustment. By their measures, which tested 867 participants with either no cognitive impairment, mild cognitive impairment, or mild dementia, appropriate cutoff scores for the MoCA were determined to be <25 for mild cognitive impairment and <21 for mild dementia (Dautzenberg et al., 2020). The researchers determined that the MoCA remains a suitable screening tool to support referral for additional cognitive evaluation, but is not specific enough to diagnose mild cognitive impairment or dementia. while a MoCA score of 25 or below is associated with increased likelihood of driving cessation and a score of 20 or below is associated with the onset of dementia (Dickerson et al., 2011; Kokkinakis et al., 2021).

The MoCA has also been tested as a pre-measure of cognition for driving evaluation research, demonstrating a sensitivity of 84.5% and a specificity of 50% with a cut-off of >25% (Kwok et al., 2014). Lower MoCA scores were significantly associated with on-road test failure at a confidence level of $p < .05$ in a previous study (Kwok et al., 2014). More recently, MoCA scores <26 have been shown to correlate with a higher likelihood of driving cessation (Kokkinakis et al.,, 2021). The performance groups used for analysis of the MoCA were, therefore: 1) less than or equal to 21, 2) between 22-25, and 3) greater than or equal to 26.

Performance Analysis of Driving Ability

The *Performance Analysis of Driving Ability* (P-Drive) (Patomella, 2014) (see Appendix F) is a standardized assessment tool that rates 25 driving skills within four subgroups: 1) *maneuver,* including items such as steering and using turn signals, 2) *orient*, including items such as way finding and planning, 3) *follow regulations*, including items such as obeying stop signs and speed limit signs, and 4) *attending and acting on traffic-related stimuli*, including items such as attending to and responding to regulatory signs as well as traffic-related problem solving (Patomella & Bundy, 2015). Similar to the AMPS, items are rated on a scale of 4 (competent) to 1 (incompetent), with a score of 3 indicating questionable performance and a score of 2 indicating a problem in performance (Patomella et al., 2006). In standard testing procedure, all of the skills are observable several times and in a variety of situations.

Research has been conducted over the past several years to continually test the validity and reliability of this measure of driving performance in various populations and with variations in items (Patomella et al., 2006; Patomella et al., 2010; Patomella & Bundy, 2015; Sawada et al., 2019; Vaucher et al., 2015). Initial research on the use of the P-drive by the developers yielded acceptable person response validity for a post-stroke sample (97% goodness-of-fit) using 20 of the current 27 items (Patomella et al., 2006). Internal scale validity demonstrated acceptable goodness-of-fit for 19 of the 20 items, with the item of exception being "controlling speed" (Patomella et al., 2006). A study following the addition of seven new items supported the validity of P-Drive for measuring driving ability in those who had experienced stroke, as well as those diagnosed with dementia and mild cognitive impairment (Patomella et al., 2010).

Studies completed by outside researchers have also demonstrated support for the measure (Sawada et al., 2019; Vaucher et al., 2015). Systematic review of on-road driving assessment tools identified the P-drive as good to excellent for item response theory, high quality in internal consistency and structural validity, and as having the highest quality of items out of all the tools assessed (Sawada et al., 2019). P-drive has also been indicated as a stable assessment, with near-perfect between-rate reliability (Vaucher et al., 2015). Considering the raters' interpretations of driving performance are largely subjective, this is an excellent psychometric in support of use of the P-drive. Additionally, support for use with older adults is indicated (Vaucher et al., 2015).

Patomella and Bundy's 2015 study indicated that the assessment was capable of separating 99 participants into four groups by driving ability, however the item "controlling speed" was consistently unable to conform to Rasch model expectations (Patomella & Bundy, 2015). The P-Drive's four performance groupings were, therefore, determined based on the 2015 study in which a failing score was less than 80. However, P-Drive outcomes were also assessed by area of testing, including but not limited to heeding, orienting, and following regulations.

The performance groups for the P-Drive were, therefore: 1) less than 80, 2) between 81-84, 3) between 85-89, and 4) greater than or equal to 89.

Equipment

G2 Tracking Device

G2 Tracking Device (Azuga, 2013)

The equipment necessary for the study included a global positioning system (GPS) data logger (G2 Tracking Device™, Azuga Inc, San Jose, CA) connected to the onboard diagnostics port of participant vehicles for tracking driving outcome variables. The system collected general driving data including the following: length of trips, timing of trips, on versus off-route driving, driving speed, and number of stops every 30 seconds during all driving of the vehicle (Roe et al., 2019). Instances of speeding were logged at 6 miles per hour or more above the posted speed limit. The system continuously reported all instances of aggressive action (hard braking, sudden acceleration, and speeding) as these are important indicators of poor and/or declining skill in driving (Roe et al., 2019). For the purposes of this study, naturalistic driving metrics logged for analysis included 1) instances of speeding per drive, 2) instances of hard stops per drive, 3) driving distance per drive, 4) driving radius from primary location, 5) number of drives taken, and 6) amount of time spent driving during daylight hours. These metrics were converted into three driving behaviors for data analysis: *aggression* (sum of hard stops and speeding per drive/per week), *number of trips* (mean number of drives per week), and *daylight driving* (ratio of time spent driving during daylight hours versus night hours) (Babulal et al., 2016). Daylight hours were defined as between sunrise and sunset each day. All means were taken per week of participation as well as a total mean for the entire participation period. The data was also visually reviewed for events of abnormal driving patterns (i.e., large numbers of aggressive driving events). These events were verified by phone interview with participants. In response, three participants reported dates in which another person drove their vehicle. These dates were removed from analysis.

Procedure

Participants were screened via e-mail or phone call to ensure they met inclusion criteria and were available to participate for the 20-week period. Prior to data collection, the researcher met with participants at the research lab to explain study procedures and the contents of the consent form as well as methods of compensation, and to allow participants to ask questions about the study and its requirements. The researcher also collected demographic data including age, gender, date of birth, and race/ethnicity via participant interview. Following documentation of participant consent and completion of the *Modified Driving Habits Questionnaire*, participants were assigned a unique G2 Tracking Device and showed the researcher to their vehicle for device installation. The date of installation was marked as the first day of data collection for each participant.

The G2 Tracking Devices were installed by the researcher in the on-board diagnostics port of participant vehicles. Following installation, driving data was taken using the G2 Tracking Device over a period of 20-weeks. During the 20-week period of naturalistic data collection, three appointments were made to complete research assessments: a clinical evaluation appointment, an on-road drive appointment, and the time when the chip was removed.

For the clinical evaluation, participants returned to the research lab to complete multiple clinical assessments including the MoCA and the AMPS. Both the MoCA and the AMPS were administered by a member of the research team using standard procedures. For the AMPS, participants were instructed to complete two instrumental activities of daily living according to how they normally perform them in their homes. These activities were referred to as “tasks” during the evaluation. The researcher asked questions of the participant prior to each task regarding materials they intended to use, their intended order of steps, and any other considerations required to understand task preferences/performance. *Task F-1. Peanut butter and jelly sandwich*, was used across all participants as the first task. For the second task, participants were offered a choice between *F-4. Grilled cheese sandwich and a beverage for one person*, and *D-1. Eggs (scrambled or fried) and toast with a beverage for one person*. Both tasks were completed in the lab's kitchen space and were scored by an AMPS-certified member of the research team.

Participants scheduled an additional appointment to complete the on-road driving assessment. The on-road drive was conducted using the participant's primary vehicle on a 45-minute standardized route designed for evaluating fitness to drive for medically at-risk drivers. The same route was used across all participants and included a wayfinding task at the strategic level of driving. A member of the research team was present in the passenger's seat of the vehicle to observe driving skills. Participant driving skills were rated using the P-Drive assessment.

On or after the date marking 20-weeks of naturalistic data collection, the G2 devices were removed from participant vehicles. Participants were asked to report any issues encountered while using the G2 device as well as any instances of a crash. No issues with the device were reported, indicating normal data collection, and one vehicle crash was reported. Participants were debriefed and released with a total compensation of $300. All assessment tools were scored by one or more trained members of the research team.

Data Analysis

All data was entered into an Excel file and uploaded to SPSS (Version 27). Descriptive statistics were used to summarize all participant characteristics and outcome measures. Boxplots were used to explore trends in naturalistic driving performance based on demographic factors. Groupings for age were determined using a 10-year time span. Independent variables were broken down into performance groups, determined based on statistically supported cut-off values (Dickerson et al., 2011; Kokkinakis et al., 2021; Patomelola & Bundy, 2015). The dependent variables were naturalistic driving behaviors and were not grouped into performance ranges.

Dependent variables were compiled by computing the mean value of each for each participant over the course of the 20-week data collection period, resulting in a single value per participant. Tests used for data analysis included 1) analysis of variances (ANOVA), 2) t-tests of differences between means, 3) bivariate tests of correlation, and 4) a multiple regression model.

Differences in performance by gender were tested using a t-test for each driving behavior (aggression, daylight, trips), resulting in three total t-tests. Age, the AMPS, the MoCA, and the P-Drive were the independent variables in the ANOVA tests. For each of these assessments, the performance and/or age groups were represented by numerical codes (i.e. 1 = 65-59, 2 = 70-79, 3 = 80-89; 1 = poor, 2 = fair, 3 = good, 4 = excellent). For the ANOVAs, the naturalistic driving behaviors were the dependent variables and were grouped based on participants' levels of performance in each assessment. Differences in performance in each assessment and in age group were tested using each driving behavior one by one (aggression, daylight, trips), resulting in 12 total ANOVA tests.

Relationships between the variables were tested using bivariate correlations. These tests used participants' raw scores, ages, and numerical behavior values. These relationships were analyzed further using a multiple regression model to control for the effects of age and gender on the sample. The significance level for all testing was set at .05.

Calculating Naturalistic Driving Behaviors

To comprehend the significance of the results, the process of deriving value from naturalistic behaviors must be further explained.

Aggression

For each participant, a tally of specific events (i.e., sudden stops and instances of speeding) was kept during each drive taken. These numbers were summed for each week as well as in total for the duration of participation (i.e., mean across 20 weeks). The total number of instances of aggression in a single week was then averaged based on number of trips taken during that week, and repeated for each of the 20 weeks of participation. A final mean of these weekly aggression values was calculated to determine the mean number of "aggressive events" per trip taken across the entirety of the participation period. This value for each participant became their aggression mean, and communicates the typical amount of "aggressive events" that occurred during a trip. This value was then combined with other participant aggression values based on their shared demographics and/or performance ranges (i.e., percentile range on the AMPS).

Daylight

The G2 chip provided specific values for each of a participant's drives that communicated at what time of day the drive was completed. Parameters were set to determine if that time of day was during daylight or nighttime. These values were averaged for each week of driving, resulting in a "daylight" ratio between 0.0 and 1.0 for each week of driving. Values were then summed and averaged based on number of weeks (20). A final mean of these weekly ratios was calculated to determine the participant's overall mean ratio of day to night driving. A value greater than 0.5 indicates more time spent driving during the day than during the night, with a 1.0 indicating only driving during the day. This value was then combined with other participant daylight ratios based on their shared demographics and/or performance ranges (i.e., percentile range on the AMPS).

Number of Trips

The G2 week provided a tally of trips taken per week. These were summed and averaged based on the number of weeks of participation. Some participants completed fewer than 20 full weeks of driving, requiring that these values be determined based on each participant's total participation time with their chip.

4 - Results

Driving Behaviors

Summaries of the driving behaviors of the sample, including mean, standard deviation (SD), and grouping size (N) by both age and gender factors are in Tables 3-5. Mean aggression is a combined score of the mean instances of either 1) sudden stops or, 2) speeding per trip driven. Daylight is defined as the ratio of time spent driving during daytime hours (e.g., a value of 1.00 is 100% of driving time spent during daylight hours). Table 6 summarizes driving distances from primary locations in miles and number of unique destinations for the sample.

Table 3

Mean Aggression Scores Across Gender and Age

Aggression

Gender	Age	Mean	SD	N
Male	65-69	.35	.24	2
	70-79	.18	.14	9
	80-89	.44	.45	3
	Total	.26	.24	14
Female	65-69	.82	.55	9
	70-79	.32	.28	14
	80-89	.22	.15	3
	Total	.48	.45	26
Total	65-69	.74	.54	11
	70-79	.27	.24	23
	80-89	.34	.32	6
	Total	.40	.40	40

Note: Higher scores are evidence of increased aggression.

Table 4

Mean Daylight Scores Across Gender and Age

Daylight

Gender	Age	Mean	SD	N
Male	65-69	.47	.11	2
	70-79	.58	.22	9
	80-89	.75	.30	3
	Total	.60	.23	14
Female	65-69	.53	.14	9
	70-79	.60	.21	14
	80-89	.78	.21	3
	Total	.59	.20	26
Total	65-69	.52	.14	11
	70-79	.59	.21	23
	80-89	.77	.23	6
	Total	.60	.21	40

Note: The higher the mean, the more driving is done in daylight.

Table 5

Mean Number of Trips Across Gender and Age

Number of Trips

Gender	Age	Mean	SD	N
Male	65-69	33.05	4.24	2
	70-79	20.33	9.05	9
	80-89	14.15	8.72	3
	Total	20.82	9.85	14
Female	65-69	23.70	12.20	9
	70-79	26.64	16.57	14
	80-89	11.71	2.77	3
	Total	23.89	14.60	26
Total	65-69	25.40	11.63	11
	70-79	24.17	14.21	23
	80-89	12.93	5.94	6
	Total	22.82	13.08	40

Note. All values are based on participants' mean number of trips per week divided by number of weeks driven.

Table 6

Driving Location Data

Driving distances	Mean	Range	SD
Distance from primary location (mi)	19.55	0.04-1826.72	97.54
Number of unique locations visited	12.11	1-39	6.66

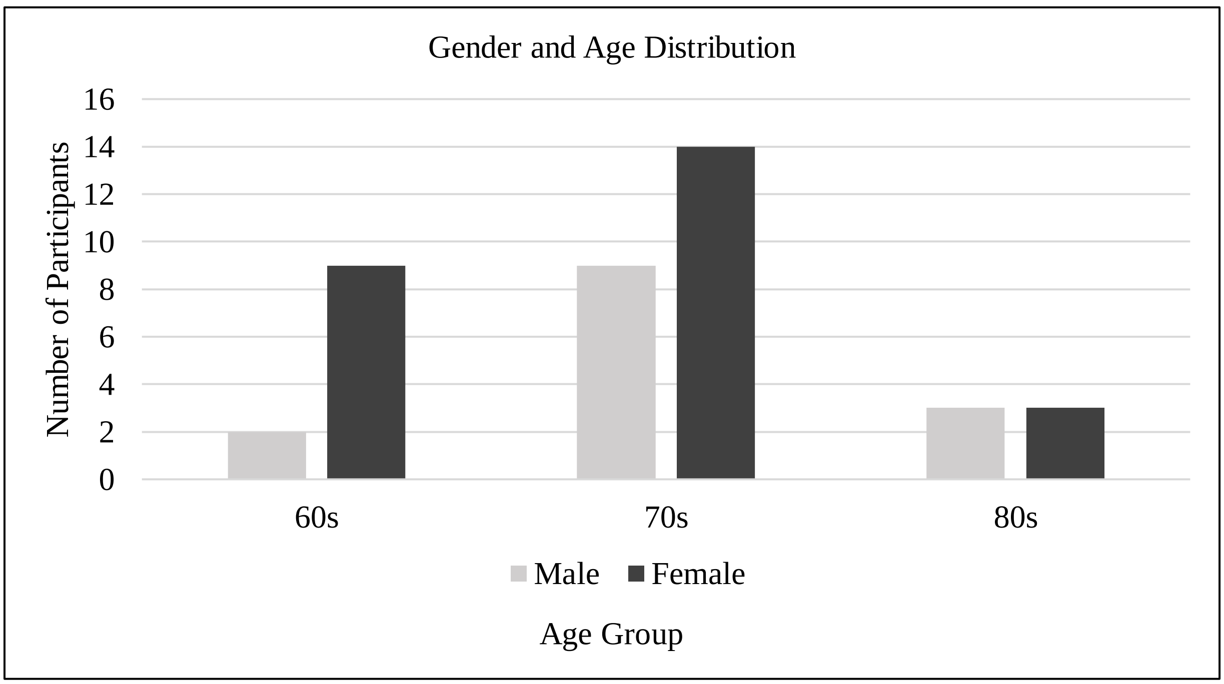
Note. All values based on weekly data from each participant.

Influences of Age and Gender

Figure 1 displays the distribution of participants by age and gender. Boxplots of the data were used to reveal the trends in naturalistic driving performance based on age and gender. Samples of boxplots demonstrating the variance of the data are shown in Figures 2-7. Gender was assessed using the analysis of variances model. Both analysis of variances and bivariate correlations were used to assess the influences of age on naturalistic driving outcomes. No significant differences were found between genders in any of the naturalistic driving behaviors.

Figure 1

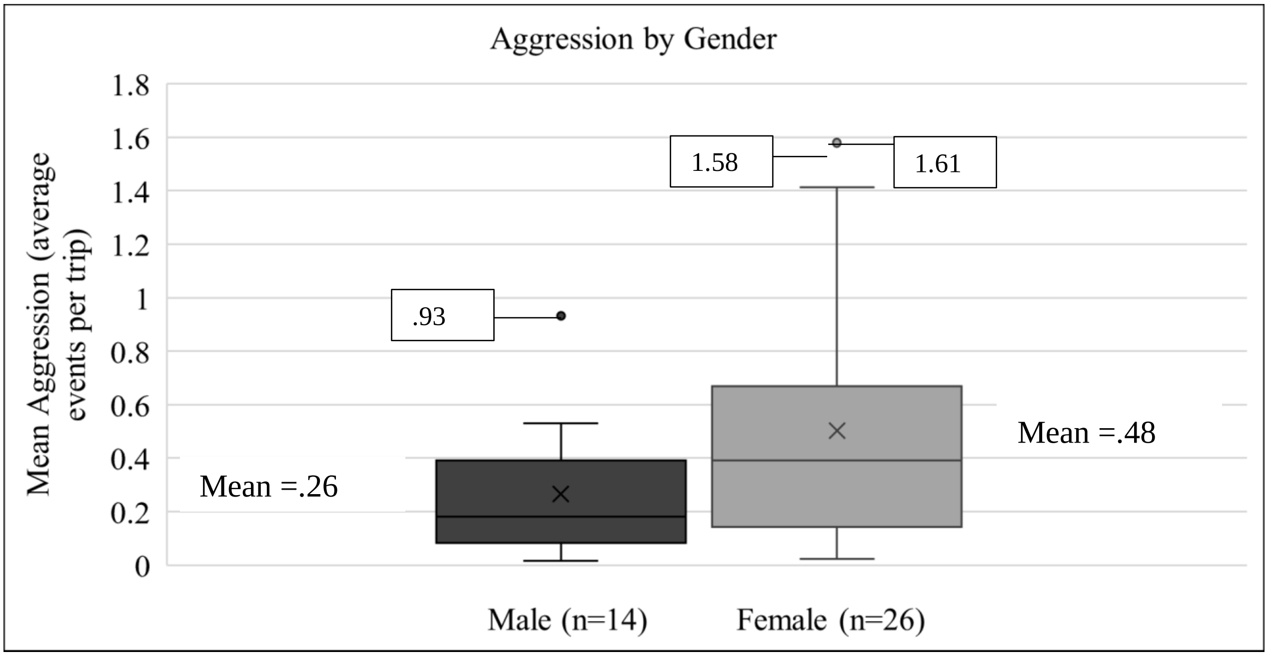
Gender and Age Distribution



Note: Differences between age group size and ratio of males to females demonstrates left skewed pattern, potentially influencing results.

Figure 2.

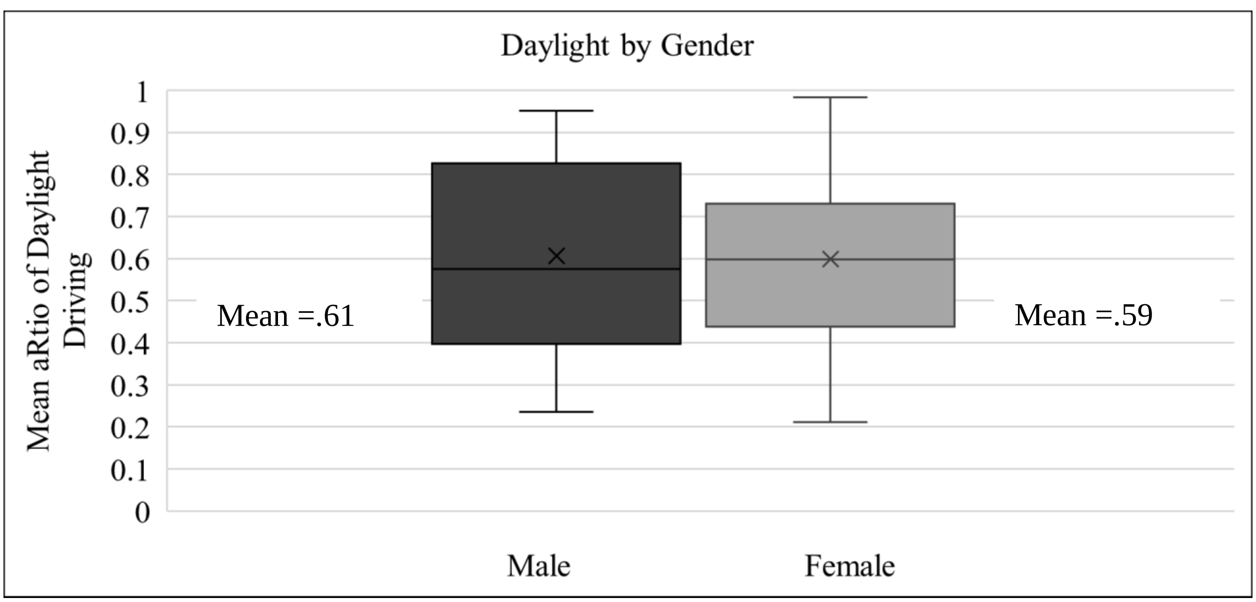
Aggression by Gender



Note: No significant difference between groups.

Figure 3

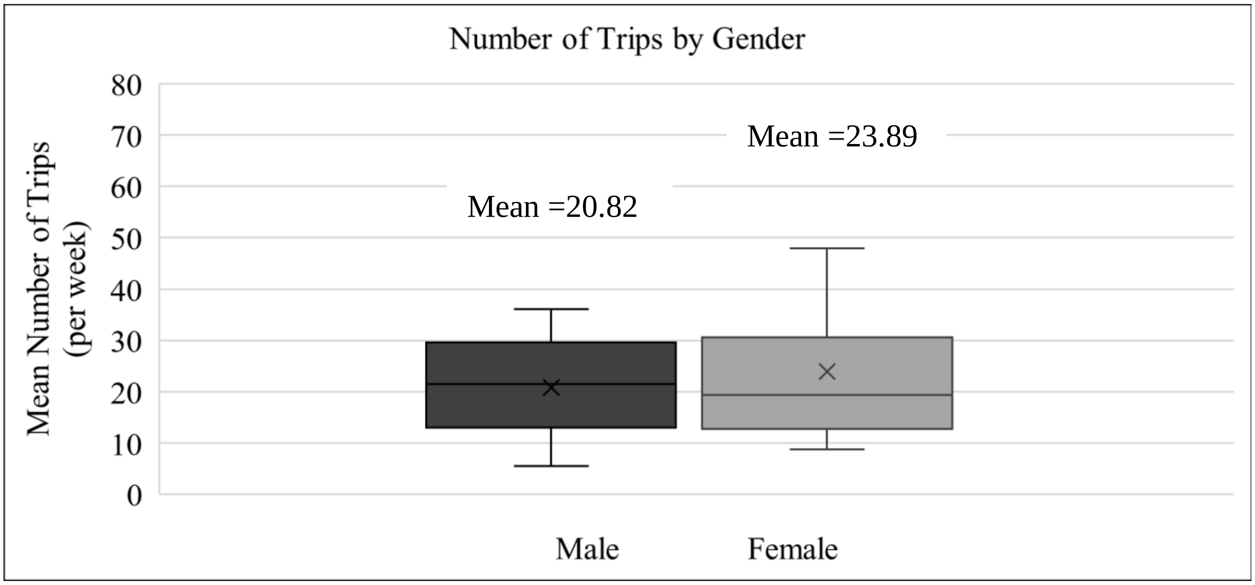
Daylight by Gender



Note. No significant differences between groups.

Figure 4

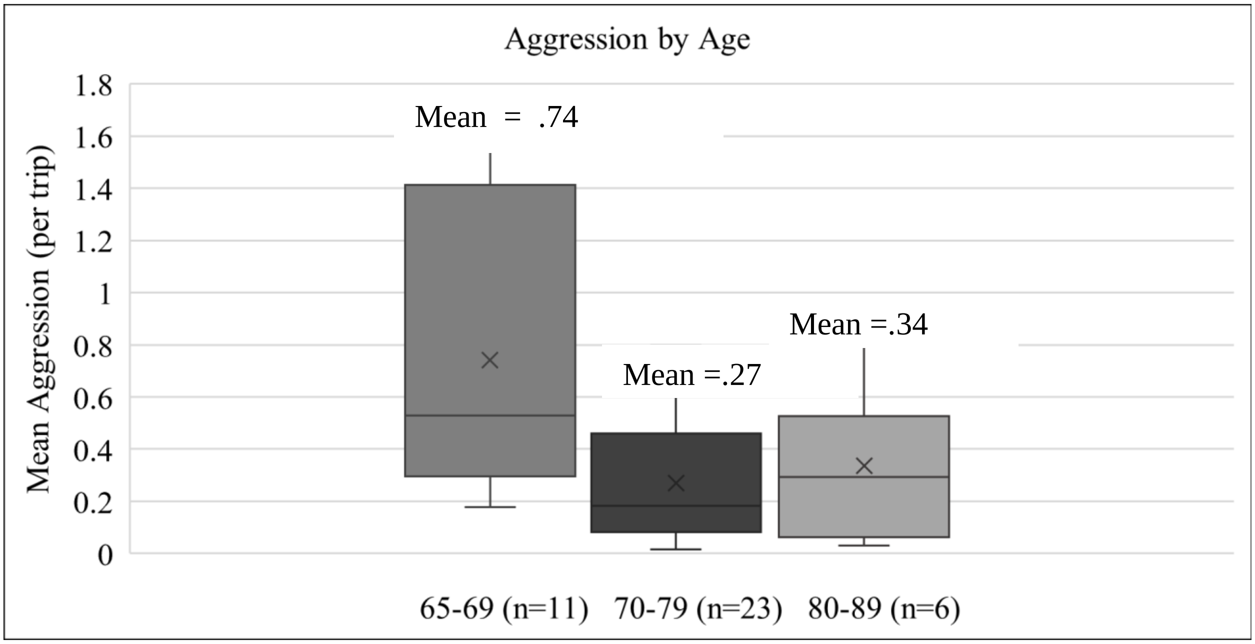
Number of Trips by Gender



Note. No significant differences between groups.

Figure 5

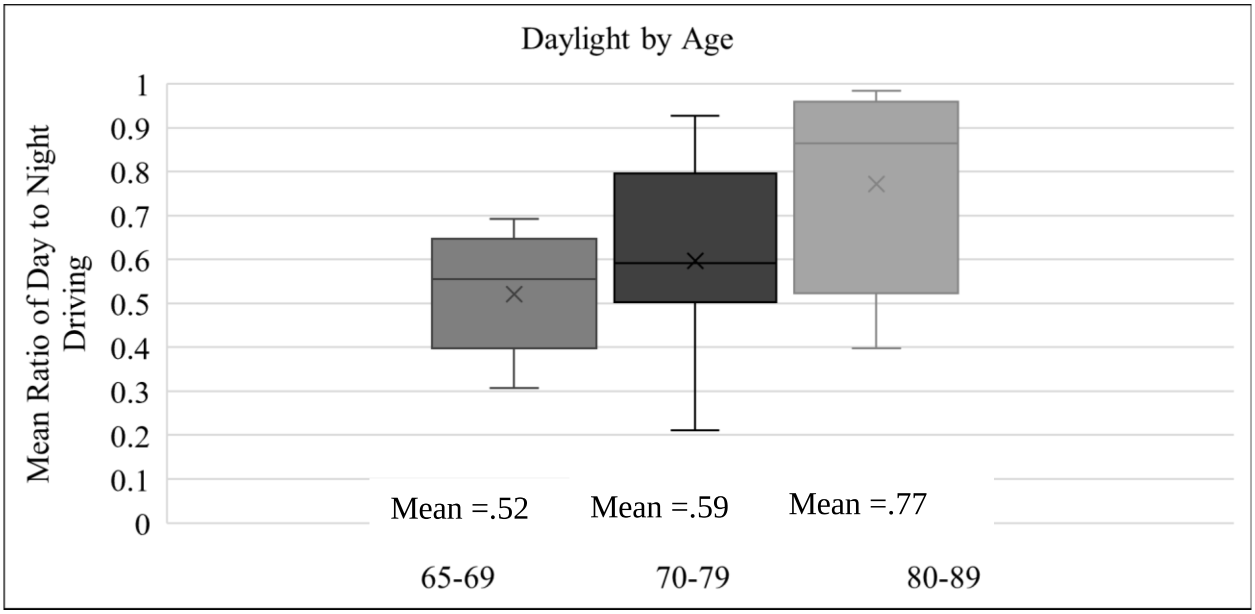
Aggression by Age



Note. Differences between groups were significant with a p-value of .004 ($p < .005$). Tukey's HSD indicated differences were significant between ages 65-69 and 70-79 ($p = .003$).

Figure 6

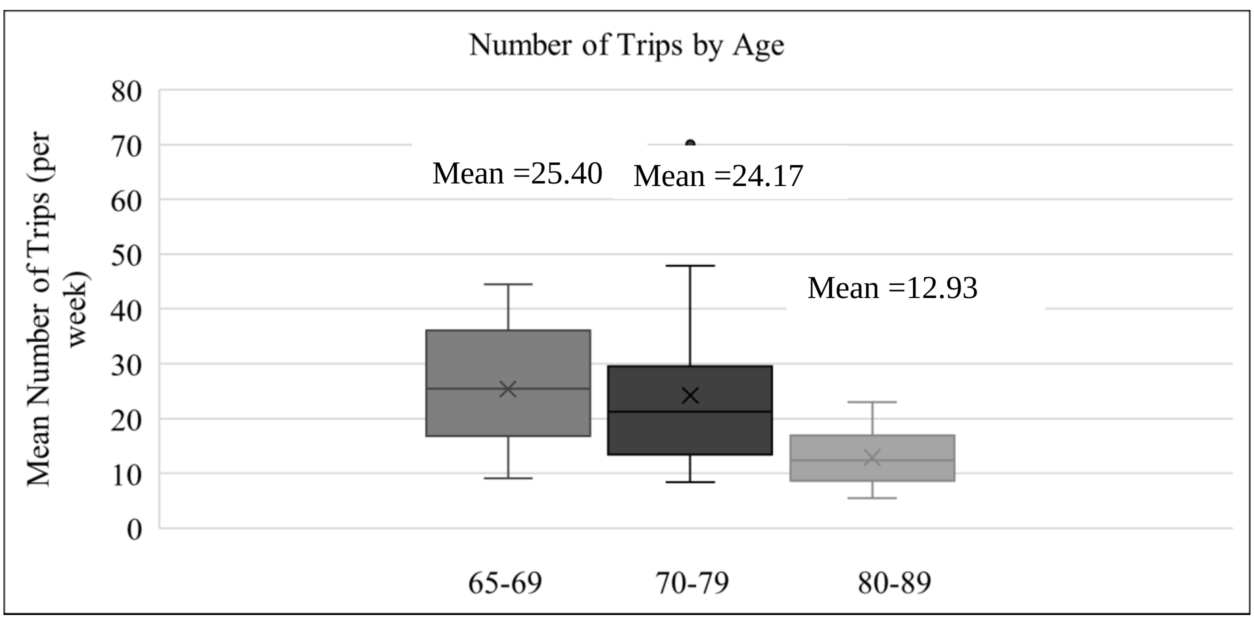
Daylight by Age



Note. No significant difference between groups.

Figure 7

Number of Trips by Age



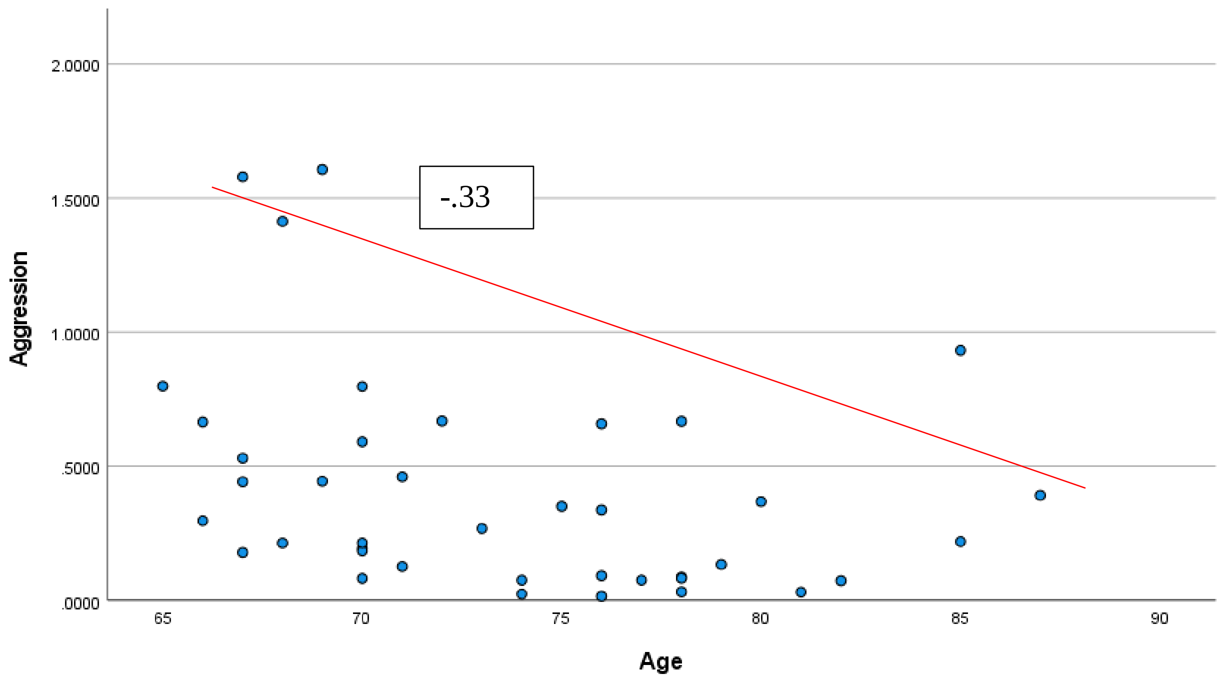
Note. No significant difference between groups.

Bivariate Correlations Between Naturalistic Driving and Age

Two relationships were found between age and driving behaviors. The relationship between age and aggressive driving demonstrated a p-value of .04 with a correlation coefficient of -.33. The relationship between age and ratio of daylight driving was also significant, with a p-value of .009 ($p < .01$) and a correlation coefficient of .409. No significant relationship was found between age and number of trips. Significant results have been visualized in Figures 8 and 9.

Figure 8

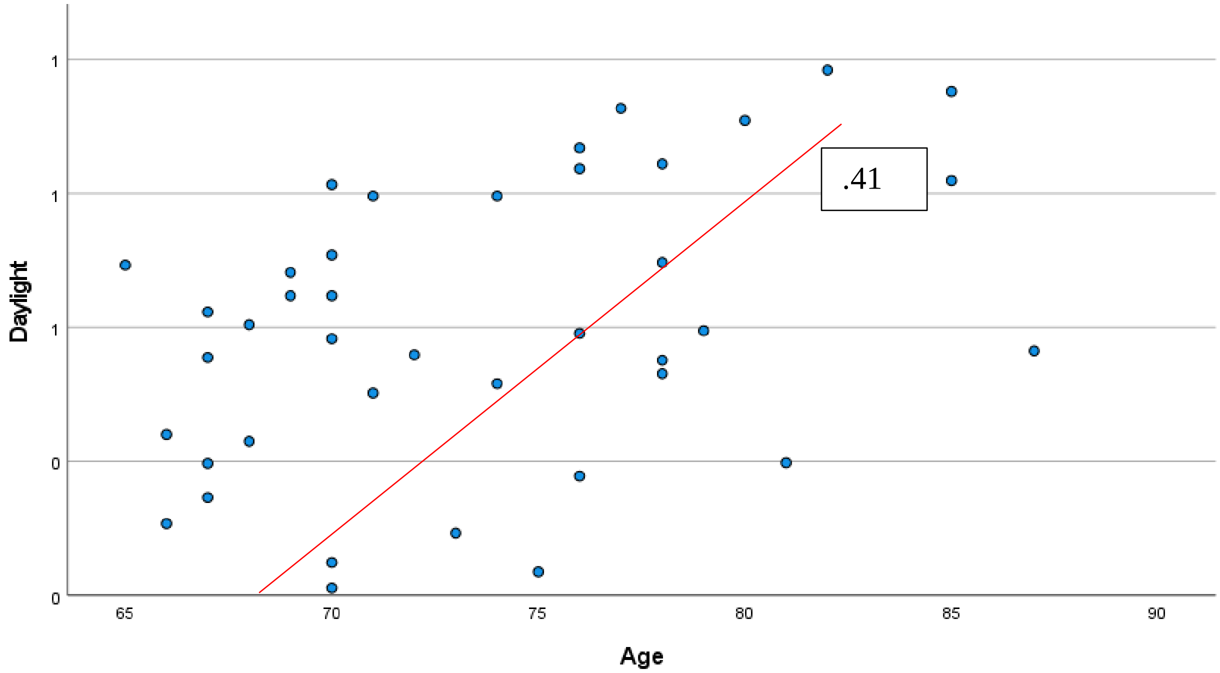
Scatterplot of Aggression by Age



Note. Negative correlation between age and amount of aggression was significant ($p < .05$). r = -.33, p = .04.

Figure 9

Scatterplot of Daylight by Age



Note. Positive correlation between age and amount of daylight driving was significant (*p* < .01). r = .41, p = .009.

Relationships Between Test and Outcome Variables

Each clinical assessment was designated as a test variable for each research question. Question one, *Is there a relationship between naturalistic driving performance and performance of IADLs?*, tested the correlation between AMPS process scores and driving behaviors. Question two, *Is there a relationship between naturalistic driving performance and cognitive measures?*, tested the correlation between MoCA score and driving behaviors. Question three, *Is there a relationship between naturalistic driving performance and standardized driving assessment?*, tested the correlation between P-Drive score and driving behaviors.

Table 7 summarizes performance in clinical assessments across the sample. Table 8 displays the results of the multiple bivariate tests of correlation, conducted to isolate the associations between each of the three driving behaviors (e.g., aggression, number of trips, daylight driving) with each of the clinical measures (e.g., MoCA, AMPS, P-Drive), as well as age.

Table 7

Performance in Standardized Assessment Tools

Assessment	Mean	Range	SD
MoCA	24.83	17-29	3.34
AMPS Process (%)	54.68	9.5-97.7	24.77
AMPS Process (Logit)	1.39	-2.3-2.3	0.71
P-Drive	88.85	73-99	6.28

Table 8

Bivariate Correlations

Test Variable	Aggression	Daylight	Number of Trips
Age			
Pearson Correlation	-.33*	.41**	-.22
P-value (2-tailed)	.04	.009	.171
N	40	40	40
MoCA			
Pearson Correlation	.26	-.34*	-.24
P-value (2-tailed)	.103	.03	.138
N	40	40	40
AMPS Process			
Pearson Correlation	-.17	-.03	-.18
P-value (2-tailed)	.301	.858	.266
N	39	39	39
P-Drive Total			
Pearson Correlation	.14	-.01	-.22
P-value (2-tailed)	.390	.938	.171
N	40	40	40
Heeding			
Pearson Correlation	.22	.05	.05
P-value (2-tailed)	.165	.766	.766
N	40	40	40
Maneuvers			
Pearson Correlation	-.03	.11	-.002
P-value (2-tailed)	.839	.488	.991
N	40	40	40
Orients			
Pearson Correlation	.02	-.09	-.34*
P-value (2-tailed)	.912	.578	.035
N	40	40	40
Follows Regulations			
Pearson Correlation	.13	-.17	.06
P-value (2-tailed)	.426	.275	.707
N	40	40	40

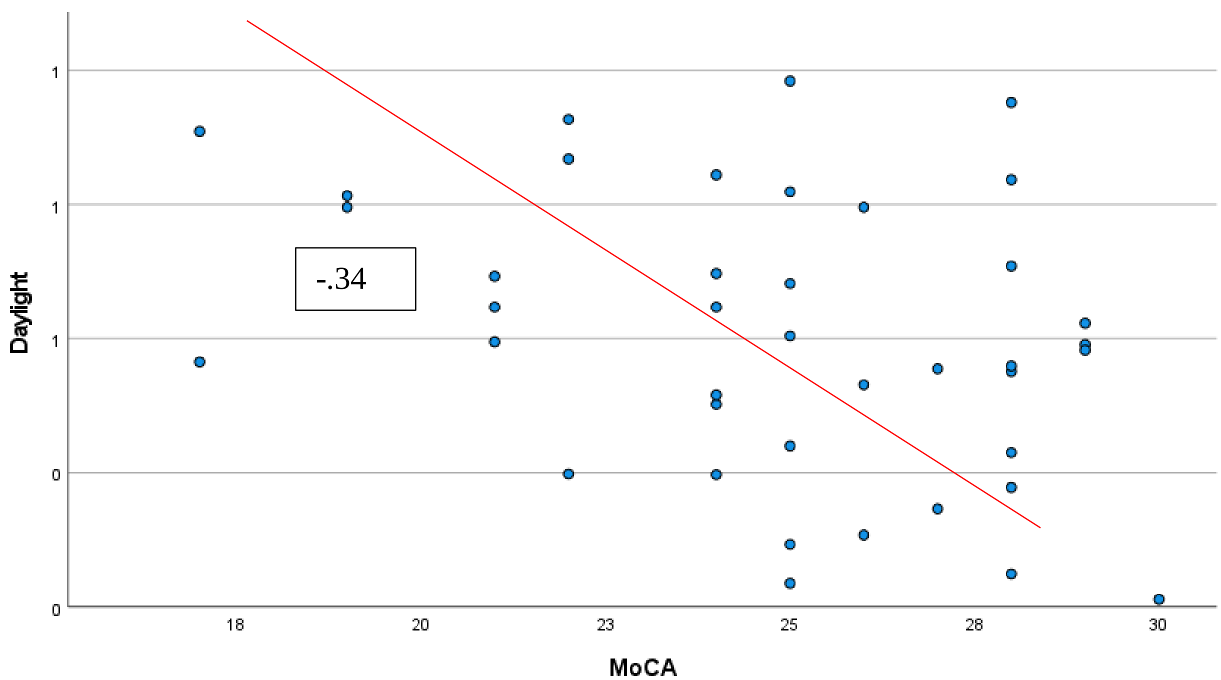
Note. *. Correlation is significant at the 0.05 level (2-tailed).

Correlation Between Clinical Assessment and Driving Behaviors

A significant relationship was found between only two, isolated comparisons, with both demonstrating negative, or inverse, relationships. The first, the relationship between amount of daylight driving and MoCA score, demonstrated a p-value of .03, with a correlation coefficient of -.34. The second, the relationship between number of trips and orienting ability on the P-Drive, demonstrated a p-value of .035 ($p < .05$), with a correlation coefficient -.33. Significant results have been visualized in Figures 10 and 11.

Figure 10

Scatterplot of Daylight by MoCA

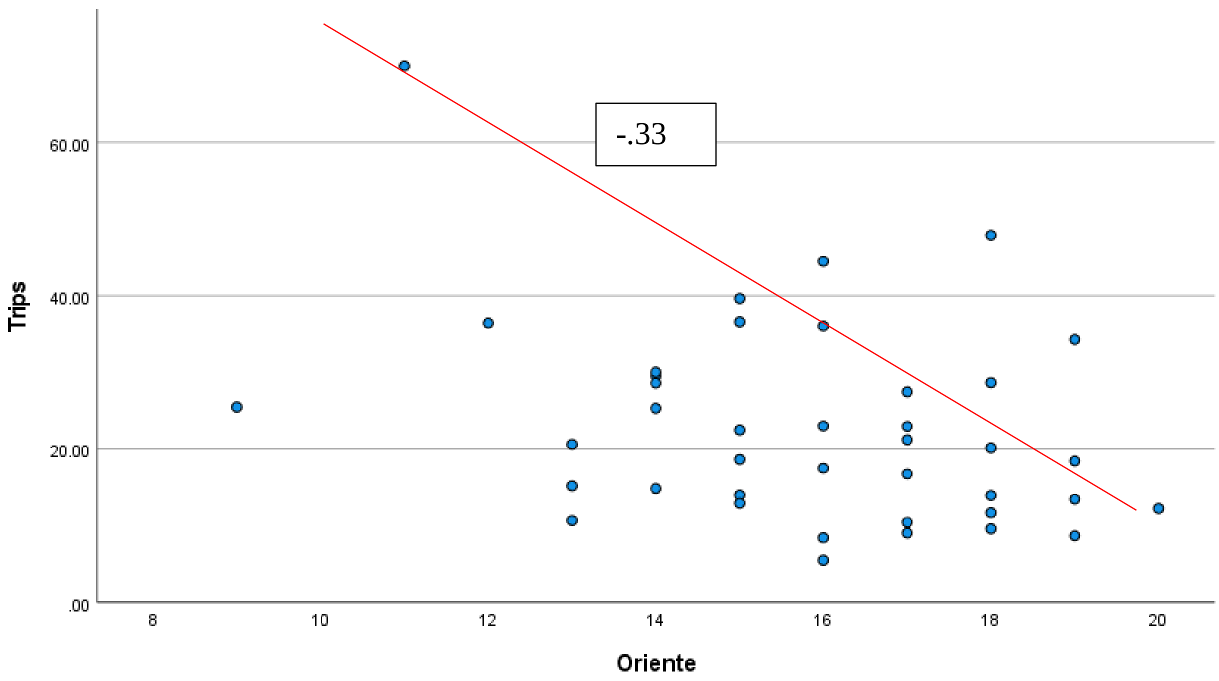


Note. Negative correlation between age and amount of aggression was significant ($p < .05$). r = -.34, p = .03.

Figure 11

Scatterplot of Number of Trips by Orients Subtest of P-Drive

Note. Negative correlation between number of trips and orients score of P-Drive was significant



($p < .05$). r = -.33, p = .035.

Modified Driving Habits Questionnaire and Daylight

Participants' amounts of daylight driving and self-rating of difficulty on the MDHQ were analyzed using a non-parametric test of correlation to provide further context to this finding. Though not significant, a negative relationship was found (r = -.27) between participants' self-rating of difficulty with night driving and their amount of driving during daylight hours.

Defining Performance by Groups

The analysis of variances and independent t-test models were used to supplement the correlational findings and to investigate more specific, isolated trends between the various independent variables and the driving behaviors. These tests used groupings of study participants based on age range, gender, and ranges of performance in the clinical assessments. No significant differences in naturalistic driving performance were noted based on participant performance on the MoCA, the AMPS, or participant gender groups. Table 9 displays results for each of the independent variables identified in the study, including age, gender, MoCA, P-Drive and AMPS process score groups.

Main Effect of Age Group

The age range (group) of participants was a significant, predictive factor of driving performance for aggressive driving. The youngest group of older adults (65-69) demonstrated the highest mean amount of aggressive driving behavior (.74), with the oldest drivers (80-89) demonstrating the lowest mean (.34). Using Tukey HSD post-hoc testing, it was determined that the difference between drivers aged 65-69 and drivers aged 70-79 demonstrated a significance level of $p = .003$. Though not significant, the difference between drivers aged 65-69 and drivers aged 80-89 demonstrated a much bigger difference than between drivers aged 70-79 and drivers aged 80-89.

Main Effect of P-Drive Performance

Significant differences were found in amount of daylight driving based on P-Drive performance ($p = .009$). Group performances were defined as excellent (95<), good (85-95), fair (80-85), and poor (<80). Using Tukey HSD post-hoc testing, it was determined that the differences were largest between poor drivers and good drivers ($p = .025$) and between good drivers and excellent drivers ($p = .02$).

Orientation and Number of Trips

Differences between groups based on each assessment category of the P-Drive were also tested. Though not significant, the largest difference between groups ($p = .065$) was found in number of trips taken based on difference in performance on the "orients" section of the P-Drive. Performance groups consisted of those who scored a 14 or below, those who scored between 15 and 17, and those who scored an 18 or higher.

Table 9

Differences in Naturalistic Driving Performance by Independent Variable

	Dependent variable							
	Aggression			Daylight			Trips	
Ind. variable	Mean (SD)	ANOVA p-value	Post hoc	Mean (SD)	ANOVA p-value	Post hoc	Mean (SD)	ANOVA p-value
Age								
65-69	.74 (.541)	0.004*	.003* (70-79) .080 (80-89)	.52 (.140)	0.06		25.40 (11.63)	0.128
70-79	.27 (.247)		.003* (65-69) .917 (80-89)	.59 (.215)			24.17 (14.21)	
80-89	.34 (.327)		.080 (65-69) .917 (80-89)	.77 (.237)			12.93 (5.94)	
Gender		t-test p-value			t-test p-value			t-test p-value
Male	.26 (.249)	.052		.61 (.232)	.416		20.82 (9.85)	.321
Fem.	.49 (.4588)			.59 (.204)			23.89 (14.60)	
MoCA		ANOVA p-value			ANOVA p-value		ANOVA p-value	
26-30	.49 (.38)	.529		.542 (.20)	.173		20.32 (10.63)	.233
22-25	.355 (.48)			.616 (.23)			22.23 (11.46)	
<21	.327 (.26)			.717 (.13)			30.25 (19.99)	
P-Drive								
Poor	.42 (.23)	.649		.39 (.16)	.009*	.222 (fair) .025* (good) .637 (excel)	20.73 (13.76)	.497

Fair	.27 (.24)			.64 (.19)		.222 (poor) .485 (good) .505 (excel)	28.76 (17.48)	
Good	.39 (.48)			.769 (.15)		.025* (poor) .485 (fair) .020* (excel)	22.05 (11.82)	
Excellent	.48 (.46)			.54 (.19)		.637 (poor) .505 (excel) .020* (good)	20.69 (11.33)	
AMPS								
>75%	.44 (.44)	. 081		.54 (.22)	.501		18.28 (10.18)	.386
25-50%	.28 (.27)			.64 (.23)			24.90 (15.14)	
<25%	.68 (.59)			.59 (.14)			23.95 (10.98)	

Note. *. Difference between groups is significant at the 0.05 level (2-tailed).

Multiple Regression Model

A multiple regression model was used to determine the presence and strength of the relationships found while controlling for possible covariates and to eliminate false positives. Table 10 describes the findings of this model. Based on these tests, little to no effects were noted for gender on the relationships present between independent and dependent variables. Age demonstrated a significant influence on both number of trips and amount of daylight driving.

Association Between Naturalistic Driving Behaviors and Age

When controlled for gender, a significant effect was found between age and 1) daylight driving, and 2) number of trips, at the .05 level. Amount of daylight driving demonstrated a significant value of $p = .033$, indicating that the amount of time driving during daylight hours increased with age. Number of trips demonstrated a significant value of $p = .045$, indicating that how often participants drove was also influenced by age. This is also indicated in Figures 6 and 7, which describe performance by age for both number of trips and amount of daylight driving.

Table 10

Regression Outcomes by Naturalistic Driving Behaviors

Aggression	F	Sig.
Corrected Model	2.35	.062
Gender	1.57	.219
	B	
Age	-.013	.293
Process	-.006	.052
MoCA	0.03	.139
P-Drive	.008	.456
Daylight	F	Sig.
Corrected Model	2.39	.058
Gender	0.61	.442
	B	
Age	0.01	.033*
Process Percentile	0.00	.825
MoCA	-.02	.083
P-Drive	.006	.321
Number of Trips	F	Sig.
Corrected Model	1.82	.136
Gender	0.93	.341
	B	
Age	-.81	.045*
Process Percentile	0.04	.725
MoCA	-1.38	.084
P-Drive	-.46	.214

Note. *. Result is significant at the .05 level.

5 - Discussion

As expected, raw age demonstrated a significant, negative correlation with aggressive driving indicating that instances of aggressive driving decline with age in a cognitively normal sample. However, this finding was not reciprocated in the multiple regression analysis, which found both number of trips and daylight driving, not aggressive driving, to be significantly associated with age. The difference in these outcomes indicates that a participant's number of trips driven is affected by their age, but not predictive of their age. This may further indicate that though older drivers may be more likely to limit their driving than younger drivers, there are other factors influencing why an older driver may or may not drive frequently. Since the multiple regression analysis controlled for the influence of gender on the sample, the effects of gender on performance may be one such factor influencing the significant relationship between age and aggressive driving. When looking at the breakdown of the sample, the number of male and female drivers aged 65-69 was low (only two males) than in the 70-79 or 80-89 age groups. Though gender was not a significant predictor of driving ability for any of the naturalistic behaviors studied, it may have had an influence on the relationships between age and naturalistic driving due to the sample's skewedness.

Results of data analysis found a significant difference in aggression between drivers in their 60s and drivers in their 70s. This may be explained by differences in driving habits between these age groups. Drivers in their 60s may still be working and taking regular commutes, may engage in more travel due to better overall health, and may feel more comfortable with risk-taking behavior than drivers in their 70s.

Influence of Age on Cognition

Drivers in their 80s demonstrated the lowest mean MoCA score (22.33), indicating that differences in cognition may have been an influential factor in this difference between groups. Interestingly, drivers in their 80s did not demonstrate the lowest mean process percentile (51%), however, they demonstrated the greatest variation in MoCA scores. This is likely due to the differences in skills measured between these two assessments. Additionally, one participant in the 80s group demonstrated an aggression value five times higher than the mean aggression of the remaining participants. With the outlier removed, the 80s group would have demonstrated the least aggression of the sample (.17). This participant also demonstrated the highest MoCA score of his age group, further suggesting a lack of relationship between the MoCA and aggression. Though not formally tested, drivers in their 80s tended to have poorer memory for recall on the MoCA, resulting in poorer scores. By contrast, drivers in their 60s with poor driving habits were more likely to demonstrate functional issues in cognition during AMPS task performance. Drivers in their 60s demonstrated the lowest mean process percentile (44%) and the (marginally) highest mean MoCA score (25.27). For drivers in their 60s, their aggression was most likely influenced by cognitive issues related to executive functioning, automatic processing, and planning/problem-solving, as measured in the AMPS. Therefore, the AMPS was a more reliable measure of driving aggression than the MoCA.

Bayat and colleagues' (2021) study found that age was the second most important indicator of pre-clinical AD, or pre-dementia, second only to cerebrospinal fluid biomarkers. Therefore, age was identified as not only a demographic factor within the sample to monitor and control, but also an essential variable for analysis. This research supports the finding that age is a relevant factor to driving behavior; those with the most aggressive driving were found as more likely to exhibit signs of "pre-dementia".

As established in the literature, cognitive decline in pre-dementia may begin to affect performance of instrumental activities, problem-solving skills, and executive functioning (Mansbach & Mace, 2018; Nguyen et al., 2020; Tangen et al., 2019). Therefore, based on the higher level of aggression in drivers in their 60s, there may be a higher likelihood that participants in this age range are diagnosable with pre-dementia and/or cognitive decline compared to those in the older age groups for this sample.

Amount of driving at night was the fourth most important factor in predicting pre-dementia in Bayat's study. Amount of daylight driving in the present study demonstrated a significant, positive correlation with age indicating that the amount of time participants drove during the day increased with age. In other words, there was a significant association between daylight driving and age. This supports Bayat's findings and other currently held findings that older drivers are less likely to drive at night than younger drivers, due to self-restricting their driving and changes in vision (Bergen et al., 2017; Naumann et al., 2011; Wood, 2019).

Roe and colleagues (2019) found that the number of trips driven by participants with pre-dementia declined significantly more than other groups over the course of 2.5 years of data collection. Because the timeline of this study was 20 weeks, the number of trips was not found to be significantly different between age ranges or significantly correlated with age in bivariate tests. However, the number of trips by participants took was found to be significantly associated with age in the multiple regression analysis, indicating that they are interrelated in some way. This finding does support the hypothesis that older drivers are more likely to self-restrict their driving as they increase in age. Overall, these results demonstrate that age was an influential factor in determining participant driving performance in terms of aggression, daylight driving, and number of trips.

Assessment of Motor and Process Skills

Research Question One: *Is there a relationship between naturalistic driving performance and performance of IADLs?*

A primary research question sought to examine the relationship between performance of an IADL as measured by the AMPS and naturalistic driving behaviors. It was hypothesized that participants with the lowest range of AMPS process scores, indicating lower cognitive functioning, would have the greatest number of naturalistic driving errors. Since the naturalistic driving behaviors included hard brakes, speeding, destinations, and number of trips, but not excessively slow driving and episodes of being lost, the only values that can be readily applied to AMPS performance are those related to driving aggression.

No significant differences were found between participants' driving behaviors based on their performance in the AMPS, nor was a linear relationship found between process skills and naturalistic driving behaviors. However, the trend shown between AMPS performance groups (low, average, high) was clear. Drivers with average AMPS performance exhibited the least amount of aggression, while those who performed both below and above average exhibited higher instances of aggression. The group with the lowest AMPS scores demonstrated the highest mean aggression of the three groups; specifically, they demonstrated one and a half times more aggression than the high-performance group and three times more aggression than the average-performance group. Therefore, participants with the lowest process score performance in the AMPS were, on average, the most aggressive drivers. The variance, or range in scores, was also largest in this low group.

While it is not surprising that the low AMPS group would have the greatest number of adverse driving behaviors, the expectation would then be that the high AMPS group would have the least. However, this was not true; the average group had the least amount of driving aggression. This finding does not support the hypothesis that individuals with cognitive decline are the most aggressive, exclusively. Rather, these findings may point to a parabolic trend in driving behavior based on process skills.

The pre-clinical AD group in Roe and colleagues' 2019 study were identifiable by demonstrating low aggression. This is the "pre-dementia" stage of the disease and does not appear to be manifested through neurological testing of cognitive performance. Rather, individuals with low aggression tended to perform in the average-range in the AMPS. Since no relationship was found between AMPS scores and aggression, this cognitively normal sample was likely not impaired enough in its naturalistic driving behavior nor in its AMPS performance to show what functional implications may result from cognitive impairment. However, the trends found suggest that with more driving data, (greater than 20 weeks and with more participants), a relationship between the AMPS and naturalistic driving outcomes may be identified.

Additional bivariate tests of correlation confirmed that a significant positive relationship was present between AMPS and MoCA scores ($p < .01$). Specifically, both scores demonstrated high cognitive performance when scores were higher. Individuals with sub-normal performance in the MoCA demonstrated lower performance in the AMPS as well. However, only the AMPS as a clinical measure demonstrated meaningful differences between groups based on aggressive driving. This is not surprising, as the MoCA is a *screening tool* for cognition while the AMPS is an established assessment tool for functional performance and will likely be more sensitive to cognitive aging and poorer performance in IADLs (Dickerson & Fisher, 1995, 1997) as well as driving performance outcomes (Dickerson et.al, 2011). Moreover, as driving has been found to be a highly relevant tool in predicting AD (Bayat et al., 2021), the AMPS may be a more reliable method of understanding, and predicting, pre-dementia and dementia behavior compared to standard, cognitive tests.

Montreal Cognitive Assessment

Research Question Two: *Is there a relationship between naturalistic driving behavior and cognitive measures?*

It was predicted that scores on cognitive measures (MoCA) would not be associated with aggressive driving behavior. As expected, no relationship between aggression and MoCA score was found. Additionally, no differences between groups of participants by MoCA score range were found for any of the driving behaviors studied, indicating that scoring in the “normal”, “MCI”, or “AD” ranges for MoCA were not predictive of aggressive driving, or adverse driving events. However, the MoCA’s significant relationship with participants’ amounts of daylight driving indicates that, as a cognitive screening tool, it may be relevant to understanding and predicting participants’ driving behavior patterns.

Participants with higher MoCA scores drove more during nighttime hours than those with lower scores. While it is worth noting that this implicates cognition as a relevant factor in ability to navigate at night, this relationship was not significant when controlled for age. Since the oldest drivers in the sample were more likely as an age group to have low MoCA scores, and also rarely drove at night, this relationship provides further support to the hypothesis that older drivers are more likely to self-limit their driving. It does not directly support that MoCA performance is indicative of driving skill. Regression analysis found that age was the only variable significantly associated with naturalistic driving behaviors when controlling for age and gender, meaning that the relationship between the MoCA and daylight driving was very likely influenced by age.

Also notable, is the low mean MoCA score of the sample (x = 24.83). This suggests that cognitive ability in screening tools alone, even when shown to be deficient, is not enough to predict driving performance. Rather, as illustrated by the case examples of participants 13 and 15, it requires evidence from a variety of tools to implicate a driver as medically fit or unfit to drive.

Performance Analysis of Driving Ability

Research Question Three: *Is there a relationship between naturalistic driving behavior and standardized driving assessment?*

Since the sample included cognitively normal older adults only, it was predicted that no participants would receive P-Drive a score that resulted in driving restrictions or cessation. However, three participants scored below the passing score (80). The study sought to determine if individuals with the poorest performance in the on-road assessments would also demonstrate the greatest number of aggressive driving behaviors. The three participants that scored below the passing score on the P-Drive demonstrated mild to moderate amounts of aggression (i.e., low ratio of events per drive) in comparison to the mean aggression of the sample (x = .41). This value illustrates that the mean number of events of aggression per drive across the sample was approximately 0.4. Participant 17 demonstrated a mean aggression value of 0.39, participant 32 demonstrated a mean aggression value of 0.21, and participant 42 demonstrated a mean aggression value of 0.66. Failure in on-road assessment was therefore associated with fewer instances of aggressive driving in two of the three drivers. Though these participants were considered the "worst" drivers during a standardized driving assessment, they were not the "worst" drivers according to the naturalistic driving data. This finding does not support the hypothesis that drivers with the lowest P-Drive scores would demonstrate the greatest number of aggressive driving events, meaning that low P-Drive scores did not predict pre-dementia driving behavior, or high aggression. Therefore, use of the P-Drive to detect preclinical dementia, a standardized on-road assessment, is not supported.

Several unmeasured factors may have contributed to this finding. Considering the lack of significant relationship between the P-Drive total scores and the naturalistic data collected, it is assumed that participants' driving performance in the P-Drive may be influenced by the presence of a rater. Participants may have been less likely to engage in aggressive driving behaviors while being observed by a rater, especially speeding. Based on the relationship established between driving self-awareness and cognitive self-awareness in older adults, drivers that know they are being assessed are likely to be cognizant and respectful of driving regulations like the speed limit, and likely also aware that to exceed the speed limit would affect their score (Paire-Ficout et al., 2021). Once the pressure of being observed is removed, these same individuals may be more likely to engage in speeding, which may also lead to increased instances of sudden stops. Additionally, though the number of trips and daylight conditions are highly controlled during participation in the P-Drive, these are up to the drivers' discretion during naturalistic data collection, and more of participants' natural and/or instinctual driving habituation directs the trends in the data.

Another possibility is that low performance in the P-Drive may not be associated with the naturalistic aspects of driving behaviors collected in this study. Low scores on the P-Drive may have been caused by excessively slow or hesitant driving that impedes the flow of traffic and/or slowed process skills for navigation; these behaviors would not show as aggressive driving. Though relevant to driving safety, these have not yet been associated with preclinical dementia in the literature (Bayat et al., 2021; Roe et al., 2017). In addition, there is some evidence that a standardized drive, typically 45-60 minutes, is not reflective of a person's true driving performance which is why further research on naturalistic driving is essential (Dickerson et al., 2014b)

However, a significant difference was found in amount of daylight driving between P-Drive performance groups. These groups included "poor" drivers (score of 79 or less), "fair" drivers (score of 80-84), "good" drivers (score of 85-89), and "excellent" drivers (score of 90 or more). Tukey's HSD post hoc tests revealed the differences between groups were significant between "poor" and "good" drivers, and between "good" and "excellent" drivers. "Poor" drivers drove at night most often ($x = .39$) and significantly more than "good" drivers, who drove during the day most often ($x = .77$). Excellent drivers were evenly split between day and night driving ($x = .54$), with significantly less daylight driving time than "good" drivers. It should be noted that nearly half of the sample ($n = 19$) scored in the excellent range which supports the majority of older drivers are driving without demonstrating risky behavior.

These observations may be explained by two possibilities: 1) that good drivers are conscientious enough to restrict their driving as needed and 2) that excellent drivers have equal levels of day and night driving comfortability due to their skill level. Older drivers that tested in the "good" range may be more likely than those in the "poor" range to attend to their limitations and make informed choices on when and how they should drive, leading to less time driving at night. Those that tested in the "excellent" range are likely aware of their skills and have maintained the ability to drive at night without self-restricting. Since self-awareness is relevant to these theories, the Modified Driving Habits Questionnaire was used for further investigation.

Modified Driving Habits Questionnaire and Daylight Driving Habits

Comparison of daylight driving time and self-rating of difficulty with night driving on the MDHQ revealed that as participants lowered in their self-ratings, the amount of time they spent driving during the day increased. This suggests not only that this sample was fairly self-aware of their driving habits, but also that some drivers in the sample were likely to limit their driving to daylight hours based on their level of difficulty with driving at night. This relationship was not significant in this sample, but was the only trend present between elements of the MDHQ and driving outcomes. Therefore, self-rating remains a questionable measure of participants' driving quality, but can be valuable to determining driving habituation, as in the case of time spent driving during the day.

Orients Subtest of the P-Drive

Results demonstrated that the number of trips taken by participants increased as their performance in the "orients" items of the P-Drive decreased. Therefore, drivers with poorer orientation skills took more trips during the course of the study. *Number of trips* was the only driving behavior found to be significantly correlated with scores in the P-Drive, despite the presence of significant differences in daylight driving between P-Drive performance groups. This may have been because these differences exist between only two pairs of performance groups, rather than between all of the performance groups.

The "orients" items of the P-Drive include following instructions (i.e., turn right at the next intersection), wayfinding, positioning on road (i.e., lane maintenance), keeping distance from other vehicles, and planning (i.e., you will need to turn left in half a mile). Compared to the other components of the P-Drive (maneuvers, following regulations, and heeding), orienting tasks require the highest level cognitive or process skills for success. When considering Michon's hierarchy, this component of the assessment would fall under the top tier of skills or, "strategic" level driving behavior. The relationship found between "orients" score and number of trips is difficult to understand based on this interpretation. What influence can orientation skills have on the amount a person chooses to drive? To understand this relationship further, the variety and distance of trips must be considered, as this is what most likely relates to issues of navigating one's environment, as the items in "orients" represent.

Case Examples

Participant 13 is a 65-year-old, female driver who demonstrated an "orients" score of 9/20. Based on location data provided by the G2 chip, participant 13 drove to more unique locations on average (14.53) than the mean number of locations of the sample (12.11), but drove a much smaller distance from her primary location on average (10.52 miles), compared to the mean distance of the sample (19.55 miles). By contrast, participant 15, a 76-year-old female, demonstrated an "orients" score of 20/20, drove to fewer unique locations on average than the sample (9.90), and drove a much greater distance from her primary location on average (204.4 miles). These two participants demonstrate inverse outcomes in both distance and variety of locations, as well as in their performance in the "orients" items of the P-Drive. This suggests that the relationship found between number of trips and orienting ability may reflect the influence of driving confidence on number of trips taken. Participant 15 was much more likely to drive further distances and, it is assumed, that she was successful in her navigation of those routes based on her performance in orientation skills of the P-Drive. Participant 13, however, drove a much more conservative distance from home. The increased number of unique locations may also be due to episodes of getting lost due to difficulty with orientation as reflected in her P-Drive orients score. It should be noted that in Roe and colleagues' 2019 study using geolocation, participants identified as having pre-clinical AD drove to fewer unique locations, but still demonstrated the smallest radius of miles driven from home. In Roe and colleagues' 2017 study, no difference was found in driving space between groups, however this was based on self-reports.

Though no significant relationship was found between the “orients” scores and aggressive driving behavior, a trend was found based on grouping participants by range of performance in “orients” items. Participant 13 demonstrated above average aggression (.79), a below average MoCA score (21) and scored in the 38th percentile for AMPS process performance. This participant’s overall performance demonstrates higher aggression paired with lower cognitive ability. By contrast, participant 15 demonstrated below average aggression (.34), the highest score on the MoCA (29), and scored in the 78th percentile for AMPS process performance, pairing lower aggression with higher cognitive ability. This supports the hypothesis that cognitive ability, as demonstrated in a variety of clinical assessments, is influential in a person’s driving behavior and, furthermore, is able to be identified in objective measures of naturalistic driving.

6 - Implications for Occupational Therapy Practice

Occupational therapy as a profession has an established role in driving rehabilitation and community mobility intervention. The client factors that affect a person's ability to sustain active participation in their community are of great importance to the occupational therapy practitioner's approach to driving rehabilitation and clinical decision-making concerning driving cessation. It has also been established that these client factors, such as cognition, visual perception, and motor skills, are integral to occupational participation of all kinds, and are both observable and assessable in a person's performance of a variety of everyday tasks. Driving is not typically used as an assessment of client factors and abilities. Rather, a person's client factors are assessed using comprehensive driving evaluation to determine what barriers to driving performance are present and if they can be resolved. However, since driving is a complex IADL that recruits multiple cognitive functions, it may be possible to use driving performance as an assessment of client cognitive status.

The results of the present study implicate naturalistic driving data as a previously untapped resource of clinical information concerning cognition for occupational therapy practitioners. This offers up driving data as a potential resource for studying the pathologies of aging and their influence on the functional abilities of older adults. More importantly, the naturalistic driving behaviors studied were representative of clinical performance in each occupational therapy assessment studied. We currently know and understand that dementia deteriorates occupational independence, but we can now see that even in individuals with "normal" cognition, the effects of aging and pre-clinical dementia influence the performance quality of IADLs, including driving. As practitioners that address the occupation of driving, occupational therapists should be aware of this change in performance quality, even in the early stages, so that we may be advocates for the safety, well-being, and self-awareness of those we serve. As driving aggression has been linked to performance of the AMPS, this implicates the AMPS as a valuable screening tool for the cognitive changes that affect performance quality. It can be used by occupational therapists to assess these cognitive changes that may be pre-clinical, and use this information to both educate and intervene ahead of the progression of cognitive decline.

These results also offer confirmation of the trends seen in older adults' driving habituation. These may also have immense value to early detection of cognitive decline. The relationship found between the "orients" items of the P-Drive and number of trips driven implicates strategic-level driving skills as influential in participants' driving patterns and routines. The amount of time spent driving during daylight hours was significantly correlated with two of the three measures, as well. Since the MoCA and P-Drive were indicators of driving restriction, the inverse is potentially also true: self-restricted driving may be indicative of subnormal cognition and/or driving skill.

It is important to note the influence of age on significant results demonstrated by the MoCA. This influence reduces the reliability of the MoCA as a screening for driving fitness, especially when used alone. Since both age and MoCA score were related to amount of daylight driving, it is much simpler to use age as a predictive factor over administering a test. This is also implicated in Bayat and colleagues' 2021 study, which found that age was a stronger predictor of pre-dementia than any of the cognitive measures used.

The trends identified in aggressive driving behavior in this sample are arguably the most relevant to the future of occupational therapy practice. Compared to the other behaviors studied, aggression is most relevant to driving quality and was tied to cognitive performance not in screening measures (MoCA), but in functional measures (AMPS). Members of the low-performing AMPS group, which demonstrated the greatest number of aggressive behaviors, may therefore be more likely to experience a crash as a result of impairments of processing speed and efficiency. This assumption implicates functional performance and naturalistic driving data as comparable measures of the cognitive processing delays seen in pre-clinical dementia. This is in contrast to the long-standing use of the MoCA as a screening tool of cognition for both dementia and for driving fitness. It also strengthens the argument that the AMPS is a clinically relevant tool to the identification of functional cognitive impairment and even to the detection of early cognitive decline. The relationship found between aggression and age is also of notable importance, as this supports the findings of Bayat and colleagues (2021), that age and driving behavior together are the strongest predictor of dementia second to genetic testing. Furthermore, this relationship was found in a sample of cognitively normal older adults.

Due to the connections between the AMPS, naturalistic driving outcomes, and the previous, groundbreaking research linking driving and pre-dementia, the AMPS may be implicated as a viable screening tool for pre-clinical cognitive decline. As an assessment used by the general occupational therapist, administration of the AMPS could allow practitioners everywhere to assess and intervene in the cognition of our older adult population, preventing both driving and occupational accidents and increasing clients' awareness of deficits for their own safety and the betterment of their quality of life.

7 - Limitations

Sample

Possible limitations to the study included relatively small sample size, lack of equal groups by age and gender, lack of diversity by race, and use of convenience sampling methods. Though the sample size (n = 40) supported the use of most statistical measures, the power of the results found may have been increased with a greater number of participants. This limitation was reduced by the researcher's provision of compensation for participation.

The lack of diversity within the sample was largely influenced by the use of convenience sampling. Recruitment occurred in a small geographical region, reducing sample diversity and encouraging those that lived in similar areas, such as a nursing home or neighborhood, to participate. Thus, findings may not be generalizable to the overall population and systematic error may have occurred.

Another possible limitation to the study was the surprisingly low mean MoCA score of the sample. Since the mean cognitive score for the sample fell in the range of mild cognitive impairment (24.82), and the standard deviation was fairly large (3.24), the variance in cognitive skills amongst the sample most likely influenced statistical results and their ability to represent a "cognitively normal" sample. However, there remains some debate in the literature concerning the value of cutoff scores for cognitive impairment.

Data Interpretation

Despite the use of advanced, well-researched technologies in this study, multiple phases of collaboration were required to obtain naturalistic driving data. The numerical values determined for each behavior were first interpreted based on the output from each chip by the collaborating team of researchers at Washington University. To interpret this output appropriately, the unique circumstances of each participants travel plans, if they shared their vehicle, and if the vehicle were undergoing repairs, had to be communicated and considered in the process. Once these values were computed, the data was then transferred to the team of researchers at East Carolina University. Both automatic (i.e., Excel) and manual mathematical calculations were then used to compute behavior values used in statistical analysis. Due to the multiple layers of processing, the likelihood for human and technological error was increased and, therefore, the likelihood of statistical error as well.

Additionally, the G2 tracking device used in the study was unable to communicate the circumstances of each event tracked, reducing understanding of the role of cognition in the case of each event. For example, an event of hard braking may have occurred because of another driver's mistake, but this is not trackable using the available technology.

Naturalistic Setting

Other limitations of the study are related to the use of a naturalistic setting for data collection. Participants' decisions to make trips, drive at certain times of day, engage in speeding or hard acceleration, and many other aspects of their driving performance patterns were likely influenced by a multitude of uncontrollable and unknowable factors related to their daily lives, schedules, and life changes throughout the participation period. The 20-week period of data collection was an intentional element of the research methods aimed at reducing the statistical likelihood of multiple, adverse and/or unlikely driving events occurring within the research period. Some participants were unable to complete 20 weeks of data collection for this reason, and their inclusion in analyses was based on the number of weeks they were able to participate.

As mentioned above, the influence of other drivers is constant when driving in a naturalistic setting, and most likely influenced participant performance in some way. Despite these effects, this limitation was essential to the purposes of the research and was not easily preventable. Adaptation of the research methods and the inclusion of additional technologies may be able to resolve this issue in future studies.

Data Collected

The G2 chip used was able to provide insight into participant location, acceleration and deceleration, start and stop times, and time of day driven, as well as sudden shifts in direction of the vehicles. Difficulties with data interpretation and collection limited the ability of the researchers in the present study to collect, interpret, and analyze vehicle jerk, or hard cornering, which has been shown to be one of the most significant factors in aggressive driving related to AD (Roe et al., 2019; Bayat et al., 2021). This may have limited the significance of the relationships between aggressive driving and the clinical assessments tested, and/or differences between performance groups. Despite this limitation, trends continued to show that speeding and braking are relevant to functional performance per trends seen in the AMPS. Inclusion of vehicle jerk in future studies will expand the body of data available for comparison with AMPS performance.

8 - Future Research

To combat these limitations, increase statistical power, and determine further implications of the results found, future studies should aim to increase the sample in both size and diversity. Larger, more diverse samples are more likely to contain equal groups by gender, race, and age, and would support sound statistical analyses between each of these groups. Due to the lack of diversity, race was unable to be considered as an independent variable in this study; however, future research may be able to determine relationships between race and naturalistic driving with an adequate sample size. Collection of vehicle jerk data should also be included and incorporated into the aggression value, or analyzed as a separate value, for each participant.

Future research should also consider use of additional technologies and/or research methods to visualize the context in which naturalistic driving behaviors occur, as they occur. The use of in-car video cameras would be able to capture the road ahead as participants drive for researchers to use as an additional source of data for comparison with the data collected by the G2 chip. Additionally, future research could consider the addition of semi-structured, periodic interviewing of participants to the research methods. This would allow researchers to gain further insight on participant driving habits as well as provide opportunities to clarify anomalies in the data as they occur (e.g., returning to the same location multiple times in one drive, sudden changes in driving behavior, presence of additional drivers, etc.).

Changes in inclusion criteria of future participants could expand the relevance and influence of this research in the fields of occupational therapy and geriatric health. Inclusion of participants with various medical diagnoses, both physical and mental, would increase the variation of driving and functional abilities within the sample to be compared with healthy, cognitively normal controls. This comparison also has the potential to strengthen the existing evidence of cognition's influence on driving ability as well as driving habituation.

9 - Conclusions

Trends in driving aggression were reflected in the process performance of the sample, linking the quality of driving to the quality of performance in IADLs. Established trends of driving restriction were confirmed by the relationships seen between age, cognition, and daytime driving. And finally, the amount of driving done by participants fluctuated based on their navigation abilities.

Our longevity as human beings pose many benefits to our world, however the diseases of old age that were once rare are now increasingly common. To protect our oldest populations and promote quality of life well into old age, addressing the warning signs of dementia is essential for proactive care and planning. Use of a single tool to identify these signs would reduce the amount of cost, risk, and inconvenience that current methods of early detection pose to our society.

In this study, naturalistic driving performance, as a single measure, was able to reflect differences in performance in all clinical assessments used. Driving behavior profiles developed from such data may, therefore, may have the ability to describe and anticipate an individual’s cognitive and performance skills as related to the deficits often seen in clinical and pre-clinical AD. Furthermore, the established connection between performance in IADLs (as measured by the AMPS) and amount of aggressive driving behavior reflects the intensifying body of evidence that functional performance is a more accurate and thorough measure of cognitive impairment. As both IADL performance and driving performance rely on the use of functional cognition, both of these performance measures provide insight into cognitive abilities without the need for invasive procedures, and do so with greater accuracy than cognitive screenings. The results of this study have expanded the possibilities for occupational therapy practitioners to provide valuable assessment and intervention to the cognitively impaired and general population as the frequency of AD diagnoses grows. In future research, the expansion and diversification of samples both in background and ability, as well as the addition of naturalistic driving variables using advanced technologies, will strengthen and clarify the understandings of these relationships and their contribution to the early prediction of AD in older adults.

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Appendix A.

IRB APPROVAL LETTER

EAST CAROLINA UNIVERSITY
University & Medical Center Institutional Review Board
4N-64 Brody Medical Sciences Building· Mail Stop 682
600 Moye Boulevard · Greenville, NC 27834
Office **252-744-2914** · Fax **252-744-2284** ·
rede.ecu.edu/umcirb/

Notification of Amendment Approval

From: Biomedical IRB
To: Anne Dickerson
CC:
Date: 1/28/2022
Re: Ame6_UMCIRB 20-000236
UMCIRB 20-000236
Examining older adult driving performance

Your Amendment has been reviewed and approved using expedited review on 1/27/2022. It was the determination of the UMCIRB Chairperson (or designee) that this revision does not impact the overall risk/benefit ratio of the study and is appropriate for the population and procedures proposed.

Please note that any further changes to this approved research may not be initiated without UMCIRB review except when necessary to eliminate an apparent immediate hazard to the participant. All unanticipated problems involving risks to participants and others must be promptly reported to the UMCIRB. The investigator must submit a Final Report application to the UMCIRB prior to the Expected End Date provided in the IRB application. If the study is not completed by this date, an Amendment will need to be submitted to extend the Expected End Date. The investigator must adhere to all reporting requirements for this study.

Approved consent documents with the IRB approval date stamped on the document should be used to consent participants (consent documents with the IRB approval date stamp are found under the Documents tab in the study workspace).

The approval includes the following items:

Document	Description
Adding Skylar Rogan and Madison Rogan to the study team.	

For research studies where a waiver or alteration of HIPAA Authorization has been approved, the IRB states that each of the waiver criteria in 45 CFR 164.512(i)(1)(i)(A) and (2)(i) through (v) have been met. Additionally, the elements of PHI to be collected as described in items 1 and 2 of the Application for Waiver of Authorization have been determined to be the minimal necessary for the specified research.

The Chairperson (or designee) does not have a potential for conflict of interest on this study.

IRB00000705 East Carolina U IRB #1 (Biomedical) IORG0000418
IRB00003781 East Carolina U IRB #2 (Behavioral/SS) IORG0000418

Appendix B.

PARTICIPANT CONSENT FORM

Informed Consent to Participate in Research
Information to consider before taking part in research that has
no more than minimal risk.

Title of Research Study: Examining older adult driving performance.
Principal Investigator: Dr. Anne Dickerson (Person in Charge of this Study)
Department: Occupational Therapy Department
Address: 1330 Health Sciences Building
Telephone #: 252-744-6190

Researchers at East Carolina University (ECU) study issues related to society, health problems, environmental problems, behavior problems and the human condition. To do this, we need the help of volunteers who are willing to take part in research.

Why am I being invited to take part in this research?
The purpose of this research is to explore how older adult everyday driving over a period of 20 weeks compares to driving a simulator, performance of other everyday tasks, and a comprehensive driving evaluation. You are being invited to take part in this research because you are a healthy volunteer. The decision to take part in this research is yours to make. By doing this research, we hope to learn if the comprehensive driving evaluation and an interactive driving simulator are accurate measures of a person's everyday driving. If you volunteer to take part in this research, you will be one of about 80 people to do so.

Are there reasons I should not take part in this research?
As a healthy volunteer over 65 years old, there is no more than usual risk in taking part of this study, as long as you are healthy, have a valid driver's license, drive at least 4 times a week, and are primary driver of your vehicle. Your vehicle must be no older than 2000. You will be asked to use an interactive driving simulator and as such, could develop simulator sickness. However, we take every precaution to prevent the occurrence, will monitor you the entire time and stop immediately if you indicate you feel any change.

What other choices do I have if I do not take part in this research?
You can choose not to participate. If you cannot tolerate the driving simulator, you will be able to participate in the other components.

Where is the research going to take place and how long will it last?
The research will be conducted at the ROADI lab, Room 1330, at the ECU's Health Science Campus. You will need to come to the lab three to four times. The first time will be to sign the consent and the installation of a computer chip in your vehicle, taking about 15 minutes. The second time will be an initial assessment for 2 hours. The third time will be a 45 minute on road drive. The fourth time will be a 45-minute simulated drive and taking the computer out after 20 weeks. The total amount of time you will be asked to volunteer for this study is 4.5 hours of direct participation and passive collection of driving data of 20 weeks in which you do not do anything.

What will I be asked to do?
You will be asked to do the following:
1. Sign the consent form with a detailed description of what you will do by a research team member.
2. A computer chip will be inserted in your vehicle into your OBD2 port. This will collect the data of your driving over the next 20 weeks after the first steps are completed and you continue to qualify for the study. <u>**This data will NOT be shared with the NC Department of Motor Vehicles, law enforcement or any**</u>

authorities, only members of the research team. After the 20 weeks, you will return to get the chip removed.

3. Complete a comprehensive driving evaluation during the 20 week period. This includes the following assessment tools: Modified Driving Habits Questionnaire (asking where and how much you drive), Assessment of Motor and Process Skills (two kitchen activities), Montreal Cognitive Assessment, Comprehensive Trail Making test (paper and pencil test), Vision testing on the Optec (visual acuity, glare recovery, peripheral vision, visual perception), Brake and force reaction timer (measure brake reaction time and how much force you can push), Free and cued selective reminding test, Vision Coach (scanning and processing speed) and scanning activities on a simulator and P-Drive (a scoring criteria for measuring your performance on the road and on the simulator).
4. The comprehensive driving evaluation also includes a 45 minute drive in Greenville in your vehicle with a research member as a passenger in the vehicle. This can be done the same or different day, will be done only in good weather and at non-rush hour times.
5. A simulated drive on an interactive driving simulator, which will be take approximately 45 minutes including accommodation to the simulator.

What might I experience if I take part in the research?
We don't know of any risks (the chance of harm) associated with this research. Any risks that may occur with this research are no more than what you would experience in everyday life. We don't know if you will benefit from taking part in this study. There may not be any personal benefit to you, but the information gained by doing this research may help others in the future.

Will I be paid for taking part in this research?
We will be able to pay you for the time you volunteer while being in this study. Based on the time, you receive $75 for completing the comprehensive driving evaluation, $50 for completing the on road drive, and $25 for completing the drive on the driving simulator. After having the driving chip in your vehicle for 20 weeks you will return to the lab to extract the chip and be paid $150.

Will it cost me to take part in this research?
It will not cost you any money to be part of the research.

Who will know that I took part in this research and learn personal information about me?
ECU and the people and organizations listed below may know that you took part in this research and may see information about you that is normally kept private. With your permission, these people may use your private information to do this research:

- The University & Medical Center Institutional Review Board (UMCIRB) and its staff have responsibility for overseeing your welfare during this research and may need to see research records that identify you.

How will you keep the information you collect about me secure? How long will you keep it?
The data from this study will be kept with for at six years. Where this is a place for your name on any paper assessments, instead, you will have an identification number to be used on these and electronic data. The only video data will be on the simulator, which does not record your face or voice, only the performance on the simulator. These recordings are kept and potentially may be used in training. The research data will be kept on computers with passwords and all data will be entered into a RedCap spreadsheet or on the PI's piratedrive. Future use of the data will have no links to your name. While identifiers might be removed from the identifiable private information and, after such removal, the information could be used for future research studies or distributed to another investigator for future research studies without additional informed consent from you or your Legally Authorized Representative (LAR). However, there still may be a chance that someone could figure out the information is about you.

What if I decide I don't want to continue in this research?
You can stop at any time after it has already started. There will be no consequences if you stop and you will not be criticized. You will not lose any benefits that you normally receive.

Who should I contact if I have questions?
The people conducting this study will be able to answer any questions concerning this research, now or in the future. You may contact the Principal Investigator at 252-746190 (between 9-5 Monday -Friday).

If you have questions about your rights as someone taking part in research, you may call the University & Medical Center Institutional Review Board (UMCIRB) at phone number 252-744-2914 (days, 8:00 am-5:00 pm). If you would like to report a complaint or concern about this research study, you may call the Director for Human Research Protections, at 252-744-2914.

Is there anything else I should know?
Identifiers might be removed from the identifiable private information and, after such removal, the information or biospecimens could be used for future research studies or distributed to another investigator for future research studies without additional informed consent from you or your Legally Authorized Representative (LAR). However, there still may be a chance that someone could figure out the information is about you.

Most people outside the research team will not see your name on your research record. This includes people who try to get your information using a court order. Information about your driving performance will only be given to you if you request it. It will not be shared with your physician, the NC DMV or law enforcement. If you request the information, it will be summarized and shared with you by the principal investigator. Content on the computer chips may not be available until weeks to months after your participation, and thus may not be available to share.

I have decided I want to take part in this research. What should I do now?
The person obtaining informed consent will ask you to read the following and if you agree, you should sign this form:

- I have read (or had read to me) all of the above information.
- I have had an opportunity to ask questions about things in this research I did not understand and have received satisfactory answers.
- I know that I can stop taking part in this study at any time.
- By signing this informed consent form, I am not giving up any of my rights.
- I have been given a copy of this consent document, and it is mine to keep.

____

Participant's Name (PRINT) **Signature** **Date**

Person Obtaining Informed Consent: I have conducted the initial informed consent process. I have orally reviewed the contents of the consent document with the person who has signed above, and answered all of the person's questions about the research.

____

Person Obtaining Consent (PRINT) **Signature** **Date**

Consent to Collect, Use and Disclose Social Security Numbers

IRB Study Number: UMCIRB 20-000236

Principal Investigator: Anne Dickerson

Payments $100.00 or more for tax reporting obligations:
You are not required to provide your Social Security Number to participate in this study. However, to receive a study participation payment totaling $100.00 or more for this study, you will need to provide your Social Security Number to the University so that the University and you comply with tax reporting laws. If you are/have received payment from participating in other studies, you also will need to provide your Social Security Number. If you do not provide your Social Security Number, we cannot provide you a study participation payment totaling $600 or more in a calendar year. However, you may still choose to participate in this study by checking the second circle below. For minors (less than the age of 18), the parent or guardian's social security number will be requested.

Please check the box signifying which payment methodology you are utilizing (required):

☐ ***Greenphire debit ClinCard:***
The research coordinator will ask you to verbally give your Social Security Number to be typed directly and into the secure Greenphire system. No written record will be maintained for this personal data. The personal data you provide is stored in a secure electronic database that has access limited to only those who need to know your information. Greenphire employs reasonable precautions to prevent your personal data from loss, misuse, unauthorized access, disclosure, alteration or destruction.

☐ ***Studies not utilizing the Greenphire debit ClinCard:***
My research coordinator/nurse will provide me with a copy of the Vendor Information Form and help me complete the form. The coordinator/nurse will then return the completed form on my behalf. I understand that means the research coordinator will know my personal information, including my Social Security Number.

○ I am willing to provide my Social Security Number so that I can be paid for participation in this study. It is federal law that payments totaling $600 or more in a calendar year must be reported to the IRS for tax purposes.

○ I choose not to provide my Social Security Number. I understand that I will not be able to receive a study participation payment totaling $600.00 or more within a calendar year unless I provide my Social Security Number.

Foreign Nationals: Payments to Foreign Nationals for their participation in research studies conducted in the United States may be subject to backup withholding pursuant to Internal Revenue Code Section 1441(a). The University must determine, on a case by case basis, if backup withholding is required on remunerations paid to Foreign National participants. The University may be required to withhold tax from the gross amount due to the Foreign National at the applicable rate (potentially up to 30%) as determined by the

International Tax Office. Research coordinators, please contact Accounts Payable office at participant_payments@ecu.edu to determine the methodology of payment and possible withholdings.

Reference: US Code Title 26; Subtitle F; Chapter 61; Subchapter B; Section 6109 &; N.C. Gen Stat. 132-1.10 Social Security Number and other Personal Identifying Information; N.C. Gen Stat. 143-64.60 State Privacy Act.

Printed Name ____

Signature ___________________________________, Date ______________

Revised 3/11/2020

Appendix C.

MODIFIED DRIVING HABITS QUESTIONNAIRE

Current Driving

1. Do you wear glasses or contacts when you drive? ____ Yes ____ No

2. Do you wear a seatbelt when you drive? ____ Always ____ Sometime ____ Never

3. Which way do you prefer to get around?
   ____Drive yourself
   ____Have someone drive you
   ____Use public transportation or a taxi

4. How fast do you usually drive compared to the general flow of traffic?
   ____Much faster ____Somewhat slower
   ____Somewhat faster ____Much slower
   ____About the same

5. Has anyone suggested over the past year that you limit your driving or stop driving?
   ____ Yes ____ No

6. How would you rate the quality of your driving?
   ____ Excellent ____ Good ____ Average ____ Fair ____ Poor

7. If you had to go somewhere and didn't want to drive yourself, what would you do?
   ____ Ask a friend or relative to drive you
   ____ Call a taxi or take the bus
   ____ Drive yourself regardless of how you feel
   ____ Cancel or postpone your plans and stay at home
   ____ Other (specify):____________________________

Exposure

8. In an average week, how many days per week do you normally drive? ____ days per week

9-11. Please pause for a minute and consider all the places you drive in a typical week. Check those places and tell me how many times per week and the number of miles.

____ Store	____ How many times a week?	____ Miles from home
____ Church	____ How many times a week?	____ Miles from home
____ Work/School	____ How many times a week?	____ Miles from home
____ Relative's Home	____ How many times a week?	____ Miles from home
____ Friend's Home	____ How many times a week?	____ Miles from home
____ Out to eat	____ How many times a week?	____ Miles from home
____ Appointments	____ How many times a week?	____ Miles from home

Are there other places you go in a typical week?

______________	____ How many times a week?	____ Miles from home

_____________ ____ How many times a week? ____ Miles from home
_____________ ____ How many times a week? ____ Miles from home

Avoidance

13a. During the past 3 months, have you driven while it has been raining?

____ Yes (go to 13b)
____ No (go to 14)

13b. Would you say that you drive when it is raining with: (please check only one answer)

____ No difficulty at all
____ A little difficulty
____ Moderate difficulty
____ Extreme difficulty

14a. During the past 3 months, have you driven alone?

____ Yes (go to 14b)
____ No (go to 15)

14b. Would you say that you drive alone with: (please check only one answer)

____ No difficulty at all
____ A little difficulty
____ Moderate difficulty
____ Extreme difficulty

15a. During the past 3 months, have you parallel parked?

____ Yes (go to 15b)
____ No (go to 15c)

15b. Would you say that you parallel park with: (please check only one answer)

____ No difficulty at all
____ A little difficulty
____ Moderate difficulty
____ Extreme difficulty

15c. Why do you not parallel park

____ Not necessary – not many parallel parking spots
____ Visual Problems
____ Never learned how
____ Other (specify): ___________________

16a. During the past 3 months, have you made left-hand turns across oncoming traffic?

____ Yes (go to 16b)
____ No (go to 17)

16b. Would you say that you make left-handed turns in traffic with: (Check one answer)

____ No difficulty at all
____ A little difficulty
____ Moderate difficulty
____ Extreme difficulty

17a. During the past 3 months, have you driven on interstates or expressways?

____ Yes (go to 17b)

____ No (go to 18)

17b. Would you say that you drive on interstates or expressways with: (Check one answer)

____ No difficulty at all

____ A little difficulty

____ Moderate difficulty

____ Extreme difficulty

18a. During the past 3 months, have you driven on high-traffic roads?

____ Yes (go to 18b)

____ No (go to 19)

18b. Would you say that you drive on high-traffic roads with: (Check one answer)

____ No difficulty at all

____ A little difficulty

____ Moderate difficulty

____ Extreme difficulty

19a. During the past 3 months, have you driven in rush hour traffic?

____ Yes (go to 19b)

____ No (go to 20)

19b. Would you say that you drive in rush hour traffic with: (Check one answer)

____ No difficulty at all

____ A little difficulty

____ Moderate difficulty

____ Extreme difficulty

20a. During the past 3 months, have you driven at night?

____ Yes (go to 20b)

____ No (go to 21)

20b. Would you say that you drive at night with: (Check one answer)

____ No difficulty at all

____ A little difficulty

____ Moderate difficulty

____ Extreme difficulty

Crashes and Citations

21. How many accidents have you been involved in over the past year when you were the driver? Please tell me the number of all accidents, whether or not you were at fault.

____ accidents

22. How many accidents have you been involved in over the past year when you were the driver where the police were called to the scene?

____ accidents

23. How many times over the past year have you been pulled over by the police, regardless of whether you received a ticket?

____ times

24. How many times in the past year have you received a traffic ticket (other than a parking ticket) where you were found to be guilty, regardless of whether or not you think you were at fault? ____ times

Driving Space

25. During the past year, have you driven in your immediate neighborhood?

____ Yes ____ No

26. During the past year, have you driven to places beyond your neighborhood?

____ Yes ____ No

27. During the past year, have you driven to neighboring towns?

____ Yes ____ No

28. During the past year, have you driven to more distant towns?

____ Yes ____ No

29. During the past year, have you driven to places outside the state of NC?

____ Yes ____ No

30. During the past year, have you driven to places outside of NC, SC, or VA?

____ Yes ____ No

Modified from the Driving Habit Questionnaire (DHQ)

Owsley, C., Stalvey, B., Wells, J., Sloane, M.E. (1999) Older drivers and cataract: Driving habits and crash risk. *Journal of Gerontology: Medical Sciences* 54A: M203-M211.

Appendix D.

ASSESSMENT OF MOTOR AND PROCESS SKILLS SCORE FORM

AMPS SCORE FORM (page 1 of 2)

Name: ______________________________ **OTAP ID number:** ______________________________

Occupational therapist: ______________________________

Gender: ____ Male ____ Female **Major diagnosis:** ______________________________

Birth date: ______________________________ **Secondary diagnosis:** ______________________________

Evaluation date: ______________________________ **Observation number:** ____ 1 ____ 2 ____ 3 ____ 4

Task number: ________ **Task name:** ______________________________

RATE THE PERSON'S QUALITY OF PERFORMANCE (QoP) ON *THIS* TASK:

	No problem	Questionable	Minimal	Moderate	Marked	Inordinate; cannot test
Increased effort	1	2	3	4	5	6
Decreased efficiency	1	2	3	4	5	6
Decreased safety	1	2	3	4	5	6
Assistance provided	1	2	3	4	5	6

GLOBAL BASELINE STATEMENT: ______________________________

____

____

RATE THE PERSON'S OVERALL ABILITY TO LIVE IN THE COMMUNITY (Consider everything you know about the person):

____The person can/could live *independently*

____The person needs/should have *minimal assistance or supervision*

____The person needs/should have *moderate to maximal assistance*

NOTES:

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AMPS SCORE FORM (page 2 of 2)

ITEM RAW SCORES

ADL Motor Skills

BODY POSITION		
1.	Stabilizes	4 3 2 1
2.	Aligns	4 3 2 1
3.	Positions	4 3 2 1
OBTAINING AND HOLDING OBJECTS		
4.	Reaches	4 3 2 1
5.	Bends	4 3 2 1
6.	Grips	4 3 2 1
7.	Manipulates	4 3 2 1
8.	Coordinates	4 3 2 1
MOVING SELF AND OBJECTS		
9.	Moves	4 3 2 1
10.	Lifts	4 3 2 1
11.	Walks	4 3 2 1
12.	Transports	4 3 2 1
13.	Calibrates	4 3 2 1
14.	Flows	4 3 2 1
SUSTAINING PERFORMANCE		
15.	Endures	4 3 2 1
16.	Paces	4 3 2 1

ADL Process Skills

SUSTAINING PERFORMANCE		
16.	Paces	*Already scored under ADL motor skills*
17.	Attends	4 3 2 1
18.	Heeds	4 3 2 1
APPLYING KNOWLEDGE		
19.	Chooses	4 3 2 1
20.	Uses	4 3 2 1
21.	Handles	4 3 2 1
22.	Inquires	4 3 2 1
TEMPORAL ORGANIZATION		
23.	Initiates	4 3 2 1
24.	Continues	4 3 2 1
25.	Sequences	4 3 2 1
26.	Terminates	4 3 2 1
ORGANIZING SPACE AND OBJECTS		
27.	Searches/ Locates	4 3 2 1
28.	Gathers	4 3 2 1
29.	Organizes	4 3 2 1
30.	Restores	4 3 2 1
31.	Navigates	4 3 2 1
ADAPTING PERFORMANCE		
32.	Notices/ Responds	4 3 2 1
33.	Adjusts	4 3 2 1
34.	Accommodates	4 3 2 1
35.	Benefits	4 3 2 1

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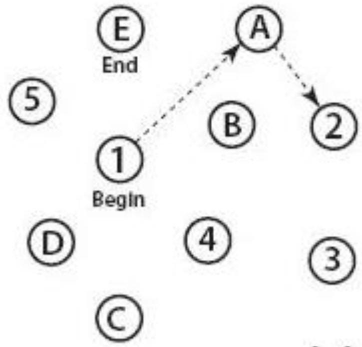
Appendix E.

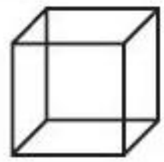
MONTREAL COGNITIVE ASSESSMENT SCORE FORM

MONTREAL COGNITIVE ASSESSMENT (MOCA)

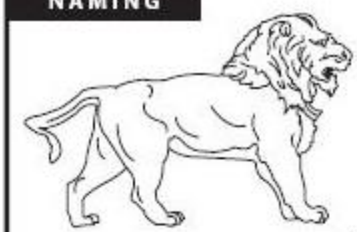
NAME :
Education : Date of birth :
Sex : DATE :

VISUOSPATIAL / EXECUTIVE			POINTS
Trail diagram [ ]	Copy cube [ ]	Draw CLOCK (Ten past eleven) (3 points) [ ] Contour [ ] Numbers [ ] Hands	___/5





NAMING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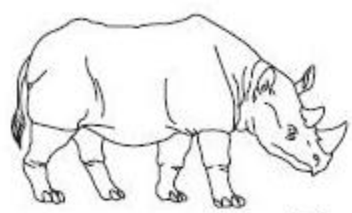
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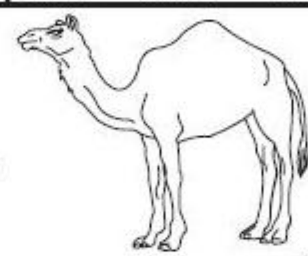
[ ]

___/3

MEMORY — Read list of words, subject must repeat them. Do 2 trials, even if 1st trial is successful. Do a recall after 5 minutes.		FACE	VELVET	CHURCH	DAISY	RED	No points
	1st trial						
	2nd trial						

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

Read list of letters. The subject must tap with his hand at each letter A. No points if ≥ 2 errors
[ ] FBACMNAAJKLBAFAKDEAAAJAMOFAAB ___/1

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

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

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

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

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

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

 Version 7.1 www.mocatest.org Normal ≥ 26 / 30 TOTAL ___/30
Add 1 point if ≤ 12 yr edu

Administered by: ______________________________________

Appendix F.

PERFORMANCE ANALYSIS OF DRIVING ABILITY SCORE FORM

P -Drive

Performance Analysis of Driving Ability

Name (not to be written for research)		Rater	Position in car (front or rear)
Id.no.	Age	Date for assessment	
Diagnosis		Date of onset	Time since diagnosis (months)
Cognitive tests done		Advised not to drive (y/n)	Driving anyway (y/n)

☐ **Manual** ☐ **Automatic** ☐ **Modification/s**___________

Actions (1-26):

Maneuvers

1. steering	4	3	2	1
2. changing gears	4	3	2	1
3. using pedals	4	3	2	1
4. contr speed, slow	4	3	2	1
5. contr speed, fast	4	3	2	1
6. using indicator	4	3	2	1
7. reversing	4	3	2	1

Orientate

8. following instruct	4	3	2	1
9. wayfinding	4	3	2	1
10. positioning on road	4	3	2	1
11. keeping distance	4	3	2	1
12. planning	4	3	2	1

Follow regulations

13. yielding	4	3	2	1
14. obeying stop	4	3	2	1
15. follow speed reg	4	3	2	1

Attending and responding (heeding)

16. straight ahead	4	3	2	1
17. to the right	4	3	2	1
18. to the left	4	3	2	1
19. to mirrors	4	3	2	1
20. to regulatory sign	4	3	2	1
21. to advisory sign	4	3	2	1
22. to fellow road users	4	3	2	1
23. reacting	4	3	2	1
24. focusing	4	3	2	1
25. problem solving	4	3	2	1

Rating scale	**Quality of performance**	**Impact on the activity**
4	Good **Competent performance**	Positive, facilitating
3	Questionable **Hesitant performance**	Causing insecurity (asking questions)
2	**Ineffective Performance**	Causing risky situation
1	**Incompetent performance**	Causing repeated risky or dangerous situations. Interruption

Other information:

Standard route ☐ Special route ☐

Signed consent form ☐

Time on-road (min):_________

OUTCOME: ☐ Pass ☐ Fail

☐ Fail with lessons

☐ Other____________