Neuropsychological Assessment of Driving Capacity

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Abstract

Clinicians are increasingly requested to make determinations regarding patients’ driving capacity in the context of neurological injury/conditions and a growing cohort of older drivers. The capability to drive safely involves a number of cognitive, physical, and sensorimotor abilities that may be impacted by injury, illness, or substances that influence alertness. Neuropsychological measures are an important component of a multidisciplinary approach for evaluation of driving capacity. Clinicians should become familiar with measures that have the best predictive validity so they may incorporate a patient’s neurocognitive strengths and weaknesses in decisions about driving ability.

Keywords: Assessment; Disability/handicaps; Elderly/geriatrics/aging; Head injury; Traumatic brain injury

For millions of people, driving is an important instrumental activity of daily living that contributes to their independence and physical, economic, and social well-being. When individuals experience a situation that decreases their ability to safely operate a motor vehicle, such as cognitive decline or a major medical condition, they may need to cease or curtail driving. Clinicians, from a variety of disciplines (e.g., psychologists, neuropsychologists, physicians, occupational therapists, etc.), are often consulted to determine if an individual possesses the ability to drive. Each clinical discipline brings its own skill set and perspective to the assessment of driving capacity. Unfortunately, in many cases, those asked to assess a patient’s ability to drive often lack specific training and knowledge related to understanding the elements that impact safe driving. A number of factors contribute to the ever-increasing demand for healthcare professionals to be involved in determining an individual’s fitness to drive. This article provides an overview of limiting conditions and a review of relevant research related to neuropsychological assessment of driving capacity. Practical guidelines for clinicians will also be provided.

Context of Driving Capacity Assessment

Based on the most recent statistics from the National Highway Traffic Safety Administration (NHTSA, 2015), there were 32,675 fatalities and 2.3 million injuries of people involved in motor vehicle accidents in 2014. Within these statistics are two particular populations relevant to the fitness to drive consideration.

Aging Population

Population growth and increased longevity means that there are an increasing number of older adults on the road. Statistics compiled by NHTSA (2016) indicate that drivers over 50 years old reached nearly 93.5 million in 2013, which reflects an increase of 22% since 2003. Drivers over 85 years old remain the fastest growing demographic group, nearly doubling from 1.76 million in 1998 to 3.48 million in 2013. Approximately 86% of Americans 65 and older continue to drive, with this cohort of 35 million older adult drivers comprising 16% of all licensed drivers in 2011. It is expected that one of every four...
licensed drivers will be an older adult by 2050, in addition to driving more miles than older drivers do today (Mizenko, Tefft, Arnold & Grabowski, 2014).

Return to Driving After Neurological Injury

Due to improvements in medical treatment, there are also an increased number of people who survive what might have previously been life-threatening conditions (e.g., stroke, brain injury, etc.). For instance, over the past 10 years, the death rate from stroke has fallen about 34% and the number of stroke deaths has dropped about 18% (Mozaffarian et al., 2016). Those who survive such significant neurological insults are often left with physical, sensory and/or cognitive deficits that may impact their ability to safely operate a motor vehicle. According to the Centers for Disease Control (CDC; 2015), about 1.7 million cases of traumatic brain injury (TBI) occur in the USA every year and approximately 5.3 million people live with a disability caused by TBI. Relevant literature indicates between 40% and 80% of people with moderate-to-severe brain injuries return to driving after their injury (Ortoleva, Brugger, Van der Linden & Walder, 2012; Fisk, Schnieder & Novak, 1998).

Conditions Impacting Ability to Drive

Neurological

Numerous neurological conditions may impact one’s ability to drive safely due to the potential effects on sensory, motor, and/or cognitive functioning (Dobbs, 2005; Yale, Hansotia, Knapp & Ehrfurth, 2003). Examples include, but are not limited to, cerebral vascular accidents, TBI, Parkinson’s disease (PD), multiple sclerosis (MS), epilepsy, and dementias.

Other Medical Considerations Relevant to Driving Capacity

In addition to the above-mentioned neurological diagnoses, one must also take into account other medically related conditions that could contribute solely, or comorbidly, to decreased capacity for safe driving.

Medications and intoxicants. The clinician charged with determining fitness to drive should consider each patient’s prescription medications, over-the-counter medications and even naturopathic supplements. One must consider not only single medications, but also the potential for interaction effects. For example, a person prescribed a benzodiazepine who also takes a muscle relaxer and over-the-counter antihistamines will likely experience a cumulative drowsiness effect. Along with medications, clinicians must evaluate the potential use of illicit drugs and intoxicants (Kelly, Darke & Ross, 2004; Neavyn, Blohm, Babu & Bird, 2014). The following is a list of medications and substances that may affect alertness, and thus vigilance, when driving:

- anticholinergics,
- anticonvulsants,
- antidepressants,
- antiemetics,
- antihistamines,
- antihypertensives,
- antiparkinsonians,
- antipsychotics,
- benzodiazepines and other sedatives/anxiolytics,
- muscle relaxants,
- narcotic analgesics,
- stimulants,
- illicit drugs,
- medical marijuana.

Psychiatric conditions. Simply having a psychiatric disorder is not necessarily indicative of risk for unsafe driving. However, there are certain conditions in which the severity and nature of the symptoms may impact driving ability. NHTSA (2010)
suggests that persons who are experiencing an acute phase of psychosis and/or severe period of anxiety or mood disorder should refrain from driving during the active phase of the condition. Additionally, these conditions are often treated with some of the above-mentioned medications that may contribute to hazardous driving conditions.

**Chronic health conditions.** Certain chronic health conditions may also contribute to reduced driving proficiency due to their impact on neurocognitive, sensory, and/or motor ability. For example, unstable and/or untreated cardiac conditions with potential for sudden, unpredictable loss of consciousness (i.e., syncope due to brady- or tachyarrhythmia), uncontrolled diabetes, severe/unmanaged kidney disease, untreated sleep apnea or narcolepsy, and significant visual disorders (e.g., macular degeneration, visual field deficits) are some examples of medical conditions that may further contribute to reduced ability to drive safely (NHTSA, 2012; Schultheis & Whipple, 2014).

Many individuals who are referred for evaluation of driving capacity have more than one potential risk factor that could lead to reduced driving ability. One must consider the cumulative effects of all known factors in determining whether driving privileges need to be limited or discontinued. Additionally, clinicians must be aware of the conditions that are deemed detrimental to driving, and how they are measured, in their particular state/province as it often varies (Galski & McDonald, 2009). For example, in the District of Columbia, conditions listed that require a medical report/clearance include vision impairment, seizure disorder/loss of consciousness, Alzheimer’s disease and insulin-dependent diabetes. In the neighboring state of Virginia, the Department of Motor Vehicles (DMV) requires a medical report/clearance for changes in the level of consciousness, seizures, vision changes, impairment in judgment, and loss of motor functions. There are also sometimes differences in the length of time one must be asymptomatic before returning to driving. For instance, some states require a 6-month period of stability (e.g., seizure-free), whereas others may require 12 months. Often, the way in which the conditions are defined is vague, presumably to be inclusive of many conditions. However, many states are also self-report states, meaning the patient, or his/her caregiver, is required to notify the DMV. Yet a layperson may have difficulty determining if his/her particular condition requires reporting.

**Assessment of Driving Capacity**

**Theoretical Models of Driving Capacity**

Lundqvist and colleagues (2011) proposed a useful clinical model for assessing driving capacity. They posit that a person who is fit to drive is able to adequately manage traffic situations and prepare oneself for action. As such, they explain that safe driving requires mental flexibility, efficient processing speed, and insight. This model emphasizes the need for a broad assessment of current and premorbid medical, psychological, and cognitive functions as well as practical driving skill (Brouwer & Ponds, 1994; Brouwer & Withaar, 1997; Lundqvist et al., 2011), and utilizes a variety of individualized evaluations across multiple disciplines (e.g., physicians, neuropsychologists, occupational therapists, and driving specialists familiar with neurological conditions). As no universally accepted, quantitative method has been identified for determining driving capacity (Schanke & Sundet, 2000; Vrkljan, McGrath, & Letts, 2011), Lundqvist and colleagues (2011) assert that both quantitative and qualitative findings are imperative for determining driving capacity.

In order to illustrate their model, Lundqvist and colleagues (2011) used this multidisciplinary team approach to evaluate 43 individuals with congenital or acquired brain injury. The team consisted of a physician, a neuropsychologist, and an occupational therapist experienced in evaluating fitness to drive. The team also consulted with a speech therapist as needed, and collaborated with a driving instructor who was specialized in driving evaluations for individuals with medical conditions. In its entirety, the approach consisted of a medical evaluation, a neuropsychological assessment, and an on-road assessment, although not every patient in the sample was required to undergo the full process. In addition to cognitive testing, the neuropsychological portion also included an interview containing questions for assessing a patient’s self-awareness and personality (premorbid and current). The occupational therapist conducting the on-road assessment had prior access to the medical and neuropsychological findings, which allowed the therapist to determine if the impairments were verified in the driving assessment or if there were mechanisms such as self-awareness, driving experience, or premorbid driving behavior that compensated for possible impairment. At the conclusion of each assessment, team members discussed their findings and collaboratively decided on an individual’s driving capacity. The qualitative aspect of each team member’s assessment was a priority and often provided clinically relevant information when interpreting quantitative results. Qualitative aspects of each evaluation included behavioral observations of the person in the assessment situation (e.g., comments and/or reactions to different aspects of the evaluation, level of self-awareness, use of compensatory, and/or coping strategies, etc.) that were factored into each team member’s judgment of the individual’s driving capacity. While the researchers acknowledge that there were several tests that...
could correctly classify the majority of patients that were deemed fit or unfit to resume driving, there was no single test that provided enough information alone to make a final decision. Thus, Lundqvist and colleagues (2011) suggest conducting a stepwise evaluation process that entails a synthesis of assessment data and consensus from an experienced driving assessment team for making final decisions about an individual’s driving capacity.

Representative Research

In general, driving safely requires adequate cognitive and psychological skills, as well as self-awareness regarding one’s own driving abilities (Brouwer & Ponds, 1994; Brouwer & Withaar, 1997). As neuropsychological evaluations are routinely used to assess cognition, psychological wellness, and self-awareness, individuals with one of the previously mentioned conditions or who have been reported to the state licensing agency are often referred for a neuropsychological evaluation to determine fitness to drive. There are other times when driving capacity is first questioned by a neuropsychologist as a result of an evaluation used to answer a different or broader referral question. A neuropsychological evaluation can also assist in determining an individual’s candidacy for and ability to benefit from a driving rehabilitation program. This determination is important, as driving rehabilitation programs can be time-intensive and costly. Although thorough exploration of such driving rehabilitation programs is beyond the scope of this article, they may include services such as pre-driving assessment, driving education, on-road driving evaluation, and training, training on the use of adaptive equipment if applicable, and preparation for state road tests (Wolfe & Clark, 2012). Some driving rehabilitation programs also include driving simulators, which are used to assess and rehabilitate reaction time, stopping distance, useful field of view (UFOV), reducing risk of accidents, and driving self-confidence (Wolfe & Clark, 2012). Neuropsychological evaluation results can be used by driving rehabilitation specialists in such programs (e.g., occupational therapists) to tailor more specialized driving assessments and interventions to meet the individual’s identified needs. Several researchers have investigated the predictive utility of cognitive measures on driving ability. A review of the relevant literature follows, divided by domain.

Brief mental status examinations. There are times when an individual’s driving capacity is called into question in a setting (e.g., primary care) where time is limited and clinicians must rely on brief mental status examinations to screen for cognitive impairment. Such measures include the Blessed Dementia Scale (Blessed, Tomlinson, & Roth, 1968), Clinical Dementia Rating (Morris, 1993), the Mini-Mental State Exam (MMSE; Folstein, Folstein, & McHugh, 1975), and the Montreal Cognitive Assessment (MoCA; Nasreddine et al., 2005). The MMSE is a popular measure used to screen for cognitive impairment in a variety of clinical settings and diagnoses (Folstein et al., 1975). As with most screening measures, it was designed as a brief tool, typically requiring 5–10 min to administer, assessing a broad range of domains including orientation, registration, attention, calculation, recall, language, and visuospatial perception. Scores range from 0 to 30, and scores less than 24 are suggestive of cognitive impairment and this has been suggested as a possible cutoff in identifying individuals at risk for unsafe driving (Iverson et al., 2010). Some researchers using the MMSE to inform fitness to drive have also suggested that those who score below 24 should stop driving or undergo further assessment (Adler, Rottunda, & Dysken, 2005) while others have found that the MMSE does not predict future crashes or violations (Zuin, Ortiz, Boromei, & Lopez, 2002; Fox, Bowden, Bashford, & Smith, 1997). Thus, using the MMSE alone to determine fitness to drive may result in overlooking potentially unsafe drivers.

To better determine the sensitivity, specificity, positive, and negative predictive values and error rate of the MMSE in predicting pass and fail outcomes on an on-road driving evaluation, Crizzle and colleagues (2012) assessed 168 community dwelling older adults, including 20 with PD. While the MMSE demonstrated poor predictive validity for the total sample, it showed statistically significant and good predictive validity for the PD group (Crizzle et al., 2012). Notably, Crizzle and colleagues cautioned that the confidence intervals were wide and the positive and negative predictive values were less than desirable. While the negative predictive validity was high using a cutoff score of 24, the positive predictive validity was considered marginal at best and decreased as the cutoff points increased. A cutoff score of 26 resulted in a high proclivity for false positives on the road test (i.e., those who scored below 26 on the MMSE but passed the road test) for the entire sample. After excluding individuals with PD, only minimal improvements in sensitivity were observed with no changes in specificity. They concluded that the MMSE alone is not sufficient for predicting pass/fail outcomes of on-road driving performance in older adults regardless of the cutoff score used (Crizzle et al., 2012).

In order to examine the association between MMSE scores and motor vehicle crash risk, Joseph and colleagues (2014) used prospective, observational data from two large pharmaceutical studies evaluating the efficacy of potential medication combinations for individuals with vascular disease or high-risk diabetes who were also intolerant of angiotensin-converting enzyme inhibitors. A total of 17,538 frequent drivers who had completed a baseline MMSE were included in the study and
were followed up after a mean of 4.5 years to determine involvement in motor vehicle crashes. Slightly more than 6% of the sample (1,068 participants) were involved in a motor vehicle crash, and lower MMSE scores were not associated with future motor vehicle crashes on multivariate analysis. The strongest predictor of future motor vehicle crash was having had a motor vehicle crash within the previous 2 years. Additional clinical factors associated with greater risk of motor vehicle crash included depression, falls within the previous year, sleep apnea, and lower baseline systolic blood pressure (Joseph et al., 2014).

The MoCA is another screening instrument used in clinical settings to quickly assess for cognitive impairment (Nasreddine et al., 2005). Some researchers have investigated the MoCA’s utility in assessing fitness to drive. In a study examining the relationship between cognitive performance, perceptions of driving, and self-reported driving practices of healthy older adults, the MoCA was not helpful in predicting driving safety (Rapoport et al., 2013). Outcomes from another study indicated that the MoCA and MMSE were equally effective in predicting on-road performance, although its limitations included a small sample size (Bowers et al., 2013).

In a retrospective cohort study of 92 adult drivers who underwent a comprehensive driving evaluation between 2010 and 2014, Hollis and colleagues (2015) investigated the effectiveness of the MoCA and the MMSE in predicting driving test outcomes for individuals with and without cognitive impairment. After medical chart review, participants were grouped based on the presence or absence of a neurological condition associated with cognitive impairment (e.g., early-stage Alzheimer’s disease, PD, and mild cognitive impairment). They concluded that a prior neurological condition associated with cognitive impairment enhanced the validity of cognitive screening measures in the identification of at-risk drivers. An individual was 1.36 times as likely to fail the road test with each one-point decrease in MoCA score. This relationship was not detected in those without such a diagnosis. Hollis and colleagues concluded that neither the MMSE nor the MoCA can be reliably used as an indicator of driving risk in healthy individuals, although the MoCA can be used to assess for driving risk in those with preestablished cognitive impairment (Hollis et al., 2015).

Visual perception and visual spatial abilities. Driving capacity requires intact visual perception and visual spatial abilities, which are vulnerable to aging and neurological dysfunction. For example, reductions in visual acuity (Owens, Wood, & Owens, 2007) and visual field loss (Wood et al., 2009) have been found to be associated with increased crash risk in older adults. However, some research has cautioned against using visual tests alone when making a determination of an individual’s driving fitness as they are poor predictors of driving performance (Wood et al., 2009). Thus, while it is imperative to assess visual acuity, visual field integrity, and neglect as part of a driving capacity evaluation, placing these factors within the context of a broader cognitive framework to better determine an individual’s ability to drive safely has been suggested (Anstey, Horswill, Wood, & Hatherly, 2012). In their study evaluating a part of the Multifactorial Model of Driving Safety, Anstey and colleagues (2012) evaluated 297 community dwelling older drivers using a battery of measures of cognitive and visual function. Factor analysis of the predictor variables indicated that Cognitive and Vision factors explained 83–95% of age-related variance in their model. They concluded that declines in several higher order cognitive abilities involving manipulation and storage of visuospatial information under speeded conditions were associated with age-related declines in the capacity to drive safely (Anstey et al., 2012).

Measures that assess visuospatial abilities often incorporated within a traditional neuropsychological evaluation battery include Block Design (from the Wechsler series; Wechsler, 2008), clock drawing tests, complex figure tests, judgment of line orientation tests, the Hooper Visual Organization Test (HVOT; Hooper, 1958), and the Motor-Free Visual Perceptual Test (MVPT; Colarusso & Hammill, 2003), among others. In a sample of individuals with dementia, meta-analytic results indicated that measures of visual spatial abilities had the strongest relationship with driving capacity, with moderate effect sizes for performance on-road tests and non-road tests, and small effect sizes for caregiver report of driving abilities (Reger et al., 2004). Among older adults, Block Design was predictive of on-road driving problems, while clock drawing and judgment of line orientation tasks were predictive of simulated driving performance (Mathias & Lucas, 2009). The MVPT and clock drawing tests were also shown to have predictive utility for driving capacity (Oswanski et al., 2007). Additionally, the MVPT has been shown to be a strong predictor of on-road failures (Schultheis & Fleksher, 2009).

Visuoperceptual and visuospatial measures have also been widely studied in various neurological populations. The Rey–Osterreith Complex Figure (ROCF; Stern et al., 1999) test and Block Design have also been found to be among the most predictive of driving abilities for those with PD (Amick, Grace, & Ott, 2007; Stolwyk, Charlton, Triggs, Ianski, & Bradshaw, 2006). Among patients recovering from stroke, the ROCF and the MVPT demonstrated utility for predicting fitness to drive (Akinwuntan et al., 2006; Mazer, Kornier-Bitensky, & Sofer, 1998). Among a sample of individuals with MS, the 7/24 Spatial Recall Test was shown to be one of the most predictive tests in a neuropsychological battery in determining on-road driving performance (Schultheis et al., 2010). Measures of visual spatial ability were found to be useful in predicting simulated and
on-road driving performance among a sample of individuals with HIV (Gorman, Foley, Ettenhofer, Hinkin, & van Gorp, 2009). Impairments in higher order visuo-integrative driving skills were most indicative for on-road failure in a study of patients with Huntington’s disease (Devos et al., 2014). Another test that is frequently used in the driving literature is the UFOV (Ball & Roenker, 1998) test, which assesses visual acuity, range of individual’s visual field, basic visual attention and information-processing speed, divided attention, and selective attention. The UFOV has been found to be associated with driving performance (simulated or real-world) among several groups, including TBI (Cyr et al., 2009), HIV (Gorman et al., 2009), older adults (Mathias & Lucas, 2009), and stroke survivors (Mazer, Sofer, Komer-Bitensky, & Gelinas, 2001).

Attention. Distracted driving, which occurs when a driver diverts attention away from critical activities for safe driving and toward a competing activity, poses a serious threat to safety even among healthy individuals (Regan, Hallet, & Gordon, 2011). Thus, thorough assessment of various aspects of attention is imperative when determining fitness to drive, particularly for individuals who have conditions that may affect attentional abilities. For example, impairments in selective attention were among the most predictive for on-road failures in a study of individuals with Huntington’s disease (Devos et al., 2014). A meta-analysis that examined cognitive predictors of driving ability in older drivers indicated that measures of attention were among the tests that best discriminated between “pass” and “fail” status of older drivers (Mathias & Lucas, 2009).

Much research has been conducted on a particular facet of attention known as divided attention, which refers to the ability to process information while conducting more than one task simultaneously. Divided attention has long been considered a requirement for safe driving (Finkelman, Zeitlin, Filippi, & Friend, 1977). In order to investigate the effect of divided attention on speed control, a virtual reality task was conducted on a small sample of individuals with TBI and healthy controls. Results indicated that drivers with TBI committed significantly more errors than control participants on a secondary task requiring them to attend to numbers in their visual field (Lengenfelder, Schultheis, Al Shihabi, Mourant, & DeLuca, 2002).

In another study examining the role of impaired divided attention in drivers with a history of TBI, Cyr and colleagues (2009) investigated behavioral reactions to four challenging simulated roadway events in two groups of drivers. One group of drivers consisted of 17 rehabilitated individuals after TBI deemed fit to drive and the other group of drivers consisted of 16 healthy control participants (Cyr et al., 2009). Participants were asked to perform a dual task during portions of the simulation. The individuals with a history of TBI were additionally administered the UFOV, subtests of the Wechsler Adult Intelligence Scale-III (WAIS-III, [Wechsler, 1997a]; Arithmetic and Digit Span Backward), subtests of the Wechsler Memory Scale-III (Wechsler, 1997b; Faces, Verbal Paired Associates, Logical Memory I, and Mental Control), and the Trail Making Test B (Reitan, 1958). Results suggested that the group of participants with TBI crashed significantly more frequently than participants in the control group. Correlations between all neuropsychological measures and crash rate were not significant in the group of participants with TBI. However, the authors noted that Trail Making Test Part B approached significance and predicted that this correlation may have been statistically significant with a larger sample size. Dual-task performance during portions of the driving simulation was significantly correlated with crash rate. The authors concluded that within-task divided attention scores predicted crash rate among drivers with TBI while traditional measures of attention and processing speed were not useful in this sample (Cyr et al., 2009).

More recently, Cuenen and colleagues (2015) investigated the potential moderating effects of attention capacity on driving performance during visual and cognitive distraction in a sample of community-dwelling, active drivers aged 70 years and older without history of stroke in the last 6 months and who had a score of 25 or above on the MMSE. Drivers were presented with a visual distraction task or a cognitive distraction task while driving. The Paced Auditory Serial Addition Task (PASAT; Gronwall, 1977) comprised the cognitive distraction task. Results indicated that when older drivers were cognitively distracted, the number of complete stops at stop signs decreased, initiation of braking at pedestrian crossings was later, and the number of crashes increased. They concluded that attention capacity is negatively related to the number of crashes in this study (Cuenen et al., 2015).

Processing speed. Speed of information processing appears to be an important aspect of safe driving, as it likely plays a role in the ability to react, brake, and efficiently adapt to new situations. There has been some discussion in the literature about the influence of processing speed on poor performance found on measures of attention. For example, upon adjustment for slowness of information processing, divided attention has been found to be relatively unimpaired in brain-injured patients (Brouwer, Ponds, Van Wolffelaar, & Van Zomeren, 1989; Veltman, Brouwer, Van Zomeren, & Van Wolffelaar, 1996). Thus, thorough assessment of processing speed is recommended when determining driving capacity, and can include measures such as Trail Making Test Part A (Reitan, 1958), Symbol Digit Modalities Test (SDMT; Smith, 1982), WAIS-IV subtests such as Symbol Search and Coding (Wechsler, 2008), as well as complex reaction time tests (Wolfe & Clark, 2012).
In a retrospective, matched case-controlled study, Cullen and colleagues (2014) investigated the ability to predict return to driving following TBI during inpatient rehabilitation. Sixty-seven participants with a history of TBI were administered the Trail Making Test Parts A and B, as well as the Digit Span Forward and Backward subtests of the WAIS-IV. Scores on Trail Making Test Parts A and B were significantly better in participants who had returned to driving compared to those who had not done so, suggesting that measures of processing speed and cognitive flexibility may predict return to driving after TBI (Cullen, Krakowski, & Taggart, 2014).

Performance on measures of processing speed has been shown to determine driving fitness in other groups as well. The SDMT Oral Version was found to be a strong predictor of on-road driving performance in a sample of participants with MS (Schultheis et al., 2010). In a group of 30 individuals with Huntington’s disease who were active drivers, the SDMT, Stroop Word Reading (Stroop, 1935), and Trail Making Test Part B provided the best model to predict fitness to drive, correctly classifying 87% of participants (Devos et al., 2012). Poor processing speed performance has also been associated with more safety errors during secondary navigation tasks in drivers who are 70 years of age or older with and without neurodegenerative disorders (Aksan, Anderson, Dawson, Uc, & Rizzo, 2015).

Language. Findings in the literature are mixed with regard to the importance of language functioning for driving capacity. From a face validity standpoint, drivers benefit from intact language functioning in order to read and understand road signs, potentially communicate with law enforcement, understand oral or visual instructions, read and understand driving laws, and pass written driving examinations. Some evidence for language dysfunction posing risk to safe driving ability includes work by Hartje and colleagues (1991), who found that driving behavior was impaired in a higher proportion of individuals with aphasia than individuals who suffered damage to the brain but did not have aphasia (Hartje et al., 1991). However, other research groups have not identified a relationship between aphasia and driving ability (Golper, Rau, & Marshall, 1980; Nouri, Tinson, & Lincoln, 1987). Mackenzie and Paton (2003) assessed 18 individuals with aphasia following stroke on their ability to recognize road signs. The aphasia group performed significantly worse on all facets of the Road Sign Recognition Test from the Stroke Driver Screening Assessment (Nouri & Lincoln, 1994) than a group of control participants (Mackenzie & Paton, 2003). Reger and colleagues (2004) performed a meta-analysis on date from studies investigating neuropsychological functioning and driving ability of individuals with dementia. Although they found medium-to-large effect sizes between language assessments and measures of driving ability (e.g., on-road tests and written non-road tests), the relationship disappeared when data from control participants were excluded from analyses (Reger et al., 2004).

Memory. Findings in the driving literature are somewhat mixed regarding the usefulness of memory assessment for determining driving fitness. For example, results from a meta-analysis suggested that several measures of memory functioning commonly used by neuropsychologists (e.g., Wechsler subtests of Facial Recognition, Logical Memory, and Visual Reproduction (Wechsler, 1997b), as well as the Benton Visual Retention Test (Sivan, 1992)) were predictive of driving performance (Reger et al., 2004). In another meta-analysis, Visual Reproduction in particular was found to have a medium-to-large effect size when classifying older drivers who passed or failed a driving evaluation (Mathias & Lucas, 2009). Along those lines, nonverbal memory performance was predictive of some facets of simulated driving in a sample of individuals with HIV (Gorman et al., 2009).

In a more recent study, Aksan and colleagues (2015) conducted assessments of on-road driving safety and cognitive functioning on 146 active drivers with valid state licenses aged 70 years and older with and without neurodegenerative diseases (i.e., probable Alzheimer’s disease and PD). Assessments of cognitive functioning included measures of memory, visuospatial construction, processing speed, and executive functioning. The majority of differences in outcome measures were observed between healthy adults and those with neurodegenerative diseases; Alzheimer’s and Parkinson’s groups were pooled for hierarchical regression analyses. The final regression equation for navigation-related secondary task performance indicated that memory performance, as well as visual sensory functioning and set shifting, predicted on-road navigation performance over and above age and disease status. In contrast, Vaughan and colleagues (2015) investigated the associations between current or former driving status in older women with mild cognitive impairment and all-cause dementia and cognitive performance as well as proxy report of cognitive and functional limitations. They administered a cognitive battery via telephone to assess attention, verbal learning and memory, verbal fluency, executive function, working memory, and global cognitive function. The cognitive battery included the modified Telephone Interview for Cognitive Status (TICS-m; De Jager, Budge, & Clarke, 2003), East Boston Memory Test (Gfelle & Horn, 1996), Oral Trail-Making Test (Mrazik, Millis, & Drane, 2010), Verbal Fluency (Animals; Benton, 1968), Digit Span forward and backward (WAIS-R; Wechsler, 1981), and the 15-item Geriatric Depression Scale (Yesavage, 1988). They also administered self-report measures of depression symptoms to the participants, and the Dementia Questionnaire (Kawas, Segal, Stewart, Corrada, & Thal, 1994) to a knowledgeable family member or
Executive functioning. Executive functioning has many face valid implications for carrying out complex behaviors associated with safe driving (e.g., planning, decision-making, judgment, response inhibition, etc.). Many clinical groups are vulnerable to executive dysfunction, and are thus at risk for unsafe driving. In the Aksan et al. (2015) study described previously, set-shifting was a significant predictor of on-road navigation performance in older drivers with and without neurodegenerative diseases. Executive dysfunction was found to predict underperformance on a driving assessment in a sample of stroke survivors (Motta, Lee, & Falkmer, 2014). Specifically, the Trail Making Test Part B and the Key Search Test of the Behavioural Assessment of the Dysexecutive Syndrome (Burgess & Alderman, 1996) were key predictors in this study.

One measure that has received much attention in the driving literature is the Trail Making Test B. While many neuropsychologists consider the Trail Making Test Part B to be a measure of complex processing speed, many others consider this test to be a measure of executive functioning. In an effort to describe changes in health status and driving status over time, Lundqvist and colleagues (2008) followed two groups of individuals with TBI or subarachnoid hemorrhage and their controls over a period of 10 years. One aspect of the study was to determine the predictive utility of a short neuropsychological battery consisting of the Trail Making Test Part B, Complex Reaction Time test, Focused Attention test, and Simultaneous Capacity test on driving status 10 years later. Based on stepwise logistic regression analysis, the brief battery correctly classified 89% of the patients with respect to driving and non-driving status. However, Trail Making Part B was the most sensitive test. In fact, when a regression analysis included the other three tests in the battery, no change in overall classification occurred.

Results from another study utilizing the Trail Making Test Part B as a measure of executive functioning lends support for its use in driving fitness assessments. Hargrave, Nupp, and Erickson (2012) investigated the predictive utility of the Trail Making Test Part B and the Frontal Assessment Battery (Dubois, Slachekovsky, Litvan, & Pillon, 2002) for on-road driving performance in 76 participants who were referred for driving assessment after stroke or TBI. Scores on the Trail Making Test Part B were significantly predictive of on-road driving performance, while scores on the Frontal Assessment Battery were not. They reported that a cutoff score of 90 seconds on the Trail Making Test Part B correctly identified 77% of participants who failed on-road driving evaluations (Hargrave et al., 2012).

In a recent study of 68 adults aged 60 years and older, McInerney and Suhr (2016) investigated the neuropsychological correlates of hazard perception, which they defined as the ability to identify and react to hazards while driving. They found that hazard perception errors were related to visuospatial/constructional skills, processing speed, memory, and executive functioning skills, with the battery of tests used accounting for 36.7% of the variance in hazard perception errors. Trail Making Test Part B was the strongest predictor of hazard perception ability (McInerney & Suhr, 2016).

Asimakopulos and colleagues (2012) conducted a structured review of executive function measures in the driving literature to describe the specific aspects of executive function they assess as well as the utility of their ability to predict safe driving. They identified 53 tools, including 27 general cognitive assessments, 19 driving-specific tools, and 7 activities of daily living/instrumental activities of daily living assessments, without any single tool measuring all aspects of executive functioning. They compiled these findings into a Driving Executive Function Tool Guide (DEFT Guide), and make helpful practical suggestions for choosing among various measures of executive functioning for determining driving capacity. As opposed to other batteries that are meant to be used in their entirety to predict fitness to drive, the DEFT is a clinical tool composed of many different measures of executive functioning that can be used to assess the specific facets of executive functioning that are most relevant to a particular individual (Asimakopulos et al., 2012).

Awareness and metacognition. Throughout the driving literature, substantial emphasis has been placed on awareness of one’s own abilities and deficits in relation to driving fitness. Awareness, which some researchers consider to be an element of metacognition (i.e., the conscious knowledge an individual has regarding his or her own cognition and to engage in selfmonitoring to regulate these activities), allows an individual to engage in appropriate selfmonitoring while driving, and subsequently make important decisions regarding compensatory strategies while driving and/or selfregulation of driving. Al Banna and colleagues (2016) reviewed the literature to identify the definitions and tools used to assess metacognition. A general finding of their review was that the concept of selfawareness was given more attention in the literature than selfregulatory and selfmonitoring processes, especially for those studies reviewed that focused on samples of stroke survivors. In fact, many clinical groups are vulnerable to the effects of decreased awareness in daily life. Thus, the importance of assessing an individual’s
awareness during a neuropsychological evaluation to determine driving capacity cannot be underestimated. Multiple assessments have been discussed in the driving literature, including the Self-Regulation and Skills Interview (Ownsworth, McFarland, & Young, 2000), the Self-Awareness of Deficits Interview (Fleming, Strong, & Ashton, 1996), the Awareness Questionnaire (Sherer, Bergloff, Boake, High, & Levin, 1998), the Patient Competency Rating Scale (Prigatano et al., 1986), and the Driving Awareness Questionnaire (DriveAware; Kay, Bundy, & Clemson, 2009).

DriveAware was specifically designed to assess drivers’ awareness of driving ability (Kay et al., 2009). This brief inventory consists of eight questions related to the examinee’s perceptions of his or her driving abilities and internal reflections of driving experiences, which are compared to a clinician’s ratings on the same questions to calculate a discrepancy score. It is intended to be used in conjunction with information provided by the referral source and the examinee’s performance on clinical tests. Using Rasch modeling, DriveAware demonstrated strong evidence for construct validity, and also appears to measure a unidimensional theoretical construct (i.e., driving ability). However, the map of items and drivers indicated that the test did not assess the full range of driving ability, and that those with the least awareness of their driving ability were insufficiently assessed. Strong evidence for interrater reliability was also found for all items. Using a raw cutoff score of 14 and a discrepancy score of 4, DriveAware was found to have a sensitivity of 84% and specificity of 94% when compared with an on-road measure of awareness, which was an occupational therapist’s ratings of awareness during a driving evaluation (Kay et al., 2009).

Driving-specific measures. There are several driving-specific measures of driving fitness that incorporate simulation and/or on-road evaluations typically carried out by other disciplines skilled in driving assessment (e.g., occupational therapy) that are beyond the scope of this review. However, there are several measures that are more likely to be incorporated into a neuropsychological evaluation of driving capacity. Such tests may offer increased opportunities or buyin during driving capacity assessment while discussing evaluation results with examinees as driving-specific measures typically offer more face validity compared to traditional neuropsychological evaluation measures.

For example, the Neuropsychological Assessment Battery (NAB; Stern & White, 2003) has one subtest called the Driving Scenes Test that was designed to measure several aspects of visual attention (i.e., working memory, visual scanning, attention to detail, and selective attention). Examinees are exposed to a scene from the perspective of a driver, and are subsequently asked to identify everything that is new or absent from a second similar scene. This is done for a total of six different scenes. In a study used to investigate the ecological validity of this subtest, the Driving Scenes Test and an on-road driving test were administered to 24 healthy older adults and 31 individuals with very mild dementia. Findings indicated a strong relationship between scores on the Driving Scenes Test and on-road driving test score, and the subtest was able to correctly classify 66% of the participants into three safety categories (i.e., safe, marginal, or unsafe) for driving (Brown et al., 2005). In contrast, results from another study investigating the utility of this subtest to predict driving status among participants with PD, Alzheimer’s disease, and healthy older adults did not find the Driving Scenes test to be a useful tool (Grace et al., 2005).

The Rookwood Driving Battery (McKenna, 2009) was designed to measure the processing of information in visual, praxic, and executive systems that were deemed essential for safe driving. This battery demonstrated overall high accuracy rate in predicting a failing performance (92%) and moderate accuracy in predicting a passing performance (71%) on an on-road test in 142 individuals with various neurological conditions (McKenna, Jefferies, Dobson, & Frude, 2004). More recently, McKenna and Bell (2007) found that a cutoff error score of >10 on this battery had a positive predictive value of 0.88 (i.e., 61 of the 69 people predicted to fail on-road did so) and a negative predictive value of 0.73 (i.e., 240 of the 327 people predicted to pass on-road did so) in a larger sample of 391 participants including individuals over 70 years old. When the researchers split the sample into two groups based on age, results from the group with individuals under 70 years of age yielded stronger positive (0.91) and negative (0.86) predictive values. However, data from the group of individuals 70 years of age and older indicated a positive predictive value of 0.86 and a negative predictive value of 0.49, which is reflective of the finding that older individuals in the sample tended to fail the on-road test even after passing the cognitive battery.

Another driving-specific measure is the Stroke Driver Screening Assessment (Nouri & Lincoln, 1994), which was originally developed in the United Kingdom to measure driving-related visual attention and executive functions in stroke survivors. It was more recently modified for use in the United States, which generally consisted of converting the test stimuli to reflect the laws and standards of driving in the United States (Akinwuntan et al., 2013). In a pilot study investigating the potential usefulness of the U.S. version, Akinwuntan et al. (2013) found high accuracy for predicting driving performance among participants with a history of stroke and healthy individuals. While these findings suggest that this version has the potential to be a good predictor of driving performance, the researchers cautioned that additional research is needed to address the limitations of the current study.
Conclusions

Much research has been conducted on factors associated with safe driving and conditions that may impact one’s ability to do so. There are also many studies assessing the predictive ability of neuropsychological measures to determine driving fitness. The present article provides a framework for clinicians to increase their understanding of these areas, but is by no means an exhaustive review of all the literature on driving capacity. In summary, the literature reviewed suggests that thorough assessment of visual perception, visual spatial abilities, attention, processing speed, and executive functioning is imperative for determining an individual’s capacity to drive safely. While impairments in other cognitive domains (e.g., language, memory) may negatively affect one’s driving capacity, the literature offers mixed findings regarding the contributions these make to safe driving. Reviewing the driving capacity literature also provides an appreciation for the utility of more sensitive and specific measures of cognitive functioning when making this important determination, as individuals at risk of unsafe driving may be overlooked if brief mental status examinations are the only source of data providers use. This is especially important when considering the risks associated with a “false negative” result from brief cognitive screeners (i.e. individuals who are inaccurately deemed safe to drive based on brief mental status examinations). Another important factor to assess in a neuropsychological evaluation of driving capacity is the individual’s self-awareness, as this allows an individual to engage in self-monitoring and utilize compensatory strategies while driving.

As is conveyed in the ABA/APA (2008), the involvement of neuropsychologists in the evaluation of driving capacity is likely to increase. Clinicians involved in determining driving capacity must consider a variety of factors and weigh the impact of cessation of driving on the individual against the risk of harm to the general population (Wolfe & Clark, 2012). As described in this article, and as outlined by Yale et al. (2003) and Wolfe and Clark (2012), there are several general recommendations for competent risk assessment that are broad enough to be applied to neuropsychology and to other disciplines as well.

- Knowledge of a patient’s full medical history including diagnoses, physical/sensory deficits, medications and psychological conditions.
- Knowledge of the minimal functional requirements for safe driving.
- Knowledge of conditions that may have a negative impact on ability to drive.
- Knowledge of the laws of the state/province in which one practices.
- Knowledge and ability to correlate assessment of the functional level with potential risk for driving accidents.

In conclusion, there remains considerable variability in the methods used to determine driving capacity. Future research in this area should continue to focus on replication studies of neuropsychological measures that show the most promising ecological validity along with longitudinal data for confirmatory analysis over time. However, in addition to studying aspects of driving capacity, we should also be increasing our efforts in determining alternative means of affordable transportation for the growing number of individuals who are no longer able to drive.

Conflict of interest

None declared.

References


