Neuropsychological Tests and Measurement of Comorbidity in Predicting Driving Competence among Memory Clinic Patients^{*}

Bernadette A. Fausto
University of South Florida,
Florida, USA

Bonnie McIntosh,
Celisa Bonner
Madonna Ptak Center for
Alzheimer's and Memory Loss at
Morton Plant Mease, Florida, USA

Angela M. McBride
Private Practice, Florida, USA

Objective: Visuospatial, executive function, and attention abilities have previously been identified as predictors of driving competence, however specific neuropsychological tests that accurately predict driving outcomes have yet to be clearly defined. In addition, little is known about the impact of medical comorbidity on fitness to drive. The objectives of this study are to determine which neuropsychological tests predict driving competence and to elucidate the contribution of medical comorbidity to driving risk. **Method:** Neuropsychological test raw scores (NPT), driving assessment scores (DA), and medical histories were collected retrospectively from a total of 138 patients who had undergone routine clinical evaluation and the computer-based DriveABLE assessment over a 5-year period. **Results:** Poorer NPT performance significantly predicted higher DA score ($R^2 = 0.530$, $p < 0.05$) indicating a greater probability of failing the road test. The combination of Coding ($B = -0.49$, $p = 0.03$), Visual Reproduction Delayed Recall ($B = -2.00$, $p < 0.001$), and Boston Naming Test 60-item ($B = -0.45$, $p = 0.08$) raw scores was significantly predictive of DA ($R^2 = 0.71$, $F(3, 38) = 12.54$, $p < 0.05$; adjusted $R^2 = 0.46$). Medical comorbidity did not offer additional predictive value. **Conclusions:** These results suggest that performance on traditional neuropsychological tests can provide additional information regarding the patient's ability to drive. Future studies should examine the specificity of NPT predictive value using normal controls and the impact of medical comorbidity on driving competence in more heterogeneous samples.

Keywords: Neuropsychological assessment, driving, comorbidity, aging, everyday function, memory disorders

As the average life expectancy increases, so will the number of older drivers on the road. Between 2002 to 2011, the number of licensed drivers 65 years of age and older increased by 21% compared to only 9% in the general population (National Highway Traffic Safety Administration, 2014). For many older adults, driving is

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Bernadette A. Fausto, MS, School of Aging Studies, University of South Florida.

Bonnie McIntosh, BS, Madonna Ptak Center for Alzheimer's and Memory Loss at Morton Plant Mease.

Celisa Bonner, LCSW, Madonna Ptak Center for Alzheimer's and Memory Loss at Morton Plant Mease.

Angela M. McBride, Ph.D., Private Practice.

vital to maintaining independence and preserving mobility in the community. Loss of driving has been associated with increased depressive symptomology and increased social isolation in older adults (Fonda, Wallace, & Herzog, 2001; Mezuk & Rebok, 2008). Therefore, it is becoming increasingly imperative to identify drivers who pose risk to traffic safety as well as those who can still drive safely.

In the past 20 years, methods for driving evaluation have focused less on the “older driver” and the impact of specific medical conditions on driving performance to a multifactorial approach. Chronological age alone is an insufficient predictor of driving ability. In addition, medical diagnoses are weak predictors of actual driving performance due to the great interindividual variability in severity and symptom presentation. A recent model characterizes driving as a complex task that places demands on visual, motor, and cognitive abilities and is further influenced by self-regulatory practices. With normal aging, reductions in visual acuity, contrast sensitivity, range of motion, motor coordination, processing speed, and attention can negatively affect driving capacity (Anstey, Wood, Lord, & Walker, 2005). In addition, there is an increased vulnerability to comorbidities and polypharmacy use with age that further impairs driving ability. Older adults have been found to be aware of age-related visual and physical impairments but are less privy to of age-related cognitive changes, precluding the ability to appropriately self-restrict their driving (West et al., 2003). Cognitive tests, particularly those measuring executive function, visuospatial, and attention abilities, can provide important information regarding one’s ability to drive safely (Grace et al., 2005; Reger et al., 2004). However, whether comorbidity and polypharmacy add value to assessing driver competence above and beyond cognitive abilities alone is unknown.

Unfortunately, the extant literature is fraught with challenges including the range of screening tests, assessments and driving outcomes used across various research methodologies. Some research groups have used traditional neuropsychological tests to predict driving ability (Dawson, Uc, Anderson, Johnson, & Rizzo, 2010) while others have developed alternative approaches such as computer-based cognitive testing (Wood, Horwsill, Lacherez, & Anstey, 2013) and new stand-alone screening measures (Wang, Kosinski, & Schwartzberg, 2010). On-road test performance remains the most ubiquitous driving outcome in both research and practice. Although dubbed the gold standard driving outcome, oftentimes the on-road driving evaluation is not viable due to the high expense to the patient, time-intensity, and the unnecessary risk it may pose to other road users. Thus, brief, accessible, cost-effective, highly sensitive screening methods hold value in facilitating the identification of those patients requiring a more formal, comprehensive driving evaluation.

Given evidence that traditional neuropsychological tests offer additional predictive value to the driving assessment (Dawson et al., 2010), the purpose of this study was to determine the association and predictive value of traditional neuropsychological tests previously identified in literature with regard to driving competence in a memory clinic population. We also wished to develop a balanced regression model relating neuropsychological test performance to driving competence. Our final goal was to determine the additional contribution of medical comorbidity burden on driving competence.

Method

Participants

Medical charts of consecutive patients seen at the Madonna Ptak Center for Alzheimer’s and Memory Loss at Morton Plant Mease in Clearwater, FL between July 2008 to July 2013 for a driving assessment were reviewed for eligibility in this study. All patients were referred by a physician secondary to concerns about

driving ability. Inclusion criteria were the following: (a) possession of a valid driver's license on the day of the driving assessment (DA); (b) between the ages of 50 to 89 years old on the day of the DA; and (c) completion of previous neurobehavioral evaluation (NBE) and neuropsychological testing (NPT) with a clinical neuropsychologist at the same memory clinic. From the original July 2008 to July 2013 cohort, 138 patients fulfilled inclusion criteria (75 females; mean age = 75.17 ± 7.94 ; mean education = 14.10 ± 2.79). In this cross-sectional, retrospective study, relevant data including descriptive statistics, NPT raw scores, DA scores, and medical history were extracted for all eligible subjects. Ethical approval was granted by the BayCare Health System Institutional Review Board.

Cognitive Measures

Table 1 details NPT performance on tests of mental status, attention, processing speed, visuospatial abilities, visual memory, and language as well as comorbidity and DA scores. Tests were selected based on frequency of use in the literature as well as in clinical practice (Chaytor & Schmitter-Edgecombe, 2003). Overall, the literature purports visually-based attention and visuospatial abilities are independently predictive of driving performance in older adults with and without dementia. However, there has been a development towards a disaggregate approach; that is, the use of individual and combinations of neuropsychological test performances to predict driving ability. For example, Dawson et al. (2009; 2010) found that a composite score of eight cognitive tests known as COGSTAT (Controlled Oral Word Association, Rey-Osterrieth Complex Figure-Copy, Rey-Osterrieth Complex Figure-Recall, Rey Auditory Verbal Learning Test, Brief Visual Retention Test, Block Design subtest, Judgment of Line Orientation, and Trail Making Test-B) was the best predictor of total safety errors on a standardized road test in cognitively normal older drivers and drivers with early AD. Moreover, a confirmatory factor analysis study conducted by Anderson et al. (2012) revealed that various neuropsychological test batteries containing one test each from processing speed, visuospatial, and memory domains was significantly moderately correlated with standardized road test safety errors such that poorer neuropsychological test performance was associated with greater total safety errors. In sum, these results lend support that the disaggregate approach better characterizes safety risk than impairment in any one neuropsychological domain and that assessment across multiple salient domains is consistent with the multifactorial demands of driving.

In the current study, a similar combinatorial approach for neuropsychological testing was used. Normative data are available for each individual test (Strauss, Sherman, & Spreen, 2006); however only unadjusted raw scores of the aforementioned tests were recorded for this study (Silverberg & Millis, 2009).

Driving Assessment

Driving performance was assessed with the in-office DriveABLE competence test administered by a certified facilitator (Dobbs, 1997). DriveABLE equipment includes a computer, touch-screen monitor, and computer mouse. The computerized assessment comprises six subtests including motor speed and control, span of attentional field, spatial judgment and decision making, speed of attention shifting, executive function, and identification of driving situations (for more details on each subtest, see Dobbs, 2013). Administration time is approximately 60 minutes.

Following DriveABLE completion, patients are given a performance outcome as their predicted probability of failing the DriveABLE on-road evaluation (DORE) with a score of approximately 1%-30% as pass, 31%-70% as inconclusive and 71% and above as fail. A performance outcome indicating inconclusive

warrants the recommendation of the DORE to resolve driving competence. Among licensed drivers referred for driving evaluation, DriveABLE differentiated between safe and unsafe drivers on the DORE with 76% sensitivity and 90% specificity (Korner-Bitensky & Sofer, 2009). The DriveABLE in-office assessment has demonstrated sufficient test-retest reliability among patients with cognitive decline (Korner-Bitensky et al., 2011). For the purposes of this study, only performance outcomes from the in-office assessment were used to operationalize driving competency.

Medical History

Thorough reviews of each subject's medical record were conducted. Pre-existing comorbid conditions and concurrent medications indicative of compromised driving ability have been previously identified (see Dobbs, 2005 for a review) and adopted for this study. The medical conditions and prescriptions present at the time of the neurobehavioral examination were tallied and added to produce the total number of comorbid medical conditions and medication use. In addition, medical condition types were also recorded as disease type present or absent for the following classifications: visual conditions/diseases, cardiovascular disease, cerebrovascular disease, diseases of the nervous system, respiratory diseases, metabolic disease, renal disease, dementia, psychiatric diseases, and polypharmacy.

Analyses

Pearson correlations were used to explore the association between NPT, comorbidity, and DA outcome. Hierarchical regression analysis was used to (1) determine the additional contribution of NPT domains ranked in order from most to least predictive according to the literature; and (2) to investigate the additional contribution of comorbidity. Backward regression modelling was employed to establish a balanced, parsimonious predictive model of DA outcome.

Table 1

Predictors and Outcome Variables Means, Standard Deviations, and Correlation with DriveABLE Probability of Failing the Road Test

Variable	Abbreviations	<i>M</i>	(<i>SD</i>)	<i>r</i> with DA _{prob} ^d
WAIS-IV Block Design	BD	24.19	(9.06)	-0.465**
Boston Naming Test-60	BNT-60	45.98	(10.90)	-0.254**
Category Fluency	CF	28.48	(9.23)	-0.410**
WAIS-IV Coding	CO	38.45	(13.22)	-0.438**
Controlled Oral Word Association Test	COWAT	30.66	(12.41)	-0.292**
Mini-Mental State Examination	MMSE	23.99	(3.77)	-0.365**
Rey Complex Figure Test-Copy	RCFT	24.59	(6.17)	-0.365**
Trail-Making Test A	TMT-A	56.02	(26.05)	0.379**
Trail-Making Test B	TMT-B	187.86	(86.00)	0.467**
WMS-IV Visual Reproduction II	VRII	5.18	(6.31)	-0.614**
Medical Comorbidity	Total Dx	3.17	(1.95)	-0.067
DriveABLE Assessment Score	DA _{prob}	65.74	(23.73)	
Categorical Outcome		%	(<i>n</i>)	
Pass		9.4	(13)	
Inconclusive		39.10	(54)	
Fail		51.4	(71)	

Note. **p* < 0.05; ***p* < 0.01.

Results

All NPT predictors were significantly associated with DA score ($p < 0.01$). The association between comorbidity and DA score was not significant. Multicollinearity, independence of errors, and equal error variances assumptions were met. In addition, the NPT predictors and DA score demonstrated a linear relationship, and there were no outliers. Thus, a five-stage hierarchical regression was employed with DA score as the dependent variable (see Table 2). At stage one, Coding and Trail-Making Test A scores contributed significantly to the regression model, $F(2, 39) = 5.375$, $p < 0.01$, predicting a significant 22% of the variance in DA score. Category Fluency, Controlled Oral Word Association Test, and Trail-Making Test B at stage two ($R^2 = 0.29$) and Rey Complex Figure Test-Copy and Block Design at stage three ($R^2 = 0.34$) did not offer additional significant variance to the prediction of DA score; however, at stage four, Mini-Mental State Examination, Boston Naming Test-60, and Visual Reproduction II explained an additional 18% of the variation in DA score ($p < 0.05$). Finally, the addition of comorbidity at stage five did not explain additional variance of DA score. In the backward stepwise regression (probability of F -to-remove ≥ 0.100), the final model included Coding ($B = -0.49$, $p = 0.03$), Visual Reproduction Delayed Recall ($B = -2.00$, $p < 0.001$), and Boston Naming Test 60-item ($B = -0.45$, $p = 0.08$) in the prediction of DA score ($R^2 = 0.71$, $F(3, 38) = 12.54$, $p < 0.05$; adjusted $R^2 = 0.46$).

Table 2

Hierarchical Regression Analyses for Predicting DA Score

Predictors	<i>B</i>	(<i>SE B</i>)	β	R^2	ΔR^2	F_{change}
Step 1						
Coding	-0.59	0.31	-0.33	0.22	0.22	5.38*
TMT-A	0.17	0.16	0.19			
Step 2						
CF	-0.52	0.44	-0.20	0.29	0.72	1.21
COWA	0.03	0.34	0.02			
TMT-B	0.06	0.58	0.22			
Step 3						
RCFT	-0.41	0.69	-0.11	0.34	0.06	1.43
BD	-0.58	0.47	-0.22			
Step 4						
MMSE	-0.40	0.93	-0.06	0.53	0.18	4.02*
BNT	-0.34	0.33	-0.16			
VR II	-2.03	0.62	-0.54			
Step 5						
Total Dx	0.72	1.68	0.06	0.53	0.00	0.18

Notes. * $p < 0.05$; TMT-A = Trail-Making Test A; CF = Category Fluency; COWAT = Controlled Oral Word Association Test; TMT-B = Trail-Making Test B; RCFT = Rey-Osterrieth Complex Figure Test; BD = WAIS-IV Block Design; MMSE = Mini-Mental State Examination; BNT = Boston Naming Test; VR II = WMS-IV Visual Reproduction II.

Discussion

The goals of this study were to determine the association and predictive value of neuropsychological testing to driving competence, explore the additional contribution of comorbidity, and develop a balanced regression model for predicting driving competence. Overall, poorer neuropsychological test performance was

associated with poorer driving competence. In the literature, attention, executive function, and visuospatial abilities demonstrate the greatest associations with driving performances as measured by on-road, in-office, and simulated driving tests. Less potent neuropsychological correlates of driving performance include mental status, global cognition, and anterograde memory. In the present study, the strongest correlates of driving competence were Visual Reproduction II, followed by Trail-Making Test B, and then by Block Design. Thus the significant associations found between driving competence and Trail-Making Test B, a purported test of executive function, and driving competence and Block Design, a test of visuospatial abilities, are consistent with the extant literature. The significant association between driving competence and Visual Reproduction II, a measure of anterograde memory, most likely reflects a global cognitive decline associated with dementing illness rather than a specific decline in cognitive skills required for driving. A global decline across the sample is further reflected by smaller but significant associations between the remaining neuropsychological tests and driving competence. This global decline may have also been reflected functionally as evidenced by the high failure rate on the DriveABLE assessment (71%).

When examining the predictive value of neuropsychological test performance, measures of processing speed and global cognition influenced driving competence. The model including all neuropsychological test scores demonstrated the best fit, predictive and generalizability estimates of driving competence. Medical comorbidity did not add to the prediction model above and beyond neuropsychological test performance alone. The finding that comorbidity did not offer additional value to the model is consistent with prior findings that the presence of chronic medical conditions does not grossly influence driving performance outcome (for a meta-analysis, see Marshall & Man-Song-Hing, 2011). Comorbidity is, however, associated with self-reported driving cessation, driving avoidance, and decline in driving mileage (Forrest, Bunker, Songer, Coben, & Cauley, 1997; Ragland, Satariano, & MacLeod, 2004). Comorbid medical conditions, therefore, appear to have little bearing on objective driving performance but have a greater impact on subjective decision-making of driving ability.

The best predictive model of driving competence included Coding (processing speed), Boston Naming Test (language), and Visual Reproduction II (anterograde memory). Again, this finding is somewhat incongruous with the literature and most likely reflects the global decline associated with dementing illness. The generalizability of these findings are likely affected by the relatively homogeneous sample and by the retrospective approach to data collection. The patients came from a single memory disorders clinic, most of whom were recommended to complete a driving evaluation due to their neuropsychological test performance. In addition, the interval between neuropsychological testing and driving evaluation varied between patients with a mean of 170.61 days ($SD = 261.68$). Thus, it is possible, given the 6.5% annual conversion rate from self-reported memory decline to Alzheimer's disease in an outpatient memory clinic (Lehrner et al., 2005) that several patients from the present sample experienced further cognitive decline during the interval between neuropsychological testing and driving assessment. Future studies should explore the impact of comorbidity and the neuropsychological predictors of driving competence from a prospective approach. A heterogeneous sample including a range of global cognitive ability from normal to demented should be used to determine cut scores for neuropsychological test performances. Specificity and sensitivity estimates for driving competence should be reported for clinical utility purposes.

In summary, the present findings suggest that neuropsychological assessment can assist in the clinical decision-making of driving competence. To better serve their patients, practitioners in primary care settings,

memory clinics, and physical/occupational therapy settings should use a brief in-office screening assessment to inform their driving referrals and recommendations. By clarifying the utility of neuropsychological assessment and comorbidity on driving, clinicians and researchers will be confident in making informed decisions that represent the best interests of the patient and the safety of the public.

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