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The Relationship Between Neuropsychological Functioning and Driving Ability in Dementia: A Meta-Analysis

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A meta-analysis of 27 primary studies was conducted to examine the relationship between neuropsychological functioning and driving ability for adults with dementia. When studies using a control group were included, the relationship between cognitive measures and on-road or non-road driving measures was significant for all reported domains; mean correlations ranged from .35 to .65. Caregiver reports of driving ability and cognitive variables were correlated significantly only on measures of mental status and visuospatial skills. When studies using a control group were excluded, moderate mean correlations were observed for visuospatial skills and on-road or non-road measures, and for mental status with non-road tests. Other effects were small or nonsignificant. Implications for basing driving recommendations on neuropsychological testing are discussed.

Alzheimer's disease (AD) is the most common form of dementia. AD is characterized by impairments in memory and at least one other cognitive domain. Although the cognitive profile in early AD is variable, gradually progressive memory impairment is typically observed in early stages. Additional deficits may be observed in performance IQ, visuoconstruction, attention, judgment, verbal fluency, and confrontation naming (Zec, 1993).

These cognitive deficits raise serious concerns about the driving safety of patients with AD and other dementias. Drivers must be able to judge distances, manage multiple stimuli simultaneously, maintain attention for long periods of time, react quickly in an emergency, and correctly interpret traffic signs and signals. In addition, safe drivers must accurately judge their abilities and adjust driving behaviors as cognitive skills decline (Johansson & Lundberg, 1997).

Evidence suggests that participants with dementia have an increased risk for automobile crashes and becoming lost while driving (Kaszniak, Nussbaum, & Allender, 1990). Individuals with dementia are 2.5 to 4.7 times more likely to be involved in an automobile crash than age-matched control participants (Friedland et al., 1988; Tuokko, Tallman, Beattie, Cooper, & Weir, 1995). Lucas-Blaustein, Filipp, Dungan, and Tune (1988) reported that 30% of the patients referred to their dementia clinic had been in an accident since the onset of cognitive symptoms.

The progressive course of dementia complicates procedures for determining which individuals are fit to drive. Although there is some consensus that individuals with moderate to severe dementia should not drive (Johansson & Lundberg, 1997), recommendations for individuals with mild dementia are more problematic. The responsibility to maintain confidentiality, encourage independent living, and protect the patient's civil liberties must be balanced with the practitioner's duty to safeguard the patient and others on the road (Post, 2000).

Therefore, it is incumbent on researchers and clinicians to develop valid and reliable procedures to accurately assess the driving risk associated with the cognitive decline in individuals with dementia. Unfortunately, standard medical evaluations do not appear to identify older individuals with increased crash risk (Johansson et al., 1996), and, in turn, many clinicians rely on cognitive testing. Out of 92 psychologists in neuropsychological settings in the United Kingdom, 70% reported that they use neuropsychological testing to make recommendations regarding fitness to drive (Christie, Savill, Buttress, Newby, & Tyerman, 2001). However, 51% of the psychologists were "not confident" or "not very confident at all" about their recommendations, and many were concerned that there is little knowledge about the relationship between cognitive testing and driving ability.

The purpose of this study was to quantitatively summarize the literature on the relationship between neuropsychological functioning and driving ability in participants with dementia and to provide a unified analysis of the functional utility of using cognitive testing to make recommendations about a patient's fitness to drive safely. Withaar, Brouwer, and Van Zomeren (2000) qualitatively reviewed studies of neuropsychological functioning, on-road driving tests, and convicted or crash-involved older drivers. They concluded that, although participants with cognitive impairment

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often performed significantly worse than controls on tests of driving skills, the size and variability of the correlations did not indicate that cognitive tests are suitable to determine fitness to drive. However, a number of questions remain. For example, these investigators did not assess domain-specific relationships to driving abilities (e.g., executive functioning). Although neuropsychological tests may not relate well to driving tests in general, deficits in specific cognitive domains such as attention or visuospatial skills may predict driving skills better than when neuropsychological studies are reviewed as a whole. In addition, a quantitative analysis provides a clearer understanding of the magnitude of the relationship between impaired cognition and driving ability than does a qualitative analysis. Attempts can also be made to address the variability noted in the current research literature. The present study sought to examine the magnitude of the relationships between three types of driving assessments (on-road, nonroad, and caregiver report of ability) and six domains of neuropsychological functioning using meta-analytic methodologies.

Method

Selection of Studies

An attempt was made to include all published studies on the relationship between driving and neuropsychological functioning in AD. A preliminary search for articles was conducted using PubMed and PsycINFO with a combination of keywords such as *driving, road, car, automobile, neuropsychology, cognitive functioning, Alzheimer's, AD,* and *dementia.* Reference lists of all relevant articles were searched manually to locate any other studies that were not identified by the preliminary search. Several articles were obtained that mixed AD participants with individuals who had other forms of dementia. These data were included, but whenever possible, the AD-only data were used. Table 1 describes the participant groups for each study.

All studies were included that met the following eligibility criteria: (a) included participants with AD, (b) used well-known neuropsychological instruments with standardized administration procedures such as those referenced by Lezak (1995) or Spreen and Strauss (1998), (c) measured driving ability through either a formal evaluation (on- or off-road tests) or by collecting caregiver reports of patients' driving ability, and (d) reported sufficient information about the study results to allow computation of an effect size (ES) estimate. Six studies were identified that appeared to meet inclusion criteria but did not report sufficient statistical information for the computation of an ES. Letters were sent to all groups requesting additional information. The authors of two articles provided the necessary statistics (Rizzo, Reinach, McGehee, & Dawson, 1997; Rizzo, McGehee, Dawson, & Anderson, 2001). No response was received from the other groups.

Our original intent was to also include state-recorded crashes as a fourth type of driving measure. Although there is a significant literature on aging and risk of automobile crash, the goals of this meta-analysis severely restricted the number of qualifying studies. In many studies, investigators examined community samples of older adults but did not diagnosis dementia. In others, investigators analyzed the risk of crash in samples with

Table 1
Participant Characteristics for Primary Studies Included in the Meta-analysis

Study	*N*	Mean age (years)	Mean education (years)	Patients' mean MMSE or alternative	Control participants included?	Type of driving measures
Bieliauskas et al. (1998)	18	71.1	14.3	19.4	Yes	Road test
Brashear et al. (1998)	84	70.5	—	CDR ≤ 1	Yes	Non-road test
Carr et al. (1998)	146	76.8	13.8	Short Blessed = 12.3	Yes	Non-road test
Cox et al. (1998)	50	71.2	14.8	21.2	Yes	Non-road test
Cushman (1992)	17	75	—	—	Yes	Road test
Cushman (1996)	123	—	—	—	Yes	Road test
Donnelly et al. (1992)	12[a]	70.25[a]	—	22.3	No[a]	Road and non-road tests
Duchek et al. (1998)	136	—	—	CDR range = .5–1	Yes	Road test
Fitten et al. (1995)	83	71.4	14.0	≥ 19	Yes	Road test
Fox et al. (1997)	19	74.3	—	21.3	No	Road test
Friedland et al. (1988)	24[a]	67.0	—	—	No[a]	Caregiver report
Gilley et al. (1991)	487	72.2	—	15.6	No	Caregiver report
Harvey et al. (1995)	13	63	—	20.8	No	Non-road test
Hunt et al. (1993)	38	73.2	13.3	Short Blessed = 7.5	Yes	Road test
Hunt et al. (1997)	123	75.2	14.2	CDR range = .5–1	Yes	Road test
Janke and Eberhard (1998)	106	73.6	—	—	Yes	Road tests
Logsdon et al. (1992)	100	74	13	19.0	No	Caregiver report
Lucas-Blaustein et al. (1988)	53	71.8	—	17.6	No	Caregiver report
Odenheimer et al. (1994)	30	72.2	77% had high school or higher	14.8	Yes	Road test
O'Jile (1998)	50	75.0	13.4	21.7	Yes	Caregiver report
O'Neill et al. (1992)	57	72.0	—	18.7	No	Caregiver report
Ott et al. (2000)	79	74.7	11.6	19.6	No	Caregiver report
Rebok et al. (1994)	10[a]	75.4[a]	13.3[a]	22.5	No[a]	Non-road tests
Rizzo et al. (1997)	39	71.7	—	—	Yes	Non-road test
Rizzo et al. (2001)	30	71.8	—	—	Yes	Non-road test
Tallman (1992)	54	62.4	12.1	23.6	Yes	Road and non-road tests
Zuin et al. (2002)	56[a]	71.8[a]	7.0[a]	—	No[a]	Caregiver report

Note. MMSE = Mini-Mental State Examination; CDR = Clinical Dementia Rating Scale; Short Blessed = Short Blessed Test.
[a]Control participants were excluded by the primary authors in data that were coded in this meta-analysis. Therefore, only statistics for the group with dementia are reported here.

dementia but did not administer neuropsychological tests. Only two studies of state-recorded crash were found that met all inclusion criteria (Trobe, Waller, Cook-Flannagan, Teshima, & Bieliauskas, 1996; Tuokko et al., 1995). Therefore, this literature is not included here. Interested readers should see Carr (1997), Wallace (1997), or Withaar et al. (2000) for reviews. On the Web at http://dx.doi.org/10.1037/0894-4105.18.1.85.supp is a list of these and other studies related to driving and aging or dementia that were not included in the meta-analysis, and the reason each study did not meet inclusion criteria is indicated.

The results of the literature search produced 27 studies that met the above criteria. The participants' mean age, education, and general characteristics are given for each primary study in Table 1. The supplementary material on the Web (http://dx.doi.org/10.1037/0894-4105.18.1.85.supp) contains a table that more thoroughly describes the participant characteristics and the nature of the driving tests used in each primary study.

Data Coding

The following information was extracted from the published articles for each coded effect: (a) nature of the driving test (on-road, nonroad, caregiver's report), (b) number and nature of participants, (c) demographics of participants, (d) neuropsychological tests, and (e) summary statistics required for computation of ESs.

Neuropsychological tests were categorized into the following six neuropsychological domains: mental status–general cognition, attention–concentration, executive functions, language–verbal functioning, visuospatial skills, and memory. Each test was coded in a single domain that was judged to best represent the primary function tested. Table 2 lists the tests that were included in each cognitive domain.

Measures of driving ability were categorized into the following three groups: on-road tests, non-road tests, and caregiver's report of driving ability. On-road tests evaluated driving ability by placing participants behind the wheel of an actual automobile. Non-road evaluations tested participants with a variety of measures, such as driving simulators or tests of driving knowledge. In studies based on a caregiver's report of driving ability, collaterals were interviewed for information regarding the participant's driving skills. Of the 27 primary studies collected, 12 included on-road driving tests, 9 included non-road tests, and 8 included caregivers' reports of participants' driving ability. Studies completed by Donnelly, Karlinsky, Young, Ridgley, and Ramble (1992) and Tallman (1992) included both on-road and non-road tests in their research.

Sixteen studies included both control and AD participants in their correlations. Therefore, the data were reanalyzed after excluding these studies to examine the relationship between neuropsychological functioning and driving ability within samples with dementia.

Table 2
Neuropsychological Tests Categorized by Cognitive Domain

Test	*n*
Mental status–general cognition	
Mini-Mental State Examination	12
Dementia Rating Scale	4
Blessed Dementia Rating Scale	3
Mattis Dementia Rating Scale	2
Temporal Orientation	2
Behavior Rating Scale	1
Clinical Dementia Ratings	1
Direct Assessment of Functional Status	1
Expanded Constructional Praxis	1
Full Scale IQ	1
Instrumental Activities of Daily Living Scale	1
Shipley IQ Estimate	1
Sum of Boxes	1
Attention and concentration	
Trails A	6
Digit Span	4
Simple or Choice/Complex Reaction Time	4
Useful Field of Vision	4
Digit Symbol	2
Attention Switching	1
Continuous Performance Test	1
Crossing-Off	1
Freed's Selective Attention	1
Letter Cancellation	1
Macksworth Clock	1
Mattis Attention	1
Sternberg Test	1
Useful Functional Field of View	1
Vigilance	1
Visual Search & Attention Test	1
Visual Tracking	1
WORLD spelled backwards	1
Visuospatial skills	
Block Design	5
Picture Completion	2
Benton Copy	1
Benton Line Orientation	1
Clock Drawing	1
Figure–Ground Test	1
Hooper Visual Organization Test	1
Mattis Construction	1
Visuospatial task–Stanford–Binet Intelligence Scale	1
Memory	
Logical Memory	5
Benton Visual Retention Test	4
Visual Reproduction	3
Facial Recognition Test	2
Associate Learning	1
Mattis Memory	1
Recognition Memory for Faces or Words	1
Spatial Recognition Test	1
Word List Learning	1
Executive functions	
Trails B	9
Word Fluency	4
Stroop Color–Word Test—C	2
Picture Arrangement	2
Category Fluency	2
Category Naming	1
Mattis Initiation/Perseveration	1
Mazes	1
Shipley Abstraction	1
Language	
Boston Naming Test	4
Information	3
Verbal IQ	2
Aphasia Battery	1
Comprehension	1
Shipley Vocabulary	1
Reading IQ Equivalent	1

Note. n = Number of journal articles within the meta-analysis that included the neuropsychological test in the primary source.

Statistical Analysis

The unit of analysis was a comparison of the neuropsychological functioning and driving ability of participants with dementia. Therefore, studies that used more than one driving or neuropsychological measure created more than one comparison. Although a single published article may contain several findings that were coded as individual effects, the term *study* will be used below to refer to a single finding that was coded as an effect.

For each study, a Pearson's product–moment correlation was calculated as the individual ESs. An ES is a standardized index of the size of the relation between two variables (Cooper & Hedges, 1994). The ES was calculated as the size of the relationship between neuropsychological functioning and driving ability in participants with dementia (e.g., Trails B [Reitan, 1992] and total on-road driving test score). With assessment instruments in which low scores indicate higher functioning, formulas were adjusted so that a positive ES always indicates a positive relationship between the two variables.

Correlations were first transformed by Fisher's variance-stabilizing z transformation as recommended by Shadish and Haddock (1994). Because individual studies with large sample sizes are more powerful than studies with smaller sample sizes, the calculation of a mean effect must weigh the correlation accordingly. Therefore, the weight given to the ES (in this case, the z transformation) was inversely proportional to the conditional variance in each study (Hedges & Olkin, 1985). At this point, each weighted z transformation described the relationship between one neuropsychological test and one driving measure. These were grouped into one of the six cognitive domains and into one of the three groups of driving measures described above. Therefore, there were 18 groups of cognitive and driving tests for which mean ESs were computed. The average ESs were calculated for each group (i.e., the average ES for all correlations between memory tests and on-road tests across all primary studies). Lastly, because these mean ESs were still in z form, the mean weighted ESs were transformed back into rs to test whether driving ability relates to neuropsychological functioning.

After we grouped individual correlations by cognitive domain and type of driving measure, some of the 18 groups had only one or two correlations to average. We calculated an average ES only when at least three studies were found within a group.

There is obviously significant variability between studies in the test measures and the methods used. The goal of all fixed effects meta-analyses is to average only the data that are thought to share a common population ES. In this case, our goal was to present mean ESs for tests that generally measure the same construct. We attempted to achieve this goal by disaggregating the large number of neuropsychological tests into cognitive domains and by grouping specific types of driving measures. The test statistic Q was used, as outlined by Hedges and Olkin (1985), to test the hypothesis that the observed variance in study ESs that make up a group mean ES was within the range that can be reasonably expected by chance if all studies share a common population ES. A significant Q statistic indicates heterogeneity of the variance. The preferred strategy for dealing with heterogeneity is to disaggregate the ESs by subdividing them into appropriate categories that might better explain the variance in terms of separate groups. However, in this case, it was expected that a number of Q statistics would reach significance even after dividing ESs by cognitive domain and type of driving measure because it was not possible to subdivide studies on the basis of other significant characteristics (i.e., specific driving measures, specific neuropsychological tests). However, a fixed effects model was chosen a priori in spite of this expectation. When Q is significant, the average ES describes a mean of observed ESs. In this case, caution must be applied to interpreting an average ES as an estimate of a single effect parameter that gave rise to the individual observed ESs.

Results

Tests of Homogeneity of Variance

The within-group homogeneity of the ESs was tested, and the results are presented in Table 3. When all neuropsychological tests were combined, Q statistics were significant in all three driving measure groups, indicating heterogeneity of the variance. Therefore, neuropsychological tests were further disaggregated by cognitive domain. This subdivision of studies was partially successful. Nine of the possible 17 Q statistics were not significant when all studies were combined by cognitive domain. These ESs can be interpreted as estimates of the population ESs. The remaining 8 ESs can each be interpreted as a mean of a group of observed ESs.

Homogeneity of the variance improved when studies with control participants were excluded from the analyses. When all neuropsychological tests were combined, on-road tests and non-road tests were not significant. Only caregiver's report indicated heterogeneity of the variance. Studies were again disaggregated by cognitive domain after excluding ESs that contained control participants. Fifteen Q statistics indicated homogeneity of the variance. Only caregiver's report in the mental status domain indicated heterogeneity of the variance when controls were excluded.

Table 3
Summary of Q Statistics for Neuropsychological Performance by Type of Driving Measure

	All studies		Excluding controls	
Domain	k	Q	k	Q
All neuropsychological tests				
On-road tests	67	156.46**	35	48.56
Non-road tests	131	391.98**	83	88.07
Caregiver's report	36	119.97**	35	72.28**
Mental status–general cognition				
On-road tests	13	23.16	6	4.18
Non-road tests	21	45.28**	15	23.27
Caregiver's report	14	76.75**	13	50.73**
Attention and concentration				
On-road tests	29	84.26**	9	9.91
Non-road tests	31	78.26**	10	7.31
Caregiver's report	—	—	—	—
Visuospatial skills				
On-road tests	8	8.40	6	14.63
Non-road tests	15	45.71**	11	5.67
Caregiver's report	5	3.52	5	4.70
Memory				
On-road tests	4	0.37	—	—
Non-road tests	30	89.15**	14	1.60
Caregiver's report	5	3.67	5	3.67
Executive functions				
On-road tests	13	29.06	10	13.54
Non-road tests	26	57.79**	19	26.29
Caregiver's report	4	2.27	4	2.27
Language				
On-road tests	6	9.28	5	6.06
Non-road tests	9	48.19**	4	3.70
Caregiver's report	4	0.17	4	0.17

Note. k is the number of individual effect sizes included in each group. Q statistics based on less than three studies were not calculated.
$^{**}p < .01$.

Mean ESs

Mean ESs were calculated for three groups of driving measures (on-road, nonroad, and caregiver's report) with all neuropsychological tests combined, and within each of the six neuropsychological domains. In addition, studies without control participants were aggregated to explore the relationship between neuropsychological functioning and driving ability among only those participants with dementia. It was not possible to calculate ESs for caregiver report in the attention and concentration domain, or on-road tests in the memory domain after excluding studies with controls, because of a lack of available data (less than three studies per group). Therefore, a total of 39 mean ESs resulted from these analyses. These data are shown in Table 4, which also includes the variance and confidence intervals for the mean ESs.

Although classification systems for ESs facilitate communication, they are based on arbitrary distinctions between magnitudes. The importance of a "small" correlation depends on the nature of the question. However, Cohen's (1988) classification system is as appropriate as any for describing the results. In his system, *r*s around .10, .30, and .50 are considered small, moderate, or large, respectively. Magnitudes are described below only for significant mean ESs ($p < .05$).

Studies with control participants included. When all studies and all neuropsychological tests were aggregated, moderate mean correlations were found in the on-road test and the non-road test groups. The ES when a caregiver's report was used was small.

When studies were disaggregated by cognitive domain, 11 of the 14 significant mean ESs fell in the moderate range. Two ESs fell in the large range (visuospatial skills and language in the non-road test groups). A small ES was found for visuospatial skills and caregiver report of driving ability.

Studies with control participants excluded. When studies with control participants were excluded and only groups of participants with dementia were averaged, ESs with all neuropsychological tests combined were small in the on-road, non-road, and caregiver report groups. When studies were disaggregated by cognitive domain, seven of the eight significant ESs fell in the small range. Only the relationship between visuospatial skills and nonroad tests ($r = .31$) fell in the moderate range. However, the relationships between visuospatial skills and on-road tests ($r = .29$) and mental status and non-road tests ($r = .29$) were nearly moderate in size. No ESs were large when studies with controls were removed from analyses.

Discussion

The results of this meta-analysis revealed a significant relationship between neuropsychological functioning and driving ability as measured by on-road tests and non-road tests. As cognitive

Table 4
Fixed Effects Weighted Means With Variances and Confidence Intervals (CIs)

Cognitive domain	On-road tests: All studies	On-road tests: Excluding controls	Non-road tests: All studies	Non-road tests: Excluding controls	Caregiver's report: All studies	Caregiver's report: Excluding controls
All neuropsychological tests						
Mean ES	.43*	.11*	.48*	.22*	.25*	.18*
Variance	.0005	.0023	.0002	.0010	.0005	.0007
95% CI	.40, .47	.01, .20	.46, .50	.16, .28	.21, .29	.13, .23
Mental status–general cognition						
Mean ES	.43*	.13	.37*	.29*	.36*	.25*
Variance	.0018	.0145	.0020	.0058	.0010	.0016
95% CI	.36, .50	−.10, .35	.29, .45	.14, .42	.30, .41	.18, .32
Attention and concentration						
Mean ES	.48*	.25*	.35*	.08	—	—
Variance	.0008	.0067	.0006	.0054	—	—
95% CI	.44, .53	.10, .40	.31, .39	−.07, .22	—	—
Visuospatial skills						
Mean ES	.41*	.29*	.56*	.31*	.20*	.19*
Variance	.0043	.0132	.0024	.0075	.0034	.0034
95% CI	.30, .51	.08, .48	.49, .62	.15, .46	.09, .31	.08, .29
Memory						
Mean ES	.44*	—	.47*	.22*	.08	.08
Variance	.0083	—	.0009	.0131	.0077	.0077
95% CI	.29, .58	—	.43, .52	.03, .40	−.09, .25	−.09, .25
Executive functions						
Mean ES	.36*	−.06	.46*	.22*	.04	.04
Variance	.0027	.0081	.0015	.0040	.0074	.0074
95% CI	.27, .45	−.24, .11	.40, .52	.11, .34	−.13, .20	−.13, .20
Language						
Mean ES	.44*	.10	.65*	.08	.06	.06
Variance	.0059	.0167	.0021	.0127	.0061	.0061
95% CI	.31, .55	−.15, .34	.59, .70	−.14, .29	−.09, .21	−.09, .21

Note. ES = effects size. ESs based on fewer than three studies were omitted.
$^*p < .05$.

functioning declines, driving abilities tend to decline. The results were mixed when we analyzed the relationship between cognitive functioning and driving ability as measured by a caregiver's report. Overall, the small correlations that remain when control participants were excluded suggest that caution must be applied when neuropsychological testing forms the basis of driving recommendations. However, tests of visuospatial skills may be most helpful in identifying at-risk drivers.

With all studies included, the moderate to large ESs found in many cognitive domains can lead to overly optimistic conclusions about the relationship between cognitive tests and driving ability. It is important to consider the ESs when control participants are removed from the analyses. Tallman (1992) wrote as follows:

> For clinicians, the most useful tests would be those that could help predict *which* cognitively impaired individuals would be likely to experience driving difficulties. . . . Thus, what is (needed) are tests that are correlated with driving abilities *within* a mildly impaired group of individuals. (p. 117)

Studies that combine AD and control participants in their correlations may not be answering the question that many clinicians must ask when faced with a patient with dementia who is still driving. Figure 1 graphically displays the mean ESs after removing studies with control participants.

When correlations with control participants were removed from the analyses, tests of visuospatial skills generally related best to driving abilities across different types of driving tests. Mean ESs were moderate in size for both on-road and nonroad tests with *r*s of .29 and .31, respectively. In addition, the visuospatial domain showed one of the few significant mean ESs when a caregiver's report of ability was used to measure driving skills. Visuospatial deficits are commonly observed in early AD (Zec, 1993) and other dementias, especially when more complex tasks are used. The importance of visuospatial skills to driving has been frequently noted (Johansson & Lundberg, 1997; Meyers, Volbrecht, & Kaster-Bundgaard, 1999; Mitchell, Castleden, & Fanthome, 1995). Safe drivers must position the automobile accurately on the road and maneuver the vehicle correctly. Visuospatial skills are also

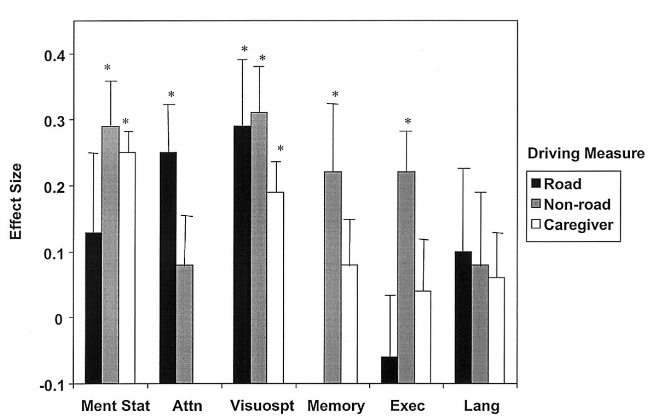

Figure 1. Mean effect sizes by cognitive domain within samples with participants with dementia only. Error bars represent standard errors. Ment Stat = mental status–general cognition; Attn = attention–concentration; Visuospt = visuospatial skills; Exec = executive functions; Lang = language. $^*p < .05$.

important to judging distances and predicting the development of traffic situations (Johansson & Lundberg, 1997). Although the results do not indicate that visuospatial deficits alone are sufficient to recommend driving restrictions, they do indicate that when visuospatial deficits are present, clinicians should complete a careful evaluation of other risk factors (see Hunt & Weston, 1999, for a review).

Mental status is frequently assessed when fitness to drive is evaluated. Fox, Withaar, and Bashford (1996) found that 94.7% of Aged Care Assessment Teams used the Mini-Mental Status Examination when assessing the impact of cognitive functioning on driving. Mental status results in this meta-analysis were mixed. When all studies were included, mental status showed a moderate relationship to road test scores ($r = .43$). However, when control participants were excluded, there was no significant relationship between mental status and on-road test scores. Following the exclusion of control participants, the mean ES was significant but small for caregiver's report of driving ability, and moderate for nonroad tests. This pattern may reflect the fact that mental status changes are reliably observed only in the middle to late stages of some dementias, including AD (Zec, 1993). At these stages of dementia, changes in driving ability would be expected to be more universal. Therefore, correlations that include patients with AD experiencing mental status changes and controls are quite large. However, when correlations with controls are removed, there is variability in the ESs, which range from nonsignificant to moderate in size.

The cognitive domain most frequently explored in relation to driving abilities is attention. Our literature review produced more studies of attention or concentration than any other cognitive domain. Several investigators have theorized that attention is one of the most important cognitive skills to assess when questions of driving arise in patients who are aging and have dementia (Ball, 1997; Duchek, Hunt, Ball, Buckles, & Morris, 1997; Parasuraman & Nestor, 1991; Perryman & Fitten, 1994; Ponds, Brouwer, & van Wolffelaar, 1988). However, our meta-analysis revealed that when all tests of attention and concentration were aggregated, the ESs were not as large as predicted. The ES for non-road tests was nonsignificant within samples with dementia. The ES for attention when on-road tests were used was a significant but small ($r = .25$) when controls were excluded. In addition, executive functions showed relatively poor relationships to measures of driving ability. These unexpected results may be due to the broad nature of the cognitive domains used in this study. Parasuraman and Nestor and Duchek and colleagues (1997) both have argued that selective attention is more specific to driving deficits in dementia than other components of attention, such as divided and sustained attention. Identifying important information in the environment while ignoring irrelevant information may be especially important driving skills that some patients with dementia lack. It is possible that as the body of literature grows in this area, specific aspects of attention will be found to relate to driving ability better than cognitive domains as a whole.

On-road tests are often considered the "gold standard" for measuring driving ability. Although debates regarding the best measure of driving ability are ongoing (Meyers et al., 1999), licensing agencies have long used on-road tests to determine fitness to drive. Neuropsychological tests that might be used to make recommendations about the driving status of a patient with dementia would be expected to correlate with on-road test scores. However, within samples with dementia, neuropsychological tests correlated poorly with on-road tests. Only visuospatial skills and attention–concentration showed significant relationships. Mean ESs were generally higher when non-road tests were considered, with significant effects in four of the six cognitive domains. The limitations of road tests include the high cost of testing; subjectivity in scoring; and the inability to control variables such as traffic flow, road conditions, and other drivers' behavior. These limitations may increase error in on-road test results and decrease the strength of their relationship with neuropsychological tests.

The stronger relationships in non-road test groups may be due in part to the nature of the tests. Although on-road tests may have the highest ecological validity, non-road tests give examiners the ability to standardize procedures and control important variables. Traffic volume, specific problems encountered, lighting, pedestrians, and other variables that may confound the results of a road test can all be controlled in simulators. Higher correlations in many of the non-road test groups may be due to purer measurements of skills thought to be important to driving.

Alternatively, the cognitive skills related to lab-based testing that are common to neuropsychological assessment and non-road tests may partially account for the higher mean ESs when compared with on-road tests. In general, non-road tests require those being tested to use skills that are often impaired in dementia. For instance, simulators may require individuals being tested to use computers or adjust to pseudoautomobile controls, which patients with dementia who have impaired executive functioning and memory may have difficulty doing. The higher ESs with nonroad tests may be an artifact of the failure of the participants with dementia to adjust to the test environment. However, this cognitive inflexibility may be relevant and important to determining fitness to drive.

Although a caregiver's report of a patient's driving ability may not be the best measure of a person's skills, it is one that many medical providers often rely on. Given that some patients with dementia demonstrate decreased awareness of deficits (Cotrell & Wild, 1999) and a strong motivation to continue driving, collaterals are frequently asked about the patient's history of accidents, tendency to become lost, and general driving ability. On the basis of the literature reviewed, caregivers' reports of driving ability do not correlate with patients' memory, executive, or language functioning. Only changes in mental status and visuospatial skills indicate that caregivers are more likely to report reduced driving skills.

It is expected that a caregiver's report would be a less reliable measure of a patient's driving ability than objective driving tests for a number of reasons (i.e., subjective opinions, desire to protect patient's independence, lack of information). However, it is also important to note that the research on caregiver reports of driving ability is limited. The average ESs for each of the four nonsignificant cognitive domains was based on only five or fewer correlations between specific neuropsychological tests and a caregiver's report of driving ability. Conclusions based on this limited research must be tentative.

There are several limitations of the current study. First, every meta-analysis struggles with the conflict between the goal of data synthesis versus the problem of between-studies variability. The current meta-analysis suffers from variability in participant characteristics, driving measures, cognitive tests, data (i.e., use of raw scores vs. age-corrected scores), and other methodological differences between studies. Although an attempt was made to disaggregate driving tests into similar groups, the study characteristics table on the Web (http://dx.doi.org/10.1037/0894-4105.18.1.85.supp) shows the significant variability in methods used to assess driving abilities. In addition, there is wide variability between studies in cognitive tests used. Grouping tests by cognitive domain reduces only some of the variability because many neuropsychological tests tap multiple cognitive domains, and each test may assess different aspects of the domain. Future research should attempt to standardize a battery of neuropsychological and driving tests that maximizes risk prediction and can be used across studies.

Publication bias is a second limitation of the results. This meta-analysis relied on published reports, and it is difficult to know how many unpublished studies have found no relationship between cognitive tests and driving abilities.

Lastly, research on the relationship between neuropsychological functioning and driving ability assumes that driving tests are valid and reliable. Some of the limitations of each type of driving test were briefly described above, and specific driving tests used in many studies have only minimal research supporting their validity. Driving is a complex behavior that involves the interaction of many variables that may be very difficult to test. The conclusions of this meta-analysis are limited by the primary studies' ability to test driving skills.

The importance of correctly estimating driving ability will only grow with the burgeoning older population and improving methods for early diagnosis. The results of this study indicate that neuropsychological testing makes a significant contribution to predicting driving ability. However, they do not indicate at what level of impairment a specific patient is unfit to drive. Additional research is needed in this area to assist neuropsychologists in fulfilling their role in the risk assessment process.

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