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Maze Test Performance and Reported Driving Ability in Early Dementia

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Abstract

A battery of standard neuropsychological tests examining various features of executive function, attention, and visual perception was administered to 27 subjects with questionable to mild dementia and compared to a 4-point caregiver rating scale of driving ability. Based on the results of this study, a computerized maze task, employing 10 mazes, was administered to a second sample of 40 normal elders and questionable to moderately demented drivers. Comparison was made to the same caregiver rating scale as well as to crash frequency. In the first study of neuropsychological tests, errors on Porteus Mazes emerged as the only significant predictor of driving ability in a stepwise regression analysis. In the follow-up study employing the computerized mazes, all 10 mazes were significantly related to driving ability ratings. Computerized tests of maze performance offer promise as a screening tool to identify potential driving impairment among cognitively impaired elderly and demented drivers.

Keywords

driving; dementia; Alzheimer's disease; neuropsychology; cognition

Elderly drivers are at higher risk than all other age groups for involvement in motor vehicle accidents on a per-mile basis,[1–3] presumably due to associated medical conditions and age-related changes in cognitive, perceptual, and motor abilities.[1,3] It is clear from numerous review articles, editorials, and investigations that moderate to severe dementia is a well-recognized risk factor for hazardous driving.[1,3–11] While most investigators and professionals agree that persons with advanced dementia should not drive, there is no consensus on whether individuals with mild or questionable dementia should be prohibited from driving.

Neuropsychological tests are a potentially reliable and economical means for identifying at-risk drivers. Despite the known utility of neuropsychological assessment in the diagnosis of early cognitive decline, however, the utility of neuropsychological measures in the determination of driving competence has not been established. Findings from the limited studies that have examined the relationship between cognitive factors and driving ability are inconsistent, likely reflecting the varied mental status and neuropsychological instruments used and the differing criterion measures of driving competence. Most studies, however,

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have found significant relationships between driving ability and tests of visual attention and perception.

The current 2-part study was undertaken to explore the utility of specific tests of executive function, attention, and visual perception as predictors of driving impairment in cognitively impaired elders, using conventional and computerized methods. A rating scale of driving ability completed by a family member or caregiver was chosen as the primary outcome variable. Subject informants independently rated the subject's driving ability during the past month on a 4-point rating scale, which is a modification of a previously used caregiver rating scale employed by Logsdon et al[12] as well as our own research group.[13]

METHODS: PART A

Subjects

Subjects consisted of 27 patients (13 men, 14 women) drawn from the Memory Disorders Clinic at Roger Williams Medical Center in Providence, Rhode Island. Participants had been evaluated by a neurologist and were referred for neuropsychological assessment to assist with diagnosis. Based on Clinical Dementia Rating[14] (CDR) criteria, 18 subjects were diagnosed with questionable or very mild dementia (CDR 0.5) and 9 were considered mildly demented (CDR 1). All subjects had probable or possible Alzheimer's disease (AD) by National Institute of Neurological and Communicative Disorders and Stroke and the Alzheimer's Disease and Related Disorders Association (NINCDS-ADRDA) diagnostic criteria.[15] The mean age of the sample was 74.8 ± 5.9 years, and the subjects had achieved an average 12.0 ± 2.6 years of education; the average Mini-Mental State Examination (MMSE) score was 21.8 ± 2.9. Subjects attained an average estimated full-scale IQ (FSIQ) score of 87.1 ± 8.7, based on Vocabulary/Block Design or Ward[16] short-form versions of the Wechsler Adult Intelligence Scale–Revised (WAIS-R).

Measures and Procedures

Driving Scale—During the neurologic examination, 1 caregiver or family member was asked to rate the patient's driving ability during the past month according to the following 4-point scale: 1 = no longer able to drive; 2 = drives when someone is present to give directions (weaves from side to side; is slow in stopping for red lights and at stop signs; drives very slowly and cautiously); 3 = drives alone, but has a tendency to lose way and get lost (occasionally drives too close to cars on either side; may overshoot a traffic light or stop sign); and 4 = drives alone and has good sense of direction and driving skills.

Neuropsychological Measures—The neuropsychological measures selected for this study were chosen from a comprehensive diagnostic battery and included the following: Porteus Mazes errors (Porteus Mazes Years VIII & XII), Controlled Oral Word Association, clock drawing, and Trail Making Test–Part B (see Lezak[17] for further description of these various measures). These measures were chosen because they were expected to reflect attention and executive function—cognitive functions that we felt were likely to be critical to driving ability.

Total number of errors on the 2 Porteus Mazes (Years VIII & XII) was recorded. Errors were determined by counting the number of times a patient entered a dead-end alley or failed to stay within the lines. The patient was informed of the error and instructed to find another path to complete the maze. The patient had a maximum of 60 seconds and 120 seconds to complete the first (Year VIII) and second (Year XII) mazes, respectively. If the patient did not complete the maze within the time limit, then the total error score included the number of remaining possible incorrect paths. Clock drawings were scored on a 5-point scale based on a modification of scoring system proposed by Henderson et al.[18] Finally, a time limit of 500 seconds was imposed on subjects' completion of Trails B.

Measures of global cognitive function included the MMSE[19] and FSIQ. The American National Adult Reading Test was included as an estimate of premorbid intelligence.

METHODS: PART B

Subjects

Subjects consisted of 40 patients (19 men, 21 women) drawn from the Memory Disorders Clinic at Memorial Hospital of Rhode Island. Based on CDR criteria, 6 subjects were normal, 18 had questionable dementia, 12 had mild dementia, and 4 had moderate dementia. Clinical dementia diagnoses were 6 normal, 21 probable AD, 11 mild cognitive impairment, one frontotemporal dementia, and 1 mixed degenerative and vascular dementia. The mean age of the sample was 73.8 ± 7.5 years, and the subjects had achieved an average of 12.8 ± 3.1 years of education. The average MMSE score was 24.5 ± 4.8.

In both parts of the study, drivers rated by their caregivers as "1" (no longer able to drive) were not actively driving. All others were active and legally licensed drivers. No subjects had clinical evidence of stroke or parkinsonism on their neurological examination. No subjects had active major depression, visual impairment, or musculoskeletal limitations that would impair their driving ability. Brain imaging with CT or MRI was performed in all subjects to exclude structural brain lesions, as well as chemistry panel, vitamin B_{12} level, thyroid function tests, and syphilis serology.

Measures and Procedures

The same driving ability rating scale described above in part A was completed by family members and caregivers for each subject. This rating of driving ability was compared to scores on 10 selected mazes with a range of difficulty chosen from a computerized maze program (MazeMaster version 1.01,©1992, Flatirons Group). In this program, path length is determined by the total number of segments traversed. Maximum score is 100 × the correct path length (range 1400–3300). Final score is the maximum score minus 25 × the number of dead ends that are reached. The predictor variable chosen for this test was the grand total of all 10 scores for the different mazes.

Maze lines were drawn by the subjects on an 18-inch touch-screen monitor, using a rubber-tipped stylus. The time required for completion of the mazes was approximately 5 to 7 minutes.

Motor vehicle crashes involving the patient as driver both in and out of traffic, irrespective of fault status, were recorded for the period of the patient s dementia preceding the assessment. This information was obtained from an interview with the patient and the caregiver. Additional information from caregivers was included since self-report from elderly drivers may underestimate actual crash frequency.[20] This method of collecting crash information has been used in previous dementia and driving studies,[21,22] which related increased frequency to patients with AD compared to normal elderly controls.

RESULTS

In the part-A study, driving abilities were rated as categories 1 through 4 in 5, 3, 12, and 7 subjects, respectively. A series of *t* tests were performed for 2 collapsed groups: those with less impairment (driving scale categories 3 + 4; n = 19) versus those with more impairment (driving scale categories 1 + 2; n = 8). The variables tested were age, education, American

National Adult Reading Test, FSIQ, CDR, MMSE, Controlled Oral Word Association, clock drawing, Trails B time, Porteus Maze time, and Porteus Maze errors. Significant results were observed for FSIQ ($F_{1,17}$ = 4.59, *P* = .047), Trails B time ($F_{1,22}$ = 6.03, *P* = .02), maze errors ($F_{1,20}$ = 7.37, *P* = .01), as well as maze drawing time ($F_{1,21}$ = 11.3, *P* = .003).

A forward stepwise multiple logistic regression analysis was then conducted to assess which variables predicted driver ratings most parsimoniously. Driver rating scores served as the criterion, and the significant variables defined by the *t* tests were entered freely as predictor variables. Porteus Maze drawing time emerged as the only significant predictor of driving ratings (chi-square = 9.14, *P* = .003), accounting for 41% of the variance in ratings. The strength of Porteus Mazes in the predictive equation may reflect its overlapping relationship with other measures of both attention and executive function.

In the part-B study employing the computerized mazes, driving abilities were rated as categories 1 through 4 in 5, 7, 14, and 14 subjects, respectively. All 10 mazes were significantly related to driving ability ratings. The total maze score was highly correlated with driving (R^2 = .57, *P* < .0005). In a multiple linear regression model, education, dementia severity measured by CDR, and crashes, along with total maze score, were significant independent predictors of driving ability (R^2 = .84, *P* < .0005). There was no significant relationship between total maze score and number of crashes.

In a subanalysis of 24 drivers with very mild to mild dementia, all 10 mazes were significantly related to driving ability ratings. The total maze score was still highly correlated with driving (R^2 = .41, *P* < .0005). In a multiple regression model, education, dementia severity measured by CDR, and crashes, along with total maze score, were significant independent predictors of driving ability (R^2 = .61, *P* = .0008). Multiple regression models are detailed in Table 1.

The distribution for the motor vehicle crash variable was skewed (30 subjects with no accidents, 9 subjects with 1 accident, and 1 subject with 2 accidents). Therefore, the multiple regression models were then recalculated after dropping the crash variable. The relationships of the remaining variables were still significant in the same patterns. Among those with none to moderate dementia, driving ability was significantly related to total maze score (*t* = 4.13, *P* < .001), education (*t* = −2.23, *P* = .03), and CDR (*t* = −5.23, *P* < .001). Among those with very mild to mild dementia, driving ability was significantly related to total maze score (*t* = 3.54, *P* = .002), education (*t* = −2.20, *P* = .04), and CDR (*t* = −3.42, *P* = .003).

DISCUSSION

Findings from the current study suggest that elderly individuals with even questionable or mild dementia have driving abilities that may be described as impaired by family members. Although the exact probability of these reported driving difficulties resulting in a motor vehicle accident is not known, such risk is likely increased relative to drivers without obvious compromise. The finding of caregiver-identified driving impairment among many of the subjects in this study again highlights the obvious but often overlooked need to find methods of assessing current driving abilities and predicting future compromise of safe driving in elderly subjects with early cognitive decline.

We sought to fill a notable gap in the literature by examining more thoroughly the utility of executive measures as predictors of driving ability. Executive functions, particularly those that also have visuomotor demands, were associated with caregiver driving ratings. Specifically, Porteus Maze performance and Trails B time were both correlated with driving scores, although only Porteus Mazes draw time was predictive of driving ratings in the multivariate regression analysis.

The issue of identifying a gold standard for a criterion measure of driving competence remains central to studies attempting to predict future driving problems. Some would argue that actual driving tests or simulations are best. However, the former are typically single-trial assessments in which older persons may be on their "best behavior" knowing that they are being observed and evaluated, while the latter are artificial. Conversely, older persons may be so anxious during these "formal" assessments that their driving ability is compromised and restricted inappropriately. Until the issue of a gold standard is resolved, studies of this nature likely will continue to produce discrepant findings.

In the study of Trobe and coworkers,[23] neuropsychological test scores as well as the MMSE did not predict future crashes or violations. Logsdon and coworkers,[12] though, reported that general screening tests such as the Mattis Dementia Rating Scale and the MMSE, as well as tests of visuospatial construction ability, were significantly different between demented drivers who stopped driving and those actively driving. Tests of memory and attention were not. This finding is somewhat surprising in light of previous theoretical and empiric evidence in the literature suggesting that declining attentional skills, particularly ability to shift visual attention, may be an important factor in driving skills among the elderly population.[24,25]

Another small-sample study of 13 active drivers with dementia examined performance in a driving simulation laboratory. Seven subjects performed normally, while 6 were rated as poor. The poor performance group scored lower on the MMSE as well as cognitive tests of nonverbal and visual perception abilities.[26]

In a driving simulator study of 21 AD subjects and 18 controls, predictors of crashes included tests of visuospatial impairment (Rey-Osterreith Copy, Trail-Making B, WAIS-R Block Design, Benton-Van Allen Facial Recognition Test), reduction of field of view, and reduced perception of 3-dimensional structure from motion.[27] More recently, a simulator study of car crashes at intersections found that crash predictors included visuospatial impairment, disordered attention, reduced processing of visual motion cues, and overall cognitive decline among persons with AD.[28] To date, the predictive value of driving simulators for crashes is unknown. It has been suggested that tasks that assess visual information processing should be the focus of future simulator studies.[29]

There have been a number of studies reported that have used on-the-road tests as the outcome variable of interest. In a report by Hunt and coworkers,[30] 25 AD subjects with questionable to mild dementia were compared to 13 age-matched controls on a 1-hour road test. They found that 40% of those rated as mildly demented failed the road test, while those rated questionable or very mild and the normal subjects all passed the examination. The CDR and the Short Blessed Test were correlated with impaired driving performance as were more specific tests of memory, language, timed performance, visuoperceptual ability, and attention.

In a follow-up study of 123 subjects employing the Washington University Road Test, 3% of elderly controls, 19% of very mild dementia subjects, and 41% of mild dementia subjects failed.[31] Performance in driving was compared to performance on 3 tests of visual attention (useful field of vision, visual monitoring task for vigilance, and a visual search task). The visual search task, which examined the ability to select a target that was either present or absent in an array of distractors, was the most highly predictive of impaired driving performance in persons with mild AD, that is, CDR = 1.[32]

A road test study from UCLA examined 13 subjects with AD, 12 with vascular dementia, 15 diabetic patients, 24 normal elder subjects, and 16 younger controls. Performance in the 2 dementia groups was similar and differed from the 3 other control groups. Normal elders performed as well as their younger counterparts. Cognitive test scores on the MMSE, short-term memory, and visual-tracking tasks correlated with driving performance. The number of collisions and moving violations per 1000 miles during the 2 years preceding the examination were also significantly correlated with driving test performance.[33]

In summary, there have been conflicting results from research to date regarding the most important cognitive factors related to driving impairment among the elderly and demented populations; however, most studies suggest that problems with attention and visual perception are important.

In this preliminary study, we chose family member ratings of driving ability as the primary outcome measure. Family member ratings may be more ecologically valid in terms of the opportunities for multiple observations and ratings of performance under typical, rather than simulated, conditions. Based on their experience in a road test study, Hunt et al[30] has reported that caregivers are generally aware of driving impairments by those with AD, although they may tolerate such impairment. Another previous study by Gilley et al[34] found that lower caregiver ratings of driving abilities were correlated with motor vehicle accidents. More recently, a caregiver questionnaire about driving abilities was significantly correlated with scores on a standardized driving test and correctly identified 83% of subjects who failed a road test.[35] Furthermore, caregiver ratings employing the same scale as the present study have been correlated with right temporo-occipital and frontal perfusion on single-photon emission computed tomography scans of drivers with AD.[16] Degeneration in these brain regions is likely to produce cognitive impairments in executive function, attention, and visual perception. Although this evidence suggests that caregiver ratings are valid measures of driving, the reliability of these ratings may be limited by variability between caregivers in amount of driving contact and the subjective nature of such ratings.

The maze tests that were related to reported driving ability in the present study can be administered quickly and easily and could serve as adjunctive screening measures for license renewal in many states where currently only visual acuity tests are used. Such screening tests would also be useful by clinicians in office practice; however, the older person should also be evaluated for deficits in motor and sensory function and for medical conditions or medications that could affect driving competence. Furthermore, such screening tests would have to be more thoroughly validated against crashes, moving violations, and road test information since these sources of information provide objective and complementary information regarding overall driving competence.

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References

1. Graca L. Driving and aging. Clin Geriatr Med. 1986; 2:577–589. [PubMed: 3742444]
2. Klein R. Age-related eye disease, visual impairment, and driving in the elderly. Hum Factors. 1991; 33:521–525. [PubMed: 1769672]
3. Vernon, MS. Accidents in the elderly population. In: Reichel, W., editor. Care of the elderly: clinical aspects of aging. Philadelphia, PA: Williams & Wilkins; 1995.
4. Donnelly RE, Karlinsky H. The impact of Alzheimer’s disease in driving ability: a review. J Geriatr Psychiatry Neurol. 1990; 2:67–72. [PubMed: 2206261]
5. Dubinsky RM, Williamson A, Gray CS, Glatt SL. Driving in Alzheimer’s disease. J Am Geriatr Soc. 1992; 40:1112–1116. [PubMed: 1401695]

6. Freedman ML, Freedman DL. Should Alzheimer's disease patients be allowed to drive? A medical, legal, and ethical dilemma. J Am Geriatr Soc. 1996; 44:876–877. [PubMed: 8675943]
7. Kazniak AW, Keyl PM, Albert MS. Dementia and the older driver. Hum Factors. 1991; 33:527–537. [PubMed: 1769673]
8. O'Neill D. The older driver. Rev Clin Gerontol. 1996; 6:295–302.
9. Post SG, Whitehouse P. Fairhill guidelines of the care of people with Alzheimer's disease: a clinical summary. J Am Geriatr Soc. 1995; 43:1423–1429. [PubMed: 7490397]
10. Rabins, P.; Blacker, D.; Bland, W. Practice guidelines for the treatment of patients with Alzheimer's disease and other dementias of late life. Washington, DC: American Psychiatric Association; 1997.
11. Reuben DB, Silliman RA, Traines M. The aging driver: medicine, policy, and ethics. J Am Geriatr Soc. 1988; 36:1135–1142. [PubMed: 3057052]
12. Logsdon RG, Teri L, Larson EB. Driving and Alzheimer's disease. J Gen Int Med. 1992; 7:583–588.
13. Ott BR, Heindel WC, Whelihan WM, et al. A SPECT imaging study of driving impairment in patients with Alzheimer s disease. Demen Geriatr Cogn Disord. 2000; 11:153–160.
14. Hughes CP, Berg L, Danziger WL, et al. A new clinical scale for the staging of dementia. Brit J Psychiat. 1982; 140:566–572.
15. McKhann G, Drachman D, Folstein M, et al. Clinical diagnosis of Alzheimer's disease: report of the NINCDS-ADRDA Work Group under the auspices of the Department of Health and Human Services Task Force on Alzheimer's disease. Neurology. 1984; 34:939–944. [PubMed: 6610841]
16. Ward LG. Prediction of verbal, performance, and full scale IQs from seven subtests of the WAIS-R. J Clin Psychology. 1990; 46:436–440.
17. Lezak, MD. Neuropsychological assessment. New York, NY: Oxford University Press; 1995.
18. Henderson VW, Mack W, Williams BW. Spatial disorientation in Alzheimer s disease. Arch Neurol. 1989; 46:391–394. [PubMed: 2705898]
19. Folstein MF, Folstein SE, McHugh PR. "Mini-Mental State": a practical method for grading the cognitive state of patients for the clinician. J Psychiat Res. 1975; 12:189–198. [PubMed: 1202204]
20. Marottoli RA, Cooney LM, Tinetti ME. Self-report versus state records for identifying crashes among older drivers. J Gerontology: Med Sci. 1997; 52A:M184–M187.
21. Drachman DA, Swearer JM. the Collaborative Group. Driving and Alzheimer's disease: the risk of crashes. Neurology. 1993; 43:2448–2456. [PubMed: 8255438]
22. Friedland RP, Koss E, Kumar A, et al. Motor vehicle crashes in dementia of the Alzheimer type. Neurology. 1988; 24:782–786.
23. Trobe JD, Waller PF, Cook-Flannagan CA, et al. Crashes and violations among drivers with Alzheimer's disease. Arch Neurol. 1996; 53:411–416. [PubMed: 8624215]
24. Parasuraman R, Nestor P. Attention and driving. Clin Geriatr Med. 1993; 9:377–386. [PubMed: 8504386]
25. Parasuraman R, Nestor PG. Attention and driving skills in aging and Alzheimer's disease. Hum Factors. 1991; 33:539–557. [PubMed: 1769674]
26. Shua-Haim JR, Gross JS. A simulated driving evaluation for patients with Alzheimer's disease. Am J Alz Dis. 1996; 11:2–7.
27. Rizzo M, Reinach S, McGehee D, Dawson J. Simulated car crashes and crash predictors in drivers with Alzheimer's disease. Arch Neurol. 1997; 54:545–551. [PubMed: 9152111]
28. Rizzo M, McGehee DV, Dawson JD, Anderson SN. Simulated car crashes at intersections in drivers with Alzheimer disease. Alz Dis Assoc Disord. 2001; 15:10–20.
29. Bylsma FW. Simulators for assessing driving skills in demented patients. Alz Dis Assoc Disord. 1997; 11(suppl 1):17–20.
30. Hunt LA, Morris JC, Edwards D, Wilson BS. Driving performance in persons with mild senile dementia of the Alzheimer type. J Am Geriatr Soc. 1993; 41:747–753. [PubMed: 8315186]
31. Hunt LA, Murphy CF, Carr D, et al. Reliability of the Washington University Road Test. Arch Neurol. 1997; 54:707–712. [PubMed: 9193205]

32. Duchek JM, Hunt L, Ball K, et al. Attention and driving performance in Alzheimer s disease. J Gerontol Psych Sci. 1998; 53B:130–141.

33. Fitten LJ, Perryman KM, Wilkinson C, et al. Alzheimer and vascular dementias and driving: a prospective road and laboratory study. JAMA. 1995; 273:1360–1365. [PubMed: 7715061]

34. Gilley DW, Wilson RS, Bennett DA, et al. Cessation of driving and unsafe motor vehicle operation by dementia patients. Arch Intern Med. 1991; 151:941–946. [PubMed: 2025142]

35. Brashear A, Unverzagt FW, Kuhn ER, et al. Simple office tools predict impaired drivers with dementia. Neurology. 2002; 58(suppl 3):A275–276.

Table 1

Multiple Linear Regression Models for Driving Scores

A. Subjects with none to moderate dementia		
Multiple regression for TOTAL, gender, education, CDR, age, MMSE, MVA		
Significant for	TOTAL	$t = 4.5$, $P < .001$
	Education	$t = -2.1$, $P = .04$
	CDR	$t = -5.6$, $P < .001$
	MVA	$t = -3.1$, $P = .005$
$R^2 = .84$; prob > F < .0001		
B. Subjects with very mild to mild dementia		
Multiple regression for TOTAL, gender, education, CDR, age, MMSE, MVA		
Significant for	TOTAL	$t = 4.1$, $P = .001$
	Education	$t = -2.4$, $P = .02$
	CDR	$t = -3.8$, $P = .001$
	MVA	$t = -3.1$, $P = .006$
$R^2 = .78$; prob > F < .0001		

TOTAL, total of all maze scores; CDR, Clinical Dementia Rating; MMSE, Mini-Mental State Examination score; MVA, number of motor vehicle accidents.