Alzheimer Disease and Associated Disorders
Vol. 11, Suppl. 1, pp. 48–56

The Role of Selective Attention in Driving and Dementia of the Alzheimer Type

Janet M. Duchek, Linda Hunt, *Karlene Ball,
†‡Virginia Buckles, and †‡§John C. Morris

*Program in Occupational Therapy, Washington University School of Medicine; *Department of Psychology, University of Alabama at Birmingham, Birmingham, Alabama; †Department of Neurology & Neurosurgery (Neurology), Washington University School of Medicine; ‡Alzheimer's Disease Research Center, Washington University School of Medicine; and §Department of Pathology (Neuropathology), Washington University School of Medicine, St. Louis, Missouri, U.S.A.*

Summary: This paper examines the relationship between cognitive processes and driving in aging and dementia of the Alzheimer type. Several studies that have explored the relationship between neuropsychological test performance and various indicators of driving safety are reviewed. It is argued that deficits in selective attention are specific to impaired driving performance in dementia of the Alzheimer type. Results from a recent study supporting this notion are presented. It is suggested that screening measures that emphasize the ability to selectively attend to relevant information and inhibit irrelevant information should be used to identify mildly demented individuals who are at risk for unsafe driving. **Key Words:** Aging—Dementia—Driving—Attention.

Recently, there has been a growing interest in the consequences of healthy aging and dementia of the Alzheimer type (DAT) on the ability to drive. This recent interest reflects current changes in the demographics of society. The older driver now represents the fastest growing segment of the driving population. The ability to drive is an important functional activity that promotes and maintains independence in older adults. In areas where mass transportation is inaccessible, the inability to drive an automobile can lead to the loss of many functional and social activities.

When one examines the driving habits of older adults, some interesting trends emerge. First, most older adults self-limit their driving. They tend to drive only about half as many miles as younger adults and not to drive in "high risk" situations, such as nighttime, bad weather conditions, etc. However, taking into consideration that older drivers self-limit their driving, the accident and fatality rate for older drivers is high compared with other age groups (Evans, 1988). Furthermore, older adults tend to have different types of accidents than younger adults. The older driver has the highest rate of accidents at intersections, with the most common cited cause of accidents cited as being "driver inattention," as opposed to driving too fast and alcohol abuse in younger adults (Shinar, 1978).

There may be many different reasons for the increased accident rate of older adults. For example, it is well known that there is a decline in various aspects of physical function and mobility that may affect one's ability to make the necessary movements to safely maneuver an automobile (e.g., restricted range of motion due to arthritis). Decline in various aspects of visual function, such as visual acuity, color vision, contrast sensitivity,

Address correspondence and reprint requests to Dr. Janet M. Duchek at Program in Occupational Therapy, Box 8505, Washington University School of Medicine, St. Louis, MO 63108, U.S.A.

and glare recovery, particularly, could impair driving performance. It is interesting to note, however, that previous studies have reported that measures of visual sensory status are not good predictors of accident rates for older adults (e.g., Owsley et al., 1991). Finally, it is possible that an age-related decline in cognitive function may be related to the higher accident rates in older adults. Given that the majority of accidents in older adults tend to occur under "high cognitive demand" situations (e.g., at intersections) and may be due to a lack of "attention," age-related cognitive deficits are prime candidate causative factors for the increased accident rate of older drivers.

One would assume that older individuals with disease-related cognitive deficits, such DAT, may be at greater risk for impaired or unsafe driving. Retrospective studies of informant reports (Friedland et al., 1988; Lucas-Blaustein et al., 1988; Coyne et al., 1990) as well as prospective studies of actual on-road driving performance (Hunt et al., 1993, 1997; Fitten et al., 1995) support this assumption. These studies clearly indicate a relationship between dementia and impaired driving and increased accident rates.

Because of the relationship between age-related disorders such as DAT and unsafe driving, there has been an increasing recognition of the need for public policy and/or physician assistance to determine driving fitness. It is not entirely clear, however, how best to evaluate driving and identify individuals at risk for unsafe driving. Although the above-mentioned studies suggest that general cognitive status (e.g., healthy cognitive aging versus DAT) is predictive of accidents and driving performance, it is important to note that general cognitive status is not a perfect predictor of driving. That is, not all DAT individuals show impaired driving performance. For example, Hunt et al. (1997) reported that 41% of mild DAT and 67% of very mild DAT individuals exhibited safe driving skills in an actual on-road driving test. Thus, some DAT individuals may retain good driving skills early in the disease, whereas others may lose these skills. It is likely that many of the basic skills necessary for maneuvering an automobile are well automatized and represent procedural knowledge that is relatively spared in the early stages of the disease (Parasuraman and Nestor, 1993). Simply determining the presence of dementia may not be specific enough to accurately predict driving fitness (also see Fitten et al., 1995). The development of sensitive screening measures for at-risk individuals is much needed both to preserve the driving privileges of individuals who are safe drivers and to protect others and society at large from unsafe driving. The development of such measures first requires a clear understanding of the cognitive processes underlying driving performance in older adults with dementia. Because driving is a highly complex activity that involves motor, visual, and cognitive functioning, it is imperative to understand *which* specific cognitive skills and processes influence driving performance in healthy aging and DAT and *how* specific cognitive processes may be impaired in drivers who exhibit unsafe driving behaviors versus those drivers who do not.

NEUROPSYCHOLOGICAL TESTING AND DRIVING PERFORMANCE

The common approach taken in the literature toward understanding how cognitive processes underlie driving performance has been to correlate neuropsychological test performance with some indicator of driving performance (e.g., on-road or simulator driving performance, informant reports, accident rates). This approach has produced equivocal results. Certain cognitive tests have been reported as predictive of driving skills, whereas others have not been predictive. Also, particular tests have been related to driving under some circumstances yet not under other circumstances. For example, in a sample of demented individuals, O'Neill et al. (1992) reported that scores on the Mini-Mental State Examination (MMSE) did *not* discriminate those individuals who were experiencing "diminished driving ability" from those individuals with "preserved driving ability," where driving ability was assessed based upon informant reports. On the other hand, MMSE scores have been significantly related to driving in several other studies using informant reports of driving ability (Logsdon et al., 1992; Marottoli et al., 1994), driving simulator performance (Rebok et al., 1994), and actual on-road driving performance (Fitten et al., 1995).

It is important to consider that the MMSE is used as a brief cognitive screening test. Although each item examines more specific cognitive skills (e.g., language processing, memory, mathematical abilities, etc.), the total score represents a measure of global cognitive status. Depending on the range or variability of global cognitive status in the sample, the MMSE scores may or may not relate to measures of driving ability. It is possible that other neuropsychological tests that assess more specific processes beyond global cognitive status may be more closely related to driving ability. For example, Marottoli et al. (1994) found that the design copy item on the MMSE was most strongly correlated with informant reports of adverse driving events in a sample of community-dwelling elderly, relative to other items on the MMSE.

Other more process-specific cognitive and neuropsychological measures have been examined in relation to driving, with equivocal findings. For example, several studies have examined the relationship between driving and cognitive measures that assess aspects of visuospatial abilities. Again, O'Neill et al. (1992) reported that a test of visuospatial ability did not discriminate impaired versus nonimpaired demented drivers. However, Fitten et al. (1995) found that a visual tracking test was highly correlated with on-road driving performance, and Logsdon et al. (1992) found that scores on the visuospatial construction task of the Mattis Dementia Rating Scale (MDRS) were more impaired for demented individuals who had stopped driving versus those who were still driving. Thus, there is mixed evidence regarding the intuitive relationship between visuospatial abilities and driving.

Cognitive measures that do not reflect visuospatial processing have been related to driving performance. Fitten et al. (1995) found that the Sternberg memory search task was related to on-road driving performance. This task involves holding and monitoring several pieces of information in working memory. Fitten et al. argued that the task may be relevant to holding information regarding road signs in memory to use that information to guide driving and that this ability, in turn, may be related to frontal lobe function. Rebok et al. (1994) reported that performance on a category fluency test was related to driving simulator performance. At first glance, performance on a category fluency test may not seem relevant to driving. However, the cognitive processes underlying category fluency also involve the ability to hold and monitor information "on-line," and this task has been used as a measure of frontal lobe processing. It is interesting to note that the abilities to keep track of multiple sources of information and monitor the appropriateness of responses are related to driving skills. On the other hand, when measures of other cognitive processes have been examined in relation to driving, such as WAIS-R (Logsdon et al., 1992), Benton line, logical memory, visual reproduction, and picture arrangement (Rebok et al., 1994), they have not been correlated with driving ability.

The apparent lack of consistency regarding specific cognitive processes may be a function of two different issues. First, the outcome measure of "driving ability/safety" varies from one study to the next, and has been determined by various types of informant reports, accident rates, simulator performance, and actual on-road driving tests. Each of these measures may represent different aspects of driving, and all have advantages and disadvantages as valid and sensitive measures of driving safety. Second, a variety of cognitive/neuropsychological measures have been used in different studies. One may question the usefulness of particular neuropsychological tests as valid and sensitive proxies for driving. It is reasonable to assume that certain aspects of cognitive processing (e.g., visuospatial abilities) would be more related to driving than other aspects of cognitive processing (e.g., verbal abilities). Of course, it is possible that *any* measure of cognition may be "statistically" related to driving performance, not because it is a proxy for driving per se but because it is related to general cognitive status, which in turn is globally related to driving. The most sensitive screening measures for identifying individuals at risk for unsafe driving should be *specifically* related to driving skills in this particular population. Specific processing skills that underlie many of these tasks also should be considered; as mentioned, category fluency, which at face value seemingly is unrelated to driving, measures properties that are quite relevant to the driving situation. In particular, *processing skills* that are most important for driving and are likely to be impaired in demented individuals should be examined in relation to valid measures of driving performance and safety.

ATTENTION, AGING, AND DRIVING

Attentional processing appears to be one aspect of cognition that correlates with driving ability. It has been suggested that "driver inattention" is a common cause of accidents, especially in older adults (Shinar, 1978), although it often is difficult to determine precisely what is meant by this term. Experimental cognitive measures of attention also have been linked to driving performance. Early studies by Kahneman et al. (1973) and Mihal and Barrett (1976) reported a relationship between performance on a dichotic listening task and frequency of accidents in commercial drivers. The dichotic listening task is a test of selective attention wherein an auditory signal serves as a cue to attend to relevant information presented to one ear and ignore irrelevant information presented to the other ear. The relevant ear changes as a function of the auditory cue. The results from these studies indicated that errors in switching attention between the ears was the best predictor of accident rates. Performance on an embedded figures test that examines the ability to visually/perceptually distinguish relevant information from a complex background of irrelevant information also was related to accident rates. Finally, the relationship between switching attention errors in the dichotic listening task and performance on the embedded figures and accidents was more pronounced in older drivers (Mihal and Barrett, 1976). Measures of both auditory and perceptual selective attention thus appear to be related to safe driving in an age-related manner.

Aspects of attentional processing are affected by age (Hartley, 1992). Age-related deficits have been reported in various tests of divided attention, sustained attention, and selective attention. Given that there are deficits in attentional performance as a function of increasing age and attentional performance is related to driving safety, it is possible that the increased accident rates in older adults are in part caused by changes in attentional processing.

Research by Ball, Owsley, and colleagues using a measure of visual attention (i.e., the percent reduction in the Useful Field of View, UFOV) has provided support for this contention [e.g., Ball and Owsley, 1991; Ball et al., 1993; Ball, 1997 (this issue)]. The UFOV represents attentional processing at an early stage of information processing and refers to the visuospatial area functionally available in a single glance (without eye or head movements) for a given task, such as target identification or localization. The size of the UFOV has been linked to accident frequency in older adults and indeed has served as a better predictor of crashes than general mental status (Owsley et al., 1991) or other measures of visual function (e.g., visual acuity, contrast sensitivity, glare recovery, etc.) (Owsley et al., 1991). Older adults who failed the UFOV task (i.e., showed greater than 40% reduction in the UFOV) had more than 3 times the accidents and 15 times more intersection accidents than older adults who passed the UFOV task. Cushman (1996) reported that reduction in the UFOV was the best predictor of the performance of older adults in an on-road driving test. The same study also found that omission errors in a vigilance-type task (i.e., continuous performance task) were highly correlated with driving performance. It is interesting to note that both the UFOV and the continuous performance task involve selective attention, where relevant (target) information must be selected from a background of irrelevant or distracting information (similar to the dichotic listening task).

ATTENTION, DRIVING, AND DEMENTIA

Attentional deficits also are present in the early stages of DAT (Parasuraman and Nestor, 1993). Specific deficits in selective attention have been reported in early-stage DAT in a number of tasks, such as Trailmaking (Grady et al., 1988), Stroop (Spieler et al., 1996), dichotic listening (Grady et al., 1989), and visual search (Nebes and Brady, 1989). In fact, Grady et al. (1988) have argued that deficits in selective attention are characteristic of the early stages of DAT, in addition to the hallmark memory deficits of the disease.

Based on both theoretical and empirical arguments, Parasuraman and Nestor (1991) have suggested that the switching component of selective attention, which is impaired in the early stages of DAT, appears to be more related to driving than other aspects of attentional processing (e.g., sustained or divided attention) and thus may be a good predictor of driving performance and increased accident risk in DAT. Unfortunately, there have been relatively few empirical studies of the relationship between specific aspects of attentional processing and driving in DAT. Cushman (1996) included a sample of patients with mild DAT in her study, but it is difficult to ascertain how individuals with a diagnosis of DAT performed on the visual attention measures (e.g., UFOV) and driving performance test. In a pilot study of driving and DAT, Hunt et al. (1993) found that a simple paper/pencil test of switching attention was highly related to actual on-road driving performance relative to other clinical measures.

We have recently reported the results from a study examining the relationship between specific aspects of visual attention and driving skills in DAT (Duchek et al., submitted). In this study, cognitively healthy older adults and individuals with very mild DAT and mild DAT were administered an on-road, in-traffic driving test [the Washington University Road Test; see Hunt et al. (1997) for a complete description] and three computerized tests of visual attention. All participants were recruited from the Alzheimer's Disease Research Center (ADRC) at Washington University School of Medicine, and the severity of dementia was staged according to the Washington University Clinical Dementia Rating (CDR) (Hughes et al., 1982; Morris, 1993). According to this scale, CDR 0, CDR 0.5, and CDR 1 represent no dementia (healthy control), very mild dementia, and mild dementia, respectively. Each visual attention task was chosen and/or designed to reflect different components of attentional processing that should be related to driving in the DAT population. The UFOV task was used as a measure of early attentional processing and the size of the functional field of view available for target identification and localization to examine relationships with actual on-road driving performance and dementia severity. A visual monitoring task measured the ability to detect infrequent changes in a visual display (i.e., vigilance); in this task, subjects simply had to respond when a target "X" occurred in a series of scrolling "O"s while monitoring one or two lines on the computer screen. Finally, a visual search task was used to examine the ability to select a target that was either present or absent in an array of distractors.

To examine the relationship between attentional performance and driving performance in these three groups of subjects, regression analyses were performed using these attentional measures, CDR, and various psychometric measures as predictors of on-road driving performance. Results indicated that error rate and reaction time during visual search were the best predictors of driving performance. Furthermore, visual search performance was predictive of driving performance above and beyond several traditional psychometric measures [see Duchek et al. (submitted) for further details].

To examine how aspects of attentional processing may be different as a function of driving performance within each of these subject groups, the results from this study also were analyzed as a function of dementia severity (CDR) and driving performance ("high" versus "low" performance based on a median split on drive test scores). As can be seen in Fig. 1, the percent reduction in the UFOV was greatest in the mildly demented individuals (CDR 1), particularly for those CDR 1 subjects who also showed poorer performance on the driving test. The larger reductions in the UFOV for the subjects with low drive scores occurred primarily in the selective attention component of the UFOV task, where subjects localize a peripheral target embedded in an array of distractors, which is consistent with the findings of Cushman (1996).

Results from the error data in the visual monitoring and visual search tasks yielded consistent findings related to driving performance and mild DAT. In the visual monitoring task, two types of errors were possible: errors of omission (missing the target) or errors of commission (false alarming in the absence of the target). It can be seen in Fig. 2 that there was no differentiation in miss or false alarm errors for subjects with high versus low drive scores in either the healthy control (CDR 0) or very mild DAT (CDR 0.5) groups. However, there was a striking increase in false alarm errors for the CDR 1 individuals who showed poorer driving performance relative to the CDR 1 individuals who exhibited good driving performance. In the visual search task, there were also two possible types of errors: miss errors (on "yes" response trials, incorrectly responding that the target is not present in the array) or false alarm errors (on "no" response trials, incorrectly responding that the target is present in the array). Again, the results in Fig. 3 illustrate that there was little differentiation in miss or false alarm errors for subjects with high versus low drive scores in either the CDR 0 or CDR 0.5 groups. However, there again is a large increase in false alarm errors for the CDR 1 individuals who performed more poorly on the driving test relative to the CDR 1 individuals who exhibited better driving performance.

The results from this study support the suggestion of Parasuraman and Nestor (1991) that visual selective attention may be related to impaired driving performance in the early stages of DAT. Mildly demented individuals who exhibited poor driving performance in a comprehensive in-traffic driving test had difficulty in the visual attention tasks, particularly in selecting relevant target information (i.e., missing targets) and inhibiting irrelevant distracting information (i.e., false alarming and erroneously mistaking irrelevant information for target information). This pattern of results is consistent with the recent cognitive literature on deficits in inhibitory control in DAT across a variety of experimental tasks (e.g., Balota and Duchek, 1991; Faust et al., 1997; Spieler et al., 1996). It has been argued that individuals with mild DAT have difficulty engaging and controlling inhibitory mechanisms necessary for selecting relevant information against irrelevant information across various task demands. Furthermore, DAT individuals may show changes in the criteria necessary to initiate a

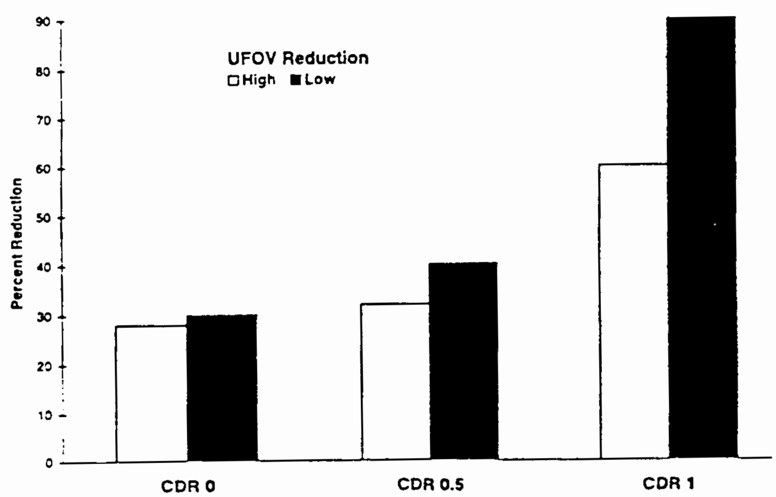

FIG. 1. Useful Field of View (UFOV) as a function of drive score ("high," above median; "low," below median) and Clinical Dementia Rating (CDR 0, healthy control; CDR 0.5, very mild DAT; CDR 1, mild DAT).

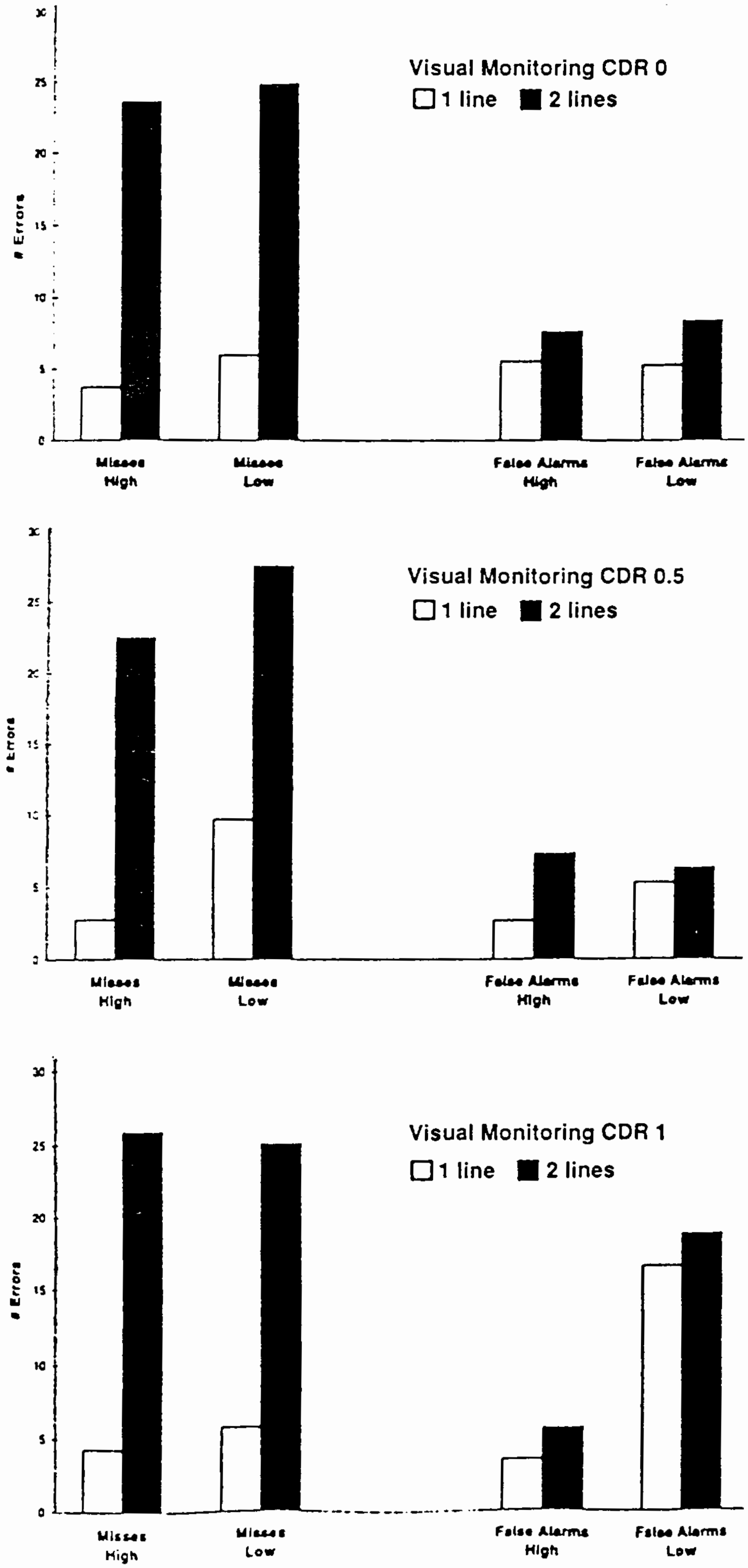

FIG. 2. Visual monitoring error rates as a function of number of lines monitored, error type, drive score ("high," above median; "low," below median), and Clinical Dementia Rating (CDR 0, healthy control; CDR 0.5, very mild DAT; CDR 1, mild DAT).

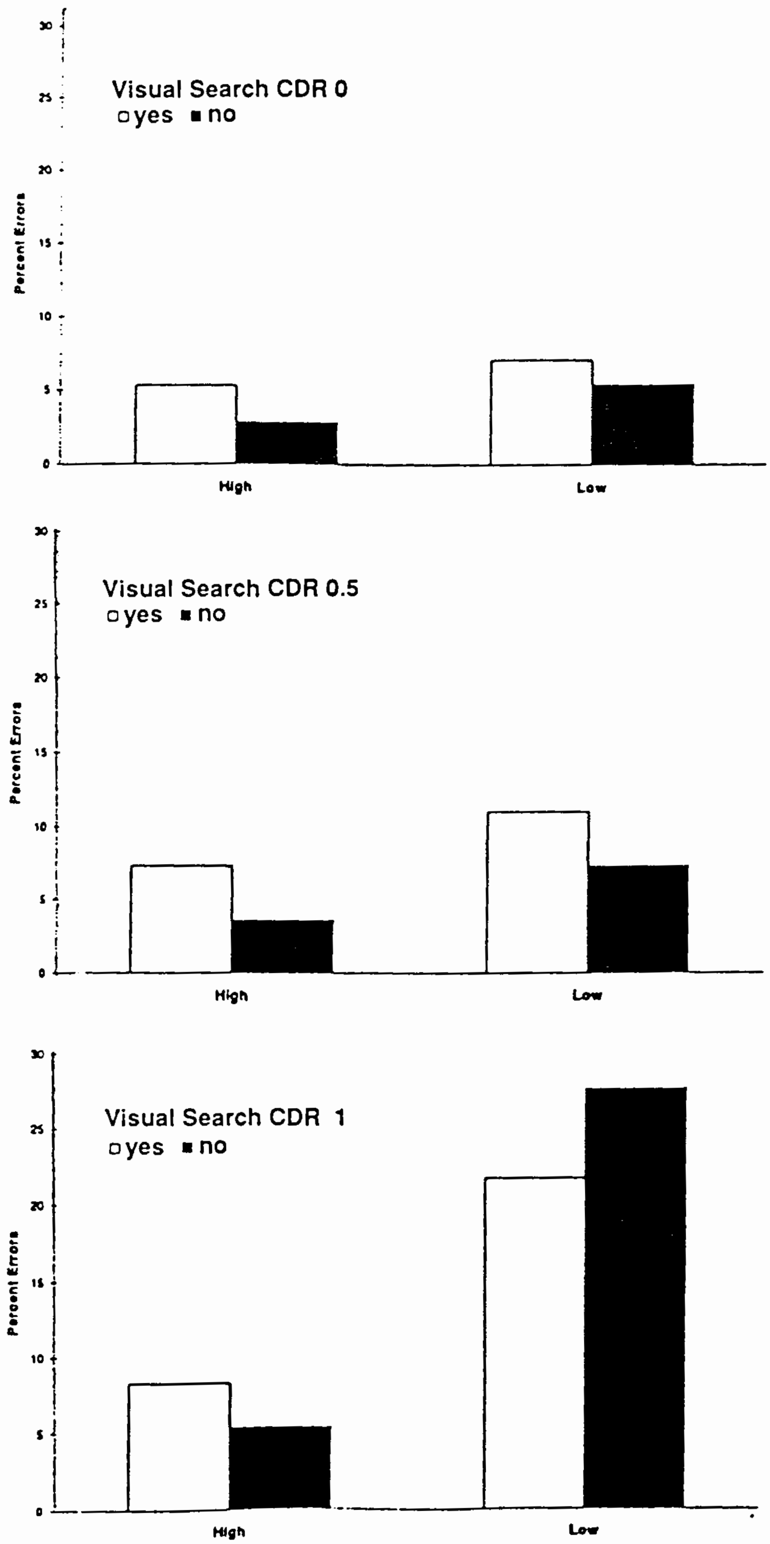

FIG. 3. Visual search error rates as a function of response type, drive score ("high," above median; "low," below median), and Clinical Dementia Rating (CDR 0, healthy control; CDR 0.5, very mild DAT; CDR 1, mild DAT).

response such that the presence of partial information may be sufficient to activate a response. Demented individuals thus may often be erroneously responding to inappropriate dimensions of the environment (i.e., false alarming, such as proceeding forward when there is a signal change from a red light to a left turn only arrow). Driving represents a real life task wherein the control of attention and inhibition is critical to consistently selecting relevant features of the environment and actively inhibiting irrelevant features. Fluctuations in attentional control (Spieler et al., 1996) underlie fluctuations in performance commonly seen in the early stages of DAT, including driving skills, as suggested by variability in driving performance by demented drivers in a 1-month follow-up road test [Hunt et al., 1997 (this issue)]. Although many of the skills involved in maneuvering an automobile may be well automatized, there are times when unpredictable events occur and attentional control must be exerted. It is precisely under such circumstances that one would expect breakdowns in driving performance in DAT.

In this light, it is interesting to note that Fitten et al. (1995) reported more errors in the DAT group in the complex stages of the driving assessment, presumably when the attentional demands are greater. Likewise, in driving simulator performance, Rebok et al. (1994) reported that DAT individuals performed poorly in skill areas, such as searching for a hazard, identifying a hazard and executing evasive actions. Deficits in such attentional control areas are critical to safe driving. Finally, Hunt et al. [1997 (this issue)] described a case of a demented driver who simply followed the flow of traffic when making a left turn rather than attending to the oncoming traffic, thereby nearly causing an accident, illustrating the potential impact of deficient attentional control on driving safety. In this instance, the environmental cue of moving traffic (i.e., inappropriate information) was sufficient to initiate a response, whereas the more relevant dimension of the environment (i.e., the oncoming traffic) was not appreciated.

SUMMARY

The current literature on cognition and driving in DAT suggests that an aspect of attentional processing, namely, selective attention, is related to driving skills in the early stages of DAT. Although global cognitive status remains a powerful predictor of driving ability, it may be fruitful to examine specific cognitive mechanisms, such as selective attention, to better understand the processes underlying safe driving in this population and to develop more sensitive screening tests to identify unsafe drivers. General cognitive status may identify at-risk individuals, and process-specific measures then possibly could be used to differentiate safe versus unsafe drivers. Based on the existing literature, tests of selective attention that capitalize on the ability to respond to appropriate dimensions of a stimulus and inhibit other responses may be sensitive to driving ability in DAT. Current licensing practices of visual screening do not tap the cognitive skills that are necessary for safe driving and that are likely to be impaired in DAT. Further work is needed to elucidate the relationship between selective attention and driving in DAT and to develop clinically feasible screening assessments for identifying demented individuals in need of on-road testing and follow-up.

Acknowledgment: This work was supported by NIA grants AG 10145, AG 03991, AG 05681, and 3P50 AG11684. We thank the Clinical and Psychometric Cores of the Alzheimer's Disease Research Center at Washington University School of Medicine for their subject evaluations and the Edward Roybal Center for Research and Applied Gerontology at the University of Alabama at Birmingham.

REFERENCES

Ball K. Attentional problems and older drivers. *Alzheimer Dis Assoc Disord* 1997;11(Suppl 1):42–7.

Ball K, Owsley C. Identifying correlates of accident involvement for the older driver. *Hum Factors* 1991;33:583–95.

Ball K, Owsley C, Sloane ME, Roenker DL, Bruni JR. Visual attention problems as a predictor of vehicle crashes in older drivers. *Invest Ophthalmol Vis Sci* 1993;34:3110–23.

Balota DA, Duchek JM. Semantic priming effects, lexical repetition effects, and contextual disambiguation effects in healthy aged individuals and individuals with senile dementia of the Alzheimer type. *Brain & Language* 1991;40:181–201.

Coyne AC, Feins LC, Powell AL, Joslin BL. The relationship between driving and dementia. Presentation at the meeting of the Cognitive Aging Conference, Atlanta, GA, 1990.

Cushman LA. Cognitive capacity and concurrent driving performance in older drivers. *IATSS Res* 1996;20:38–45.

Duchek JM, Hunt L, Ball K, Buckles V, Morris JC. Attention and driving performance in Alzheimer's disease. Submitted for publication.

Evans L. Older driver involvement in fatal and severe traffic crashes. *J Gerontol* 1988;43:189.

Faust ME, Balota DA, Duchek JM, Gernsbacher MA, Smith S. Inhibitory control during comprehension in individuals with dementia of the Alzheimer's type. *Brain & Language* 1997, in press.

Fitten LJ, Perryman KM, Wilkinson CJ, et al. Alzheimer and vascular dementias and driving: a prospective road and laboratory study. *JAMA* 1995;273:1360-5.

Friedland RP, Koss E, Kumar A, et al. Motor vehicle crashes in dementia of the Alzheimer type. *Ann Neurol* 1988;24:782–6.

Grady CL, Grimes MS, Patronas N, Sunderland T, Foster NL, Rapoport S. Divided attention as measured by dichotic speech performance in dementia of the Alzheimer type. *Arch Neurol* 1989;46:317–20.

Grady CL, Haxby JV, Horwitz B, et al. A longitudinal study of the early neuro-psychological and cerebral metabolic changes in dementia of the Alzheimer type. *J Clin Exp Neuropsychol* 1988;10:576–96.

Hartley A. Attention. In: Craik FIM, Salthouse TA, eds. *The handbook of aging and cognition*. Hillsdale, NJ: Erlbaum Associates, 1992:3–49.

Hughes CP, Berg L, Danziger W, Coben LA, Martin RL. A new clinical scale for the staging of dementia. *Br J Psychiatry* 1982;140:566–72.

Hunt L, Carr D, Duchek JM, Grant E, Buckles V, Morris JC. Reliability and validity of the Washington University Road Test: A perfor-

mance-based assessment for drivers with dementia of the Alzheimer type. *Arch Neurol* 1997, in press.
Hunt L, Morris JC, Edwards D, Wilson BS. Driving performance in persons with mild senile dementia of the Alzheimer type. *J Am Geriatr Soc* 1993;41:747–53.
Hunt LA, Murphy CF, Carr D, Duchek JM, Buckles V, Morris JC. Environmental cueing may affect performance on a road test for drivers with dementia of the Alzheimer type. *Alzheimer Dis Assoc Disord* 1997;11(Suppl 1):13–6.
Kahneman D, Ben-Ishai R, Lotan M. Relation of a test of attention to road accidents. *J Appl Psychol* 1973;58:113–5.
Logsdon RG, Teri L, Larson E. Driving and Alzheimer's disease. *J Gen Intern Med* 1992;7:583–8.
Lucas-Blaustein MJ, Filipp L, Dungan C, Tune L. Driving in patients with dementia. *J Am Geriatr Soc* 1988;36:1087–91.
Marottoli RA, Cooney LM, Wagner DR, Doucett J, Tinetti ME. Predictors of automobile crashes and moving violations among elderly drivers. *Ann Intern Med* 1994;121:842–6.
Mihal WL, Barrett GV. Individual differences in perceptual information processing and their relation to automobile accident involvement. *J Appl Psychol* 1976;61:229–33.
Morris JC. The clinical dementia rating (CDR): current version and scoring rules. *Neurology* 1993;43:2412–4.
Nebes RD, Brady CB. Focused and divided attention in Alzheimer's di ease. *Cortex* 1989;25:305–15.
O'Neill D, Neubauer K, Boyle M, Gerrard J, Surmon D, Wilcock GK Dementia and driving. *J R Soc Med* 1992;85:199–202.
Owsley C, Ball K, Sloane ME, Roenker DL, Bruni JR. Visual cognitiv correlates of vehicle accidents in older drivers. *Psychol Aging* 1991 6:403–15.
Parasuraman R, Nestor PG. Preserved cognitive operations in earl Alzheimer's disease. In: Cerella J, Rybash J, Hoyer W, Commons ML eds. *Adult information processing: limits on loss.* San Diego, CA: Aca demic Press, 1993:77–106.
Parasuraman R, Nestor PG. Attention and driving skills in aging an Alzheimer's disease. *Hum Factors* 1991;33:539–57.
Rebok GW, Keyl PM, Bylsma FW, Blaustein MJ, Tune L. The effect of Alzheimer's disease on driving-related abilities. *Alzheimer Dis Asso. Disord* 1994;8:228–40.
Shinar D. *Driver performance and individual differences in attention an information processing, vol. 1. Driver inattention.* Technical Repor DOT HS 8-801819. Washington, DC: U.S. Department of Trans portation, National Highway Traffic Safety Administration, 1978.
Spieler DH, Balota DA, Faust ME. Stroop performance in younger anc older adults and individuals with dementia of the Alzheimer's type (DAT). *J Exp Psychol Hum Percept Perform* 1996;22:461–79.

mance-based assessment for drivers with dementia of the Alzheimer type. *Arch Neurol* 1997, in press.

Hunt L, Morris JC, Edwards D, Wilson BS. Driving performance in persons with mild senile dementia of the Alzheimer type. *J Am Geriatr Soc* 1993;41:747–53.

Hunt LA, Murphy CF, Carr D, Duchek JM, Buckles V, Morris JC. Environmental cueing may affect performance on a road test for drivers with dementia of the Alzheimer type. *Alzheimer Dis Assoc Disord* 1997;11(Suppl 1):13–6.

Kahneman D, Ben-Ishai R, Lotan M. Relation of a test of attention to road accidents. *J Appl Psychol* 1973;58:113–5.

Logsdon RG, Teri L, Larson E. Driving and Alzheimer's disease. *J Gen Intern Med* 1992;7:583–8.

Lucas-Blaustein MJ, Filipp L, Dungan C, Tune L. Driving in patients with dementia. *J Am Geriatr Soc* 1988;36:1087–91.

Marottoli RA, Cooney LM, Wagner DR, Doucett J, Tinetti ME. Predictors of automobile crashes and moving violations among elderly drivers. *Ann Intern Med* 1994;121:842–6.

Mihal WL, Barrett GV. Individual differences in perceptual information processing and their relation to automobile accident involvement. *J Appl Psychol* 1976;61:229–33.

Morris JC. The clinical dementia rating (CDR): current version and scoring rules. *Neurology* 1993;43:2412–4.

Nebes RD, Brady CB. Focused and divided attention in Alzheimer's d ease. *Cortex* 1989;25:305–15.

O'Neill D, Neubauer K, Boyle M, Gerrard J, Surmon D, Wilcock G Dementia and driving. *J R Soc Med* 1992;85:199–202.

Owsley C, Ball K, Sloane ME, Roenker DL, Bruni JR. Visual/cogniti correlates of vehicle accidents in older drivers. *Psychol Aging* 199 6:403–15.

Parasuraman R, Nestor PG. Preserved cognitive operations in ear Alzheimer's disease. In: Cerella J, Rybash J, Hoyer W, Commons M eds. *Adult information processing: limits on loss.* San Diego, CA: Ac demic Press, 1993:77–106.

Parasuraman R, Nestor PG. Attention and driving skills in aging an Alzheimer's disease. *Hum Factors* 1991;33:539–57.

Rebok GW, Keyl PM, Bylsma FW, Blaustein MJ, Tune L. The effec of Alzheimer's disease on driving-related abilities. *Alzheimer Dis Assc Disord* 1994;8:228–40.

Shinar D. *Driver performance and individual differences in attention an information processing, vol. 1. Driver inattention.* Technical Repoı DOT HS 8-801819. Washington, DC: U.S. Department of Trans portation, National Highway Traffic Safety Administration, 1978.

Spieler DH, Balota DA, Faust ME. Stroop performance in younger an older adults and individuals with dementia of the Alzheimer's typ (DAT). *J Exp Psychol Hum Percept Perform* 1996;22:461–79.