

Attention and Driving Performance in Alzheimer's Disease

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The present study examined the relationship between visual attention measures and driving performance in healthy older adults and individuals with very mild and mild dementia of the Alzheimer type (DAT). Subjects were administered an on-road driving assessment and three visual attention tasks (visual search, visual monitoring, and useful field of view). The 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 simple dementia severity and several traditional psychometric tests. The results suggest that general cognitive status may be useful for identifying individuals "at risk" for unsafe driving. However, measures of selective attention may serve to better differentiate safe versus unsafe drivers, especially in the DAT population.

THE older driver represents the fastest growing segment of the driving population. While driving is an important functional activity which promotes independence in older adults, there are concerns regarding driving safety in this group. Taking into consideration that older drivers travel fewer miles than younger drivers and tend to drive in "low-risk" situations (e.g., daylight, good weather), the accident and fatality rates for older drivers are considerably higher than those for other age groups (Evans, 1988). Furthermore, older individuals with cognitive deficits are at a greater risk for impaired driving (Drachman & Swearer, 1993). Thus, there is an increasing recognition of the need for public policy to determine "driving fitness."

Clearly, age-associated illnesses that affect cognition, such as Alzheimer's disease, would be expected to impair driving ability. Retrospective studies that have examined the relationship between dementia of the Alzheimer type (DAT) and driving performance based upon informant report suggest that dementia is associated with unsafe driving (Coyne, Feins, Powell, & Joslin, 1990; Friedland et al., 1988; Lucas-Blaustein, Filipp, Dungan, & Tune, 1988). For example, Friedland et al. found that 77% of the informants reported that the DAT individuals had shown a change in driving performance over the past 5 years and that individuals with DAT were five times more likely to be involved in a motor vehicle accident than healthy age-matched controls. Furthermore, 58% of the DAT individuals who had stopped driving during this time did so only after having an accident.

There have been a few prospective studies of actual on-the-road driving performance in Alzheimer's disease. Fitten et al. (1995) found that individuals with mild DAT performed significantly worse on a road test than either a

group of healthy control subjects or diabetic control subjects. Specifically, the DAT group drove more slowly and made more errors (e.g., driving into a street marked "do not enter") particularly in the more complex stage of the driving assessment. The driving scores on the road assessment in this study were correlated with the number of collisions and moving violations during the preceding 2 years. In another study of actual driving performance in DAT, Hunt, Morris, Edwards, and Wilson (1993) found that driving performance was related to dementia severity. In this study, individuals with mild DAT were more likely to fail the driving assessment than individuals with very mild DAT or healthy controls. Likewise, in an expanded longitudinal study, Hunt et al. (1997) reported that only 3% of the healthy controls failed an on-the-road driving test, whereas 19% of the very mild DAT group failed the driving test, and 41% of the mild DAT group failed the driving test.

These studies indicate that there is a relationship between impaired driving abilities and DAT based upon both informant reports of motor vehicle accidents and moving violations, and actual on-road driving performance. However, it is important to note that not all DAT individuals exhibit poor driving performance. That is, 59% of the mild DAT and 81% of the very mild DAT individuals in the Hunt et al. (1997) study did *not* fail the driving test and hence appear to retain relatively safe driving skills, at least in the early stages of the disease. Given that driving represents a highly automatized skill, it is possible that driving behaviors would not show a decline in the early stages of the disease, because some relatively automatic tasks appear to be well preserved in DAT (e.g., see Balota & Duchek, 1991). Thus, diagnosis of DAT alone may not serve as the best predictor of driving (see Drachman, 1988).

It has been suggested that cognitive screening measures should be developed to predict driving ability and identify individuals with DAT who are at risk for unsafe driving (e.g., Cushman, 1996; Hunt et al., 1993; Kaszniak, Keyl, & Albert, 1991). In this light, many of the above-mentioned studies also have attempted to examine performance on various cognitive and neuropsychological measures in relation to driving. For example, in the Fitten et al. (1995) study, Sternberg memory search (Sternberg, 1975), visual tracking, and Mini-Mental State Examination (Folstein, Folstein, & McHugh, 1975) scores were best correlated with driving scores relative to other cognitive measures (together accounting for 68% of the variance in drive scores). Because driving is a highly complex skill that involves visual, motor, and cognitive functioning, it would seem paramount to understand how *specific* skills and processes influence driving performance to better identify screening measures, which would be predictive of unsafe driving in the older adult and DAT population.

Aspects of attentional processing have been identified in the literature as related to driving. For example, Shinar (1978) suggested that 25–50% of accidents are due to driver "inattention." In an earlier study, Kahneman, Ben-Ishai, and Lotan (1973) found that errors of shifting attention in a dichotic listening task were the best predictor of accidents in a group of commercial bus drivers (also see Mihal & Barret, 1976). In reference to older drivers, studies by Ball and her colleagues have found that a measure of visual attention (i.e., the size of the useful field of view; UFOV) is a relatively strong predictor of driving ability and vehicle accidents (Ball & Owsley, 1991; Ball, Owsley, Sloane, Roenker, & Bruni, 1993; also see Cushman, 1996). The UFOV refers to the visual spatial area functionally available in a single glance (without head or eye movements) for a given visual task, such as target identification or localization. Owsley, Ball, Sloane, Roenker, and Bruni (1991) found that the UFOV followed by general mental status were the best predictors of accident frequency in a sample of older adults (together accounting for 20% of the variance). Furthermore, older adults who failed the UFOV task in this study had 3–4 times more accidents overall and 15 times more intersection accidents than older adults who passed the UFOV task. In a prospective study utilizing a structural equation (LISREL) model, only the UFOV directly predicted crash frequency (Owsley, Ball, Sloane, Overley, & White, 1994). Measures of visual sensory function (e.g., acuity, contrast sensitivity, glare sensitivity) were only indirectly related to crash frequency and were mediated by the UFOV.

Based upon the above-mentioned studies, it appears that measures of attention, especially visual attention, are related to driving in the older adult population. Clearly, attentional deficits are present in DAT, even in the earlier stages of the disease when individuals are more likely to be still driving (Parasuraman & Nestor, 1991). Deficits in selective attention have been reported in DAT across various tasks, such as Stroop (Spieler, Balota, & Faust, 1996), dichotic listening (Grady et al., 1989), and visual search (Nebes & Brady, 1989). Given that individuals with DAT exhibit deficits in attentional processing, and performance in some attentional tasks has been shown to be predictive of accidents in older

adults, it is plausible that attentional deficits may be linked to impaired driving performance in DAT. In fact, in the Hunt et al. (1993) study of driving in DAT, a simple paper/pencil test of switching attention was highly related to driving performance relative to other clinical measures.

The purpose of the present study was to examine the relationship between *specific* aspects of visual attention performance and actual on-road driving performance in healthy aging and various stages of DAT. The inclusion of two levels of DAT (i.e., very mild and mild) is important in understanding how aspects of attention may be related to driving performance as the disease progresses, particularly because driving represents a relatively automatized skill that may not decline in the earliest stages of the disease (e.g., Hunt et al., 1997). This study was conducted as part of a larger longitudinal research project examining driving in DAT.

In this study, healthy older adults, individuals with very mild DAT, and individuals with mild DAT were administered three visual attention tasks (visual search, visual monitoring, UFOV) and an on-road driving test. The visual attention tasks were chosen to reflect various aspects of attentional processing which are important to the driving situation. The visual search task was employed as a measure of selective attention and the ability to select a target from an array of distractors. In this task, subjects make a speeded decision as to whether or not a target letter is present in an array of 2, 4, or 6 letters. Clearly, the typical driving situation involves constant monitoring of the environment and the selection of relevant information from a myriad of distracting information. The visual monitoring task was used to examine the ability to sustain and divide attention and detect infrequent changes in a visual display. In this task, subjects make a response whenever they detect an "X" either in 1 or 2 scrolling columns of "Os." Clearly, efficient vigilance is necessary during prolonged periods of driving. The UFOV task, as described above, was utilized because it represents attentional processing at an early pre-attentive level and has been linked to accident frequency in older adults (e.g., Owsley et al., 1991).

Two basic issues were addressed in this study. First, to determine the impact of DAT on visual attention processing and driving, we examined performance on the three attention tasks and the driving task as a function of dementia severity in a series of ANOVAs. Second, to examine the relationship between attentional performance and driving performance in these three groups of subjects, regression analyses were performed utilizing the various attentional measures as predictors of on-road driving performance. In addition, various psychometric tests that are routinely administered to all the study participants also were included in the regression analyses to determine whether the specific measures of visual attention were better predictors of driving performance than other more general measures of cognitive processing.

METHOD

Subjects

Three groups of participants were included in this study: healthy controls, individuals with very mild DAT, and indi-

viduals with mild DAT. All participants were still driving at the time of the study, had a valid driver's license, had at least 10 years of driving experience, and had corrected visual acuity of at least 20/50. Participants were recruited from the Alzheimer's Disease Research Center (ADRC) at Washington University School of Medicine and were originally screened for depression, hypertension, reversible dementias, and other disorders that could potentially produce cognitive impairment. The inclusionary and exclusionary criteria for DAT are consistent with the criteria of the National Institute of Neurological and Communicative Disorders and Stroke and the Alzheimer's Disease and Related Disorders Association (NINCDS-ADRDA; McKhann, Drachman, Folstein, Katzman, Price, & Stadlan, 1984). The severity of dementia was staged according to the Washington University Clinical Dementia Rating (CDR) Scale (Hughes, Berg, Danziger, Coben, & Martin, 1982; Morris, 1993). According to this scale, CDR 0, 0.5, and 1 represent no dementia, very mild dementia, and mild dementia, respectively. The CDR is based on a 90-minute interview with both the subject and a collateral source. This interview assesses the subject's cognitive abilities in the areas of memory, orientation, judgment and problem solving, community affairs, home and hobbies, and personal care. Both the reliability of the CDR and validation of the diagnosis with this research team have been excellent and well-documented (Berg et al., 1990; Burke et al., 1988; Morris, McKeel, Fulling, Torack, & Berg, 1988; Morris et al., 1991). Presently, 97% of the individuals diagnosed with DAT have had Alzheimer's disease confirmed upon autopsy (Berg & Morris, 1994).

As part of the larger longitudinal study, 58 CDR 0s, 49 CDR 0.5s, and 29 CDR 1s performed the on-road driving test. However, a different number of subjects from each CDR group participated in the three visual attention tasks for various reasons, such as the difficulty of the particular task, time constraints, and when the task was initiated in the larger study. The UFOV was initiated later in the study and results are available only from 28 CDR 0s, 21 CDR 0.5s, and 6 CDR 1s for the UFOV task. It was clear that the present version of the UFOV task utilized in this study was very difficult for the CDR 1s to perform. Specifically, the CDR 1s had difficulty performing both the central and the peripheral tasks and utilizing the touch screen to make their responses. There were 36 CDR 0s, 34 CDR 0.5s, and 18 CDR 1s for the visual monitoring task, and there were 47 CDR 0s, 37 CDR 0.5s, and 18 CDR 1s for the visual search task. Neither the visual monitoring nor the visual search task appeared to be too difficult for the DAT individuals to perform.

Given that all subjects who participated in the on-road driving test did not perform all the visual attention tasks, it is important to determine whether the missing subjects' driving performance was different from those subjects who participated in the various attention tasks. There were no apparent differences in mean scores on the driving test for those CDR 0 subjects who did versus did not perform the UFOV task (103 vs 101, respectively, $p = .25$), the visual monitoring task (102 vs 102, $p = .83$), and the visual search task (102 vs 101, $p = .34$). It appears there was no difference in mean drive scores for those CDR 0.5 subjects who

did versus did not perform the UFOV task (102 vs 99, respectively, $p = .16$), but there were differences in the visual monitoring task (101 vs 95, $p < .03$) and the visual search task (101 vs 95, $p < .03$). Also, there was no significant difference in mean drive scores for those CDR 1 subjects who did versus did not perform the UFOV task (98 vs 91, respectively, $p = .20$), but there were differences in the visual monitoring task (96 vs 86, $p < .03$), and the visual search task (96 vs 86, $p < .03$). Thus it appears that both CDR 0.5 and CDR 1 subjects who did not perform the visual monitoring and visual search tasks had overall lower drive scores, suggesting that these subjects had a slightly poorer cognitive status than those who performed these attention tasks.

Visual Attention Tasks

All three visual attention tasks were presented on a computer monitor, which both controlled stimulus presentation and recorded subjects' responses. The UFOV task was controlled by a Model 2000 Visual Attention Analyzer. Both the visual monitoring and visual search tasks were controlled by an IBM compatible computer that measures response latency to the nearest millisecond.

Visual search task.—The visual search task examined the ability to select a target in a visual array. In this task, a fixation mark (+) was presented in the center of the screen for 1 second followed by a target letter which was presented for 1 second. After the target letter was presented, a visual array of either 2, 4, or 6 letters was presented immediately in the center of the screen. The letters in the array could appear in 6 potential positions (2 rows of 3 positions). The 3 positions in a row were spaced 1.28 cm apart and the 2 rows were double-spaced. All letters were presented in 12 point font (approximately 0.3 degrees of visual angle) and the width of the visual array subtended approximately 3 degrees of visual angle. The letters in the visual array occurred across the 6 potential positions as equally often as possible. Half of the time the target letter was present in the array and half of the time the target was not present in the array. The subject responded *yes* or *no* as to whether the target was present in the array by pressing the designated key on the computer. The visual array stayed on the screen for 5 seconds or until the subject made a response. There were 20 *yes* trials and 20 *no* trials for each visual display (2, 4, or 6), yielding a total of 120 trials. Trial types were randomly presented. Both response latency and accuracy were measured. Practice trials were given before the test trials to ensure that subjects understood the task.

Visual monitoring task.—The visual monitoring task examined the ability to sustain and divide attention and detect a change in a visual display. In the first half of this task, a column of "O's" scrolled up the screen at a constant rate for approximately 7 minutes. At varying intervals an "X" appeared in the column and the subjects' task was to press a key on the computer whenever they detected an "X." The onset of the "X" was randomly varied to occur within a 3–10 second time frame. The response latency to the "X" was measured from onset up to 2 seconds after the "X" occurred. When the subject did not make a response within the 2-second time frame,

this was scored as a "miss." A "false alarm" was scored if the subject made a response outside the 2-second time frame. In the first half of the task, an "X" appeared 70 times (approximately 8% of the stimulus events). In the second half of the task, the subject monitored two columns of scrolling "Os" for approximately 7 minutes. The two columns were spaced approximately 15 cm apart and required eye movements from one column to another to monitor the events. At different varying intervals, an "X" appeared in either column and the subject pressed a different designated key on the computer for each column. In the second half of the task, an "X" appeared 35 times in each column (approximately 4% of the stimulus events per column). Throughout the entire task, the letters (Xs and Os) were presented in 12-point font at a rate of 2 letters/second. Each letter subtended approximately 0.3 degrees of visual angle. Both response latency and accuracy were measured. Practice trials were given before the test trials to ensure that subjects understood the task.

Useful field of view.—The UFOV task consisted of a central identification task and a peripheral localization task. The UFOV task was presented as three subtests. In the first subtest, a central stimulus (a graphic representation of either a car or truck) was briefly flashed at varying durations in the center of the screen and the subject had to make a correct identification by pointing to either a car or truck on the touch screen. This comprised the central task. In the second subtest, the subject performed the same central task and also had to localize a peripheral target. The peripheral target was presented unpredictably at one of eight different meridians at either 10, 20, or 30 degrees eccentricity at the same time the central stimulus was presented. The duration of the display was varied to measure the speed of visual processing for this divided attention task. When the central and peripheral stimuli went off the screen, the subject identified the central stimulus on the touch screen and then localized the peripheral target by touching the correct position on a spoke that appeared on the screen. In the third subtest, the same central and peripheral stimuli were presented, but the peripheral target was embedded in a series of distractors (selective attention).

For subtest 1, the minimum duration at which subjects could perform the task with 75% accuracy was measured. For subtests 2 and 3, the best fitting line reflecting the relationship between eccentricity and localization errors was first computed for each test duration, and the size of the UFOV was defined for that stimulus duration as that eccentricity at which the participant could localize the peripheral target correctly 50% of the time. Performance in each of the three subtests was then scaled, in each case along a duration continuum, to arrive at three scores representing the extent of difficulty with respect to speed of processing (subtest 1), divided attention (subtest 2), and selective attention (subtest 3). These scores ranged from 0 (*no problem*) to 30 (*great difficulty*). For example, within subtest 1, if a participant was unable to identify the central target correctly 75% of the time at the longest stimulus duration (240 ms), that participant received a score of 30 on subtest 1. If, however, this 75% criterion was reached at an average of less than 40 ms duration, then the scaled value was 0. Similarly, in subtests 2 and 3, if

the computed size of the UFOV was less than 5 degrees at 240 ms, then the maximum score of 30 was assigned. However, if the computed size of the UFOV was 30 degrees at a 40 ms duration, then a score of 0 was assigned. To summarize performance, the three scaled scores are summed to yield a composite score between 0 and 90, which represents the total percentage reduction of the UFOV.

Driving Test

All subjects were administered the Washington University Road Test (WURT) (see Hunt et al., 1997). The WURT is a 45-minute in-traffic road test along a predetermined route. The test was given to all participants in a standard car with dual brakes at approximately the same time of day in good road conditions. A driving instructor was seated in the front and an investigator was seated in the back of the car. Both the driving instructor and investigator were unaware of the CDR of the subject and the performance of the individual on the visual attention tasks. The WURT consisted of two testing components: a closed course and an open course test. The closed course test was given in a large parking lot. Subjects were familiarized with the controls of the car and asked to perform various basic maneuvers, such as starting the car, driving forward, stopping, and making a left turn. Each of these behaviors was scored as either "pass" or "fail." If both the driving instructor and investigator agreed that the subject passed the items on the closed course, they then proceeded to the open course test. All subjects in the study passed the closed course test. The open course test was conducted in traffic and assessed several typical driving skills such as maintaining speed, obeying traffic signs, signaling, turning, changing lanes, and negotiating intersections. The investigator scored these skills and maneuvers along the route. Each skill was scored on a 2- or 3-point scale, thus yielding a total quantitative driving score, ranging from 0–108 (perfect performance). The test-retest reliability for the WURT is $r = .76$ (see Hunt et al., 1997).

Psychometric Testing

Each participant from the ADRC was administered a 2-hr comprehensive psychometric battery that assesses various aspects of memory, psychomotor performance, and language. Memory and language were assessed with the Boston Naming Test and the Wechsler Memory Scale (Logical Memory, forward and backward digit span, Paired Associate Learning, Mental Control; Wechsler & Stone, 1973), the Benton Visual Retention Test (BVRT) picture memory (Benton, 1963), and the Word Fluency Test (Thurstone & Thurstone, 1949). Intelligence was assessed with the following subtests of the Wechsler Adult Intelligence Scale (WAIS): Information, Block Design, and Digit Symbol (Wechsler, 1955). Perceptual motor performance was assessed with the BVRT copy test and Part A of the Trail Making Test (Armitage, 1946).

RESULTS

Data Analysis

The data analysis for this study was organized to address two basic issues. First, we examined the effect of dementia

severity on visual attention, psychometric, and driving performance. Separate analyses of variance (ANOVAs) were performed for each of the visual attention and psychometric tasks and the driving test with subject group as a between-subject factor. These analyses provide data on the range of performance of the different subject groups on the targeted tasks. Second and more important, we examined whether aspects of visual attention and psychometric test performance were predictive of on-road driving performance. A series of regression analyses were performed with performance on the attention tasks and psychometric tests as predictor variables and driving performance as the dependent measure.

ANOVAs on the Attention, Psychometric, and Driving Tasks

Visual search task performance and dementia severity:— Figure 1 displays response latencies in the visual search task as a function of CDR, set size, and response type. The results of a 3 (CDR) \times 3 (set size) \times 2 (response type) ANOVA yielded three significant main effects of CDR, $F(2,99) = 18.52$, $MSe = 10968239$, $p < .0001$; set size, $F(2,198) = 246.62$, $MSe = 7213960$, $p < .0001$; and response type, $F(1,99) = 220.59$, $MSe = 10378117$, $p < .0001$. These main effects were qualified by three significant interactions. First, there was a set size \times response type interaction typically found in visual search tasks indicating

that the slope of the *no* response trials, as a function of set size, was greater than the slope of the *yes* response trials, $F(2,198) = 92.77$, $MSe = 1492196$, $p < .0001$. This pattern of data is consistent across CDR groups suggesting that all groups were performing a self-terminating search (Sternberg, 1975). Second, there was a significant CDR \times set size interaction, $F(4,198) = 3.31$, $MSe = 96725$, $p < .02$, which indicated that the CDR 1 group was particularly slower with the larger set size 6 relative to the CDR 0.5 and CDR 0 groups. Third, there was a significant CDR \times response type interaction, $F(2,99) = 7.11$, $MSe = 334579.3$, $p < .002$, which indicated that the CDR 1 group was particularly slower when making a *no* response than a *yes* response relative to the CDR 0.5 and CDR 0 groups.

Error rates for the visual search task are presented in Figure 2 as a function of CDR, set size, and response type. A 3 (CDR) \times 3 (set size) \times 2 (response type) ANOVA yielded significant main effects of CDR, $F(2,99) = 9.47$, $MSe = 4625.9$, $p = .0002$; set size, $F(2,198) = 7.10$, $MSe = 182.3$, $p < .002$; and response type, $F(1,99) = 3.93$, $MSe = 282.2$, $p = .05$. The analysis also yielded two significant interactions: CDR \times set size, $F(4,198) = 2.96$, $MSe = 75.9$, $p < .03$; and CDR \times response type, $F(2,99) = 3.45$, $MSe = 247.8$, $p < .04$. These interactions were qualified by a significant CDR \times set size \times response type interaction, $F(4,198) = 2.72$, $MSe = 74.0$, $p < .04$, which indicated that the CDR 0 group made more errors on *yes* response trials

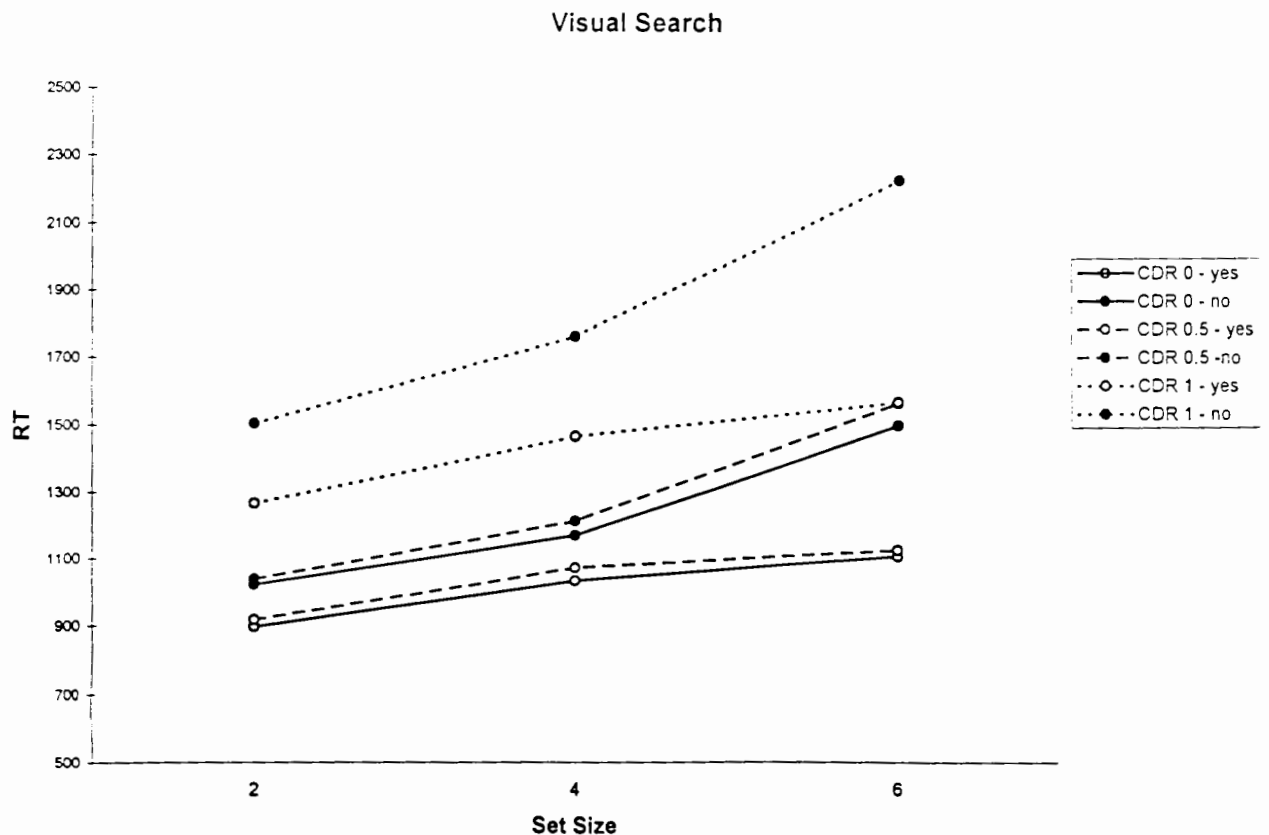


Figure 1. Visual search response latencies (ms) as a function of set size, response type, and CDR (Clinical Dementia Rating).

Visual Search

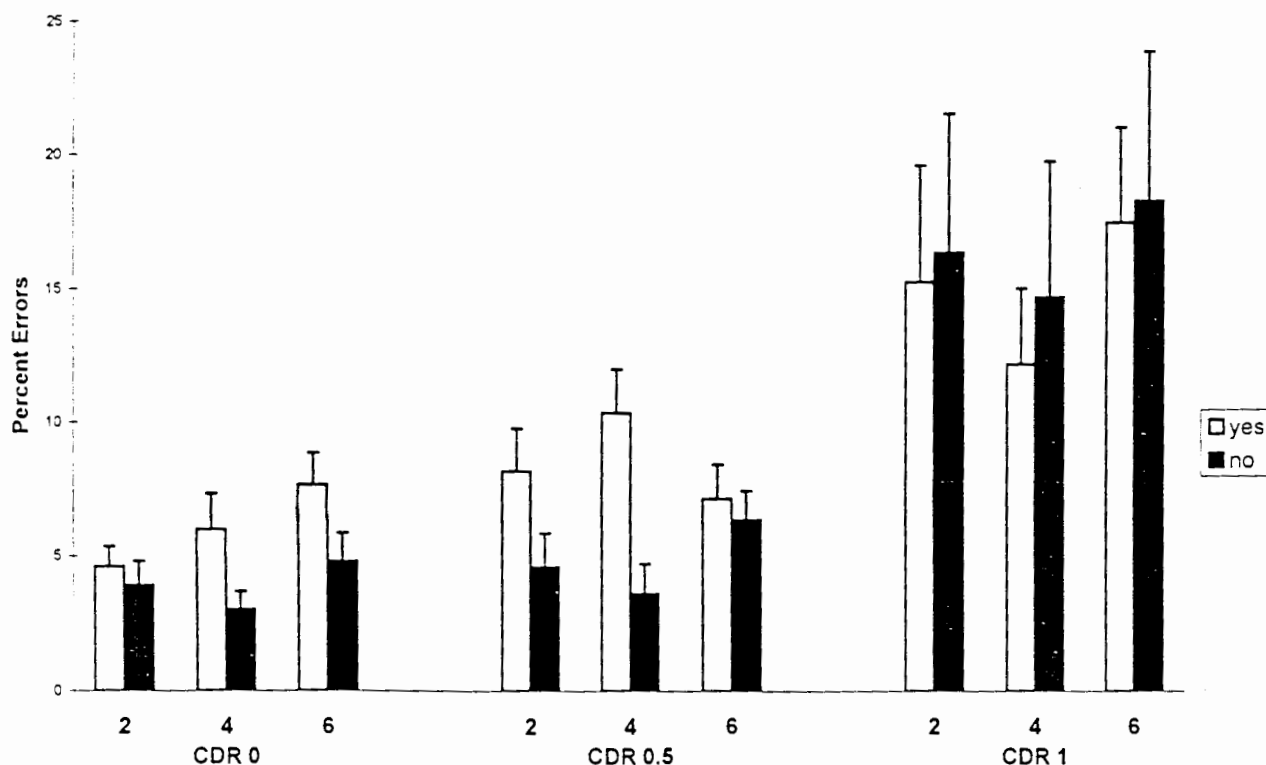


Figure 2. Visual search error rates as a function of response type and CDR (Clinical Dementia Rating).

than *no* response trials with set sizes 4 and 6, the CDR 0.5 group made more errors on *yes* response trials than *no* response trials with set sizes 2 and 4, whereas the CDR 1 group made slightly more errors on *no* response trials than *yes* response trials across all set sizes. A post hoc analysis comparing the CDR 0 versus CDR 1 group yielded a marginally significant CDR \times response type interaction, $F(1,63) = 3.46, p < .07$. Likewise, a post hoc analysis comparing the CDR 0.5 versus CDR 1 group yielded a significant CDR \times response type interaction, $F(1,53) = 4.77, p < .04$. These results suggest that the CDR 1 group was more likely to "false alarm" (i.e., incorrectly respond *yes* on a *no* response trial) than "miss" in the visual search task than either the CDR 0 or CDR 0.5 groups.

Visual monitoring task performance and dementia severity.—The results of a 3 (group) \times 2 (lines monitored) ANOVA on response latencies in the visual monitoring task yielded one significant main effect. Response latencies were slower when subjects monitored 2 lines versus 1 line, $F(1,85) = 61.01, MSe = 1418970, p < .0001$. There was no significant main effect of CDR, $F(2,85) = 1.69, p = .19$. Separate analyses were conducted on the "miss" error data and the "false alarm" error data. A "miss" error occurred when the subject did not respond to the "X" and a "false alarm" error occurred when the subject made a response when the "X" was not present. Error data (misses and false

alarms) for the visual monitoring task are presented in Figure 3 as a function of CDR and lines monitored. First, for the "miss" error data, a 3 (CDR) \times 2 (lines monitored) ANOVA yielded a significant main effect for lines monitored which indicated that subjects made far more miss errors when monitoring 2 lines versus 1 line, $F(1,85) = 498.49, MSe = 14933.7, p < .0001$. There was no main effect of CDR, $F(2,85) = .01, p = .99$. Second, for the "false alarm" error data, a 3 (CDR) \times 2 (lines monitored) ANOVA yielded a main effect of CDR, $F(2,85) = 4.08, MSe = 340, p = .02$, and lines monitored, $F(1,85) = 4.30, MSe = 280.4, p = .04$. The CDR 1 group made more false alarm errors than the CDR 0 or CDR 0.5 groups and all groups made more false alarm errors when monitoring 2 lines versus 1 line. Thus, the CDR 1 group was more likely to respond that a target had occurred when it did not. This is consistent with the increase in false alarms found in the visual search task described above.

UFOV task performance and dementia severity.—The UFOV task yielded an estimate of the percent reduction in the UFOV. Thus, the higher the score, the greater the reduction or shrinkage in the UFOV. The results of a one-way ANOVA indicated that UFOV reduction increased with dementia severity, $F(2,52) = 15.36, MSe = 5371.5, p < .0001$. Specifically, the CDR 1 group showed the greatest UFOV reduction (75%) relative to the CDR 0.5 group (34%) and

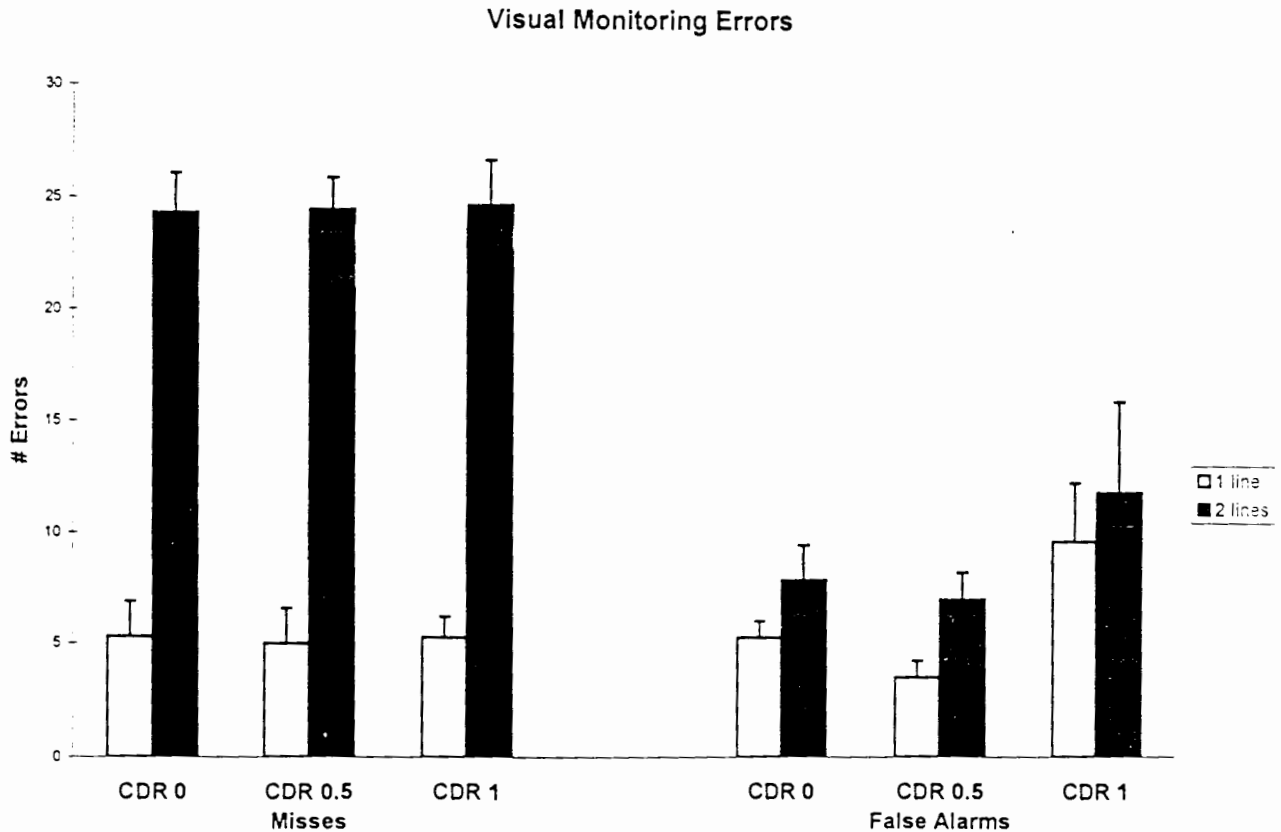


Figure 3. Visual monitoring error rates as a function of lines monitored, error type, and CDR (Clinical Dementia Rating).

CDR 0 group (29%). The CDR 0 and CDR 0.5 groups did not differ in terms of UFOV reduction, $F(1,47) = 1.17$, $MSe = 384.5$, $p = .28$. Again, it is important to note the small sample size for the CDR 1 group ($n = 6$).

Psychometric test performance and dementia severity.—The means and standard deviations from the psychometric measures are presented in Table 1 as a function of CDR. A series of one-way ANOVAs indicated that performance on all measures worsened with dementia severity, all $ps < .02$.

Driving performance and dementia severity.—Before turning to the regression analyses, it is important to examine driving performance as a function of dementia severity. The descriptive data for driving scores by group are presented in Table 2. It can be seen that driving scores decreased with dementia severity, $F(2,133) = 13.52$, $MSe = 864.2$, $p < .0001$. It is also clear that the variability of driving scores increased with dementia severity, with the CDR 1 group showing the greatest variability.

Regression Analyses Using Attention and Psychometric Tasks and CDR to Predict Driving Performance

In order to examine the relationship between on-road driving performance and performance on the visual attention tasks, a series of stepwise regression analyses were performed utilizing CDR and the various attentional and

psychometric measures as predictor variables and driving score as the dependent variable. Different predictor variables were created from the visual monitoring and visual search tasks as these tasks represent factorial designs. For the visual monitoring task, the following variables were created: average overall reaction time (*Monitoring RT*), RT 2 lines–RT 1 line (*Monitoring slope RT*), average miss errors (*Monitoring misses*), average false alarm errors (*Monitoring false alarms*), 2 lines–1 line miss errors (*Monitoring slope misses*), 2 lines–1 line false alarm errors (*Monitoring slope false alarms*). These measures reflect the ability to maintain attention across time as a function of difficulty. For the visual search task, the following variables were created: average overall RT (*Search RT*), RT set size 6–RT set size 2 (*Search slope RT*), RT no response trials–RT yes response trials (*Search response RT*), search slope RT \times search response RT (*Search interaction RT*), average overall errors (*Search errors*), set size 6 errors–set size 2 errors (*Search slope errors*), no response trial errors–yes response trial errors (*Search response errors*), search slope errors \times search response errors (*Search interaction errors*) (see Appendix, note 1). These measures reflect the ability to select a target amidst varying amounts of distraction.

Regression Models

First, a stepwise regression equation was constructed utilizing CDR and the visual search and visual monitoring

Table 1. Psychometric Test Performance as a Function of Dementia Severity (CDR)

	CDR 0 (n = 55)	CDR 0.5 (n = 48)	CDR 1 (n = 24)
Logical Memory	9.2 (3.44)	6.6 (3.42)	1.7 (1.90)
Digits forward	6.7 (1.21)	6.4 (1.29)	5.8 (1.48)
Digits backwards	5.2 (1.40)	4.6 (1.20)	3.6 (1.08)
PA Easy	17.1 (1.33)	15.4 (2.44)	11.8 (3.50)
PA Hard	6.3 (3.46)	2.9 (3.40)	0.2 (0.53)
Trailmaking A*	42.3 (14.4)	48.4 (18.5)	83.5 (35.8)
WAIS Info.	22.1 (4.26)	17.5 (5.54)	10.3 (6.42)
Block Design	32.7 (9.08)	27.4 (9.11)	18.0 (10.2)
Digit Symbol	47.9 (12.0)	38.3 (13.4)	24.9 (11.0)
Benton Recall	6.4 (1.62)	5.1 (1.66)	3.5 (1.63)
Benton Copy	9.6 (1.45)	9.5 (1.09)	8.2 (2.44)
Boston Naming	54.2 (8.44)	48.6 (12.8)	35.8 (15.4)
Mental Control	7.7 (2.01)	6.9 (2.15)	5.3 (2.36)
Benton Error Copy	6.1 (3.47)	9.1 (4.78)	16.0 (5.06)
Benton Error Delay	0.3 (0.62)	0.6 (1.23)	1.9 (3.04)
Word Fluency	33.9 (11.9)	26.8 (11.0)	20.4 (11.7)

Note. Standard deviations appear in parentheses.

PA = paired associate.

*Represents time in seconds.

Table 2. Drive Scores as a Function of Dementia Severity (CDR)

Group	Mean drive score	SD	Range
CDR 0 (n = 55)	101.9	5.06	86-108
CDR 0.5 (n = 49)	99.6	7.82	68-108
CDR 1 (n = 29)	92.5	12.10	62-107

measures as predictor variables ($N = 81$). The UFOV reduction was not included as a predictor variable in the following regression models as its inclusion greatly restricted the sample size ($N = 38$). The results from the regression analysis are presented in Table 3 showing the R^2 and change in R^2 at each step in the analysis. It can be seen that *Search errors* significantly accounted for 19% of the variance in drive score at Step 1. Then *Search interaction RT* entered at Step 2 accounting for an additional 6% of the variance, followed by *Search RT* at Step 3 accounting for an additional 9% of the variance. Thus, these three measures from the visual search task significantly accounted for 34% of the variance in drive score. No other variables resulted in significant changes in R^2 in the regression equation.

In order to determine whether any of the specific attentional measures would predict drive score above and beyond traditional psychometric measures, a second stepwise regression equation was constructed by first allowing all psychometric measures to be considered for entry into the equation by order of their simple correlations with drive score and then allowing all the attention measures to be considered for entry by order of their simple correlations with drive score ($N = 75$). The results from the regression analysis are presented in Table 4 showing the R^2 and change in R^2 at each step in the analysis. It can be seen that WAIS Block Design significantly accounted for 17% of the variance in drive score at Step 1 and Boston Naming en-

Table 3. Regression Analysis with Attention Variables* as Predictors of Drive Score

Step	Variable Entered	R^2	Change in R^2
1	Search errors	.19	.19
2	Search interaction RT	.25	.06
3	Search RT	.34	.09

Note. RT = reaction time.

*Without UFOV.

Table 4. Regression Analysis with Psychometric Variables Entered as Predictors Before Attention Variables*

Step	Variable Entered	Variable Removed	R^2	Change in R^2
1	WAIS Block Design		.17	.17
2	Boston Naming		.23	.06
3	Search errors		.35	.12
4		WAIS Block Design	.33	-.02
5	Search slope errors		.39	.06
6	Search interaction RT		.43	.04
7	Search RT		.47	.04

Note. RT = reaction time; WAIS = Wechsler Adult Intelligence Scale.

*Without UFOV.

tered at Step 2 accounted for an additional 6% of the variance. No other psychometric measures significantly contributed to the regression equation. At Step 3, *Search errors* accounted for an additional 12% of the variance. At Step 4, WAIS Block Design no longer retained significance in the equation. The *Search slope errors* accounted for an additional 6% of variance at Step 5, the *Search interaction RT* accounted for an additional 4% of the variance at Step 6, and *Search RT* accounted for an additional 4% of variance in the final step. Thus, these five measures significantly accounted for 47% of the variance in drive score. It is clear that the various error and RT measures from the visual search task accounted for variance in drive score above and beyond all of the traditional psychometric measures, except Boston Naming.

A third regression equation was constructed by first allowing CDR to be considered in the equation, followed by all the psychometric measures and then the attention measures to determine whether the psychometric and attentional measures would predict drive score above and beyond simple dementia severity ($N = 75$). The results from this regression analysis indicated that CDR significantly accounted for 9% of the variance at Step 1. WAIS Block Design accounted for an additional 10% of variance at Step 2 and at Step 3, CDR no longer retained significance in the equation. Again, Boston Naming, *Search errors*, *Search slope errors*, *Search interaction RT*, and *Search RT* accounted for 47% of the variance in drive score. Thus, Boston Naming and the attentional measures predicted drive score above and beyond simple dementia severity.

Next, separate regression equations were constructed for the healthy control group (CDR 0, $N = 31$) and the DAT group (CDR 0.5 and CDR 1, $N = 44$) by allowing each po-

tential attentional and psychometric predictor variable to enter the equation without specifying order of entry to determine which variables were the best predictors of driving for each of these groups. In the healthy control group, no predictor variables contributed significantly to the regression equation, presumably due to the relative lack of covariability of drive score with the predictors in this group. The results from the regression analysis for the DAT group are presented in Table 5. It can be seen that *Search errors* entered at Step 1 and accounted for 30% of the variance in drive score. Then Boston Naming at Step 2 added an additional 10% of variance, *Search response RT* at Step 3 added an additional 11% of variance, and *Search slope errors* added an additional 10% of variance at Step 4. Finally, at Step 5, *Monitoring slope false alarms* added an additional 4% of variance. Thus, these five measures explained a relatively large amount (65%) of the variance in drive score in the DAT group.

Finally, a stepwise regression equation was constructed in the restricted sample of subjects who could do all attention tasks, including the UFOV ($N = 38$; CDR 0, $n = 19$; CDR 0.5, $n = 15$; CDR 1, $n = 4$). All the attention task measures and CDR were used as predictor variables. The results from the regression analysis indicated that *Search response RT* significantly accounted for 14% of the variance in drive score at Step 1. No other variables resulted in significant changes in R^2 in the regression equation. It is important to note that many subjects did not perform the UFOV, thus including the percent UFOV reduction in the regression model greatly reduced the sample size ($N = 38$) and predictive power of the model. It should be noted, however, that UFOV reduction was significantly correlated with drive score, $r = -.56$, $p < .01$ ($N = 55$), indicating that greater UFOV reduction was related to lower on-road drive scores. It is also worth noting that *Search response RT* was a better predictor than UFOV in this small sample.

DISCUSSION

The purpose of the present study was to examine the relationship between different measures of visual attention and driving performance in healthy older adults and individuals with very mild and mild DAT. The results of the study indicated that specific aspects of attentional processing are affected by dementia severity and are predictive of on-road driving performance. We shall first briefly discuss the findings from each of the visual attention tasks as a function of dementia severity (i.e., CDR), followed by a discussion of measures of visual attention as predictors of driving performance in older adults and individuals with DAT.

Table 5. Regression Analysis with Psychometric and Attention Variables* as Predictors for DAT subjects (CDR 0.5 and CDR 1)

Step	Variable Entered	R^2	Change in R^2
1	Search errors	.30	.30
2	Boston Naming	.40	.10
3	Search response RT	.51	.11
4	Search slope errors	.61	.10
5	Monitoring slope false alarms	.65	.04

*Without UFOV.

Visual Attention Performance in DAT

In the visual search task, there were some interesting findings in response latencies as a function of CDR. Mild DAT subjects (CDR 1) were particularly slower to search the largest set size (i.e., set size 6) compared with the healthy controls (CDR 0) and very mild DAT (CDR 0.5) subjects. Also they were slower to make *no* responses than *yes* responses compared with the CDR 0 and CDR 0.5 subjects. Thus, mild DAT subjects have relatively more difficulty searching for a target when more information is present and deciding that a target is *not* present in the array. These findings are similar to the results reported by Nebes and Brady (1989) regarding visual search performance in DAT. Such results could have relevance to a driving situation which often involves searching the environment for a specific target in a relatively complex field with many distractions (e.g., a street sign at an intersection).

The visual search data also indicated that errors increased with increasing dementia severity (also see Nebes & Brady, 1989). The most interesting data relate to the pattern of error types across CDR. In both the CDR 0 and CDR 0.5 groups, subjects made more *yes* response trial errors than *no* response trial errors. That is, these subjects were more likely to incorrectly respond *no* a target was *not* present in the array when it was (i.e., they were more likely to "miss" the target) than incorrectly respond *yes* a target was present in the array when it was not (i.e., false alarm). However, the CDR 1 subjects made slightly more *no* response trial errors than *yes* response trial errors, suggesting that CDR 1 subjects were more likely to false alarm and respond that a target was present in the array when it was not.

In the visual monitoring task, response latencies did not differ as a function of dementia severity. This is not surprising given the simple nature of the task. Because subjects were merely responding to the detection of a target, the more interesting data came from the errors subjects made in detection. All subjects made more detection errors when required to monitor more information (i.e., 2 lines vs 1 line) and all subjects were much more likely to "miss" a target when they were monitoring more information. Dementia severity was only related to "false alarm" errors, where the CDR 1 group made nearly twice as many such errors. That is, the CDR 1 group was much more likely to respond to targets when they were not present (i.e., false alarming).

It is interesting that the error data in both the visual monitoring and visual search tasks differentiate the mildly demented subjects from the very mildly demented and healthy control subjects. In both of these tasks, mildly demented subjects were not only missing the relevant target information, but also were more likely to false alarm to irrelevant information and erroneously mistake it for the target information. This pattern of results is consistent with recent arguments regarding deficits in inhibitory control and changes in criteria for responding in DAT individuals (Balota & Duchek, 1991; Faust, Balota, Duchek, Gernsbacher, & Smith, 1997; Faust, Balota, & Duchek, 1995; Spieler et al., 1996). It has been suggested that DAT individuals often have difficulty engaging and controlling the inhibitory mechanisms necessary to select out relevant information from the environment and inhibit irrelevant infor-

mation. Furthermore, there may be changes in DAT in the criteria used to respond, such that partial information may be sufficient to make a response to the inappropriate dimensions of the stimulus (i.e., false alarm). The control of selection and inhibition and changes in the criteria necessary to respond clearly have relevance to the driving situation where one must consistently select for relevant features of the driving environment (e.g., changing traffic signals) and actively inhibit distracting features (e.g., advertisements on billboards). It is evident from the present results that mild DAT individuals had difficulty engaging inhibitory mechanisms to accurately select target information and *not* respond to partially active but irrelevant information.

The present study also indicated that UFOV performance is related to dementia severity. That is, the reduction in the UFOV increased with increasing dementia severity with the mild DAT group (CDR 1) overall showing the largest reduction (75%) compared with the very mild DAT and healthy control groups. This finding is consistent with the Owsley et al. (1991) study which indicated that UFOV performance was related to mental status. Thus, there appears to be a deficit in mild DAT in the ability to process peripheral target information amidst visual distractors, while simultaneously monitoring a central task. Again, it is important to note that the sample size was very small for the CDR 1 group ($n = 6$) because the present version of the task was very difficult for these subjects to perform.

Visual Attention and Psychometric Tests as Predictors of Driving

The major purpose of this study was to examine the relationship between specific measures of visual attention and on-road driving performance in healthy aging and DAT. Previous literature indicates that visual attention performance is related to the frequency of accidents in older adults (e.g., Owsley et al., 1991; Owsley et al., 1994). However, there are relatively few data examining whether visual attention performance is predictive of actual on-road driving performance in healthy aging and DAT. The results from this study indicate that aspects of visual search performance are predictive of driving performance. Specifically, overall error rate in visual search was the best predictor of drive score among the visual attention measures, accounting for 19% of the variance in the entire sample. Also, overall RT in visual search and the interaction between slope RT and response trial RT significantly contributed to the prediction of drive scores in the entire sample. When the psychometric measures were entered into the regression equation *before* the attentional measures, errors in visual search significantly contributed to the prediction of driving above and beyond the psychometric measures, along with the search slope errors and search interaction RT and overall visual search RT. Likewise, error rate in visual search accounted for 30% of the variance in the DAT sample, even when the psychometric measures were included as potential predictors. Finally, the RT difference on *no* response trials versus *yes* response trials and the error difference on set size 6 versus set size 2 significantly contributed to the prediction of driving in the DAT sample. Thus, aspects of visual search, namely errors, were related to driving performance.

Given that visual search and the detection of relevant information in a complex visual environment is paramount to driving, the inability to detect relevant information amidst distracting information should be a good predictor of poor or unsafe driving performance. In this light, it is interesting to note that performance in the UFOV task, which is predictive of accidents in older adults also relies upon the ability to detect and localize a target among distractors. Thus, it appears that measures of *selective* attention are good predictors of driving in the older adult population (Barrett, Mihal, Panek, Sterns, & Alexander, 1977; Mihal & Barrett, 1976), particularly in DAT. Unfortunately, including UFOV performance in the regression model restricted the sample size, and thus the predictive power of the task could not be adequately assessed in this study. However, UFOV performance was significantly correlated with on-road driving performance in this study and thus it would appear to be a good predictor of driving in the demented population relative to other aspects of attention and psychometric performance. However, a simpler version of the test would be necessary for DAT subjects to test this assumption.

The visual monitoring task was utilized as a measure of the ability to sustain attention and detect changes in a visual display. The visual monitoring task was not a good predictor of driving score in the present study. The only measure from the visual monitoring task that contributed to the regression equation for the DAT sample was the false alarm error difference in 2 lines versus 1 line. Although this measure only contributed an additional 4% of variance to the regression model, it does reflect the inability to distinguish distracting information from target information. Thus, it appears to be consistent with the findings from the visual search task.

In terms of the psychometric measures, Boston Naming test performance was the only significant predictor of driving, even when the psychometric tests were allowed to enter the regression model before the visual attention measures. Why is performance on the Boston Naming test predictive of driving? The Boston Naming test is a confrontational picture naming task which involves visual pattern recognition and the retrieval of labels from semantic memory. Performance on the Boston Naming test has been shown to be very sensitive to the effects of mild dementia (e.g., Knesevich, LaBarge, & Edwards, 1986; LaBarge, Balota, Storandt, & Smith, 1992). Although it may serve more as an indicator of cognitive status, which in turn is related to driving performance, it is quite possible that pattern recognition and the retrieval of information from semantic memory are both processes related to driving.

It is interesting that the remainder of psychometric measures in this study were not predictive of driving performance. In particular, one might expect that measures which rely more on visual spatial abilities, such as Trailmaking A, WAIS Block Design, and BVRT, would be predictive of driving performance. However, the results of this study indicate that measures of selective attention (i.e., visual search performance) were better predictors of driving and were predictive above and beyond psychometric performance. It is possible that because many psychometric tests tend not to be process-specific, but instead may reflect sev-

eral processes, these tests may be more predictive of general cognitive status, rather than driving skills per se, at least within the older adult and DAT population.

The results of the present study support the general conclusion that global cognitive status is related to driving performance. The driving scores clearly decreased with increasing dementia severity. Indeed, CDR did account for 9% of the variance when entered into the regression equation first (although it dropped out of the equation at Step 3). Certainly, the relationship between cognitive status and driving has been well-documented in various other studies as well (e.g., Fitten et al., 1995; Hunt et al., 1993, 1997; Owsley et al., 1991). Given that driving represents a highly complex activity which involves the interplay among a variety of cognitive skills, this relationship is not surprising. However, it should also be noted that there was wide variability in drive scores among the DAT subjects with some overlap in driving scores between the DAT (CDR 0.5 and CDR 1) groups and the CDR 0 group. Clearly, the results indicate that selective attention during visual search performance predicts on-road driving performance, above and beyond general cognitive status. In fact, a large proportion of the variance in drive scores (65%) in the DAT sample could be accounted for by measures of selective visual attention and Boston Naming performance. It is also important to note that this study represents an exploratory examination of the potential predictors of driving in the demented population. We have included (a) a relatively large number of predictor variables given the sample size; and (b) attentional predictor measures derived from factorial designs, which are intercorrelated. This may somewhat limit our ability to define precisely which aspects of visual search are the best predictors of driving. However, this does not minimize the overall finding that attentional performance is a better predictor of driving than either general cognitive status or traditional psychometric measures. Clearly, further research is needed to elucidate the specific aspects of visual search that are related to driving.

Due to the relatively high accident and fatality rates of the older driver, there is increasing concern over driving safety in this population and the need to develop screening measures which would identify older adults "at risk" for unsafe driving (see Kaszniak et al., 1991). The present study indicates that selective attention is related to driving skills in the early stages of DAT. Whereas general cognitive status may be useful for identifying individuals "at risk" for unsafe driving, measures of attentional processing that rely on the ability to select for the relevant dimensions of the stimulus environment and inhibit the irrelevant dimensions may serve to differentiate good versus poor drivers in the demented population. Furthermore, one may argue that examining the specific aspects of attentional deficits in unsafe older drivers may suggest *specific reasons* for unsafe driving and potential interventions, when appropriate.

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Appendix

1. It is important to note that the interaction terms (*Search interaction RT* and *Search interaction errors*) are used in the regression analyses solely as predictors. Thus, when interpreting these interaction terms as significant predictors in the regression models (Tables 3 and 4), it should be recognized that these terms are confounded with the simple linear effects of their constituent components and do not represent the "pure" multiplicative component.