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Predicting Driving Ability in Alzheimer's Disease Patients.

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PREDICTING DRIVING ABILITY IN ALZHEIMER'S DISEASE PATIENTS

A Dissertation

Submitted to the Graduate Faculty of the Louisiana State University and Agricultural and Mechanical College in partial fulfillment of the requirements for the degree of Doctor of Philosophy in The Department of Psychology

by

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B.S., Georgia State University, 1990
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# Table of Contents

Acknowledgements..............................................................................................................ii  
List of Tables............................................................................................................................v  
Abstract.................................................................................................................................vi  
Introduction............................................................................................................................1  
Review of the Literature........................................................................................................3
   Alzheimer's Disease........................................................................................................3
   Prevalence.........................................................................................................................3
   Description of the Disease..............................................................................................4
      General Characteristics and Diagnosis...................................................................4
      Pathophysiological Changes.................................................................................5
      Other Characteristics.............................................................................................7
   Etiology of AD..................................................................................................................10
      Genetic Basis...............................................................................................................10
      Transmissible Agent Theory....................................................................................12
      Environmental Toxin Theory....................................................................................12
      Abnormal Protein Theory..........................................................................................12
      Acetylcholine Theory.................................................................................................13
      Inflammation Theory.................................................................................................14
      Other Theories............................................................................................................14
   Summary............................................................................................................................15
The Controversy Regarding Drivers with Alzheimer's Disease....................15
Factors Involved in Driving.......................................................................................19
   Restriction of Driving....................................................................................................22
Empirical Studies of Alzheimer's Disease and Driving.............................22
   Consideration of Previously Used Methodologies.....................................................26
   Rationale for Study.........................................................................................................27
   Research Questions and Hypotheses.........................................................................30
Method......................................................................................................................................32
Subjects...............................................................................................................................32
   Measures.........................................................................................................................33
      Demographic/Driving History Questionnaire.........................................................33
      Mini-Mental State Exam (MMSE)............................................................................33
      Trail Making Test..........................................................................................................34
      Boston Naming Test.....................................................................................................35
      Wechsler Memory Scale-Revised: Logical Memory.................................................35
      Wechsler Memory Scale-Revised: Visual Reproduction............................................36
      Category Fluency..........................................................................................................36
      Driver Performance Test............................................................................................36
      Driver Risk Index........................................................................................................37
Procedure..............................................................................................................................37
Results....................................................................................................................................40
Tests of Hypotheses..............................................................................................................40
Additional Analyses.............................................................................................................44
Discussion..............................................................................................................................51
References..............................................................................................................................59
Vita..........................................................................................................................................69
List of Tables

1. Demographic Information..................................................................................41
2. Comparisons of Control Subjects by State (LA and NH)............................42
3. Summary of Hierarchical Regression Analysis for Predictors of Total Driving Index Without Correction for Miles Driven...........................................................................................................43
4. Correlations of Total Driving Index With Neuropsychological and Driving Measures Without Correction for Miles Driven...........................................................................................................45
5. Summary of Hierarchical Regression Analysis for Predictors of Total Driving Index With Correction for Miles Driven..............................................................47
6. Comparison of Results of Neuropsychological Test Scores, Driving Measures, and Total Driving Index by Group..................48
7. Correlations of Total Driving Index With Neuropsychological and Driving Measures With Correction for Miles Driven.....49
8. Comparisons of Frequencies of Driving Characteristics by Kruskall Wallis One Way Analysis of Variance..............................................50
Abstract

Studies have shown that individuals with Alzheimer's disease have a greater number of automobile crashes than normal elderly controls. Assessment of driving ability is usually conducted by use of an on-the-road examination. These examinations are costly, time intensive, and sometimes dangerous. Finding other measures that are predictive of driving ability will enable screening of patients to decrease the number of on-road examinations. Alzheimer's disease patients and normal elderly control subjects were administered neuropsychological measures as well as the Driver Performance Test (DPT) and Driver Risk Index (DRI), both videotaped tests of driving knowledge and risk assessment. Driving histories based on collateral report were obtained for each subject, quantifying confusion while driving, moving violations, and crashes. These three factors were weighted to provide a Total Driving Index (TDI) as an overall indicator of the subjects' driving ability. There were no significant differences between the two groups of subjects on the TDI, although AD subjects were statistically more likely than controls to be rated as unsafe. Predictors of driving ability as measured by the TDI were different for the two groups, with Trails A accounting for the most incremental variance for AD subjects and Delayed Visual Reproduction accounting for the most incremental variance for controls. Results for control subjects were significantly better than AD subjects for all neuropsychological measures, the DRI, and the DPT Total. These findings indicate the need for more sensitive predictors of driving ability which includes better assessment of risky driving behaviors.
Introduction

Dementia is one of the most common mental health problems in the elderly (Amaducci, Falcini, & Lippi, 1992). Clinically, it is characterized by the inevitable progression of degeneration of neurons within the cerebral hemispheres with an accompanying progressive global deterioration of intellect and personality (Lezak, 1995).

Alzheimer's disease (AD) was first described in 1907 by Alois Alzheimer (Katzman & Jackson, 1991). His patient was a 51 year old woman who had a progressive dementia with insidious onset, which included language and behavioral involvement. After four years, this woman became totally apathetic and incontinent, confined to her bed in a fetal position (Franssen, Kluger, Torossian, & Reisberg, 1993). AD was originally considered to be a presenile condition, but it has now been accepted as a common disorder of old age (Kolb & Wishaw, 1990; La Rue, 1992).

The prevalence of probable AD for people over age 65 is estimated at 10.3% (Zee, 1993), and, of those who are demented, AD may account for 75% of those cases (Edwards, Larson, Hughes, & Kukull, 1991). In the US, cost for diagnosis and management of AD is $80 billion annually (Davis & Haroutunian, 1993). With the increase of older persons in our population, the medical, economic, and emotional ramifications are staggering (Edwards et al., 1991). In spite of remarkable progress made in understanding the molecular basis of AD, comparatively little progress has been made regarding treatment or prevention of this disorder (Pendlebury & Solomon, 1994).

By definition, AD must involve difficulties with memory as well as either aphasia, apraxia, agnosia, or executive functioning disturbance. The
particular cognitive functions that are affected and the severity of these dysfunctions can vary greatly, particularly in the mild stages of dementia (Butters, Salmon, & Butters, 1994). Additionally, anosognosia has been found in the early stages of AD (McGlynn & Schacter, 1989) which impairs the individual's judgment concerning his or her ability to perform tasks competently. While this can affect many tasks, such as balancing a checkbook or cooking, one that has the greatest potential for personal and societal danger is driving. Individuals with AD are at risk for unsafe driving due to problems with memory, judgment, visuospatial abilities, and inattentiveness (Reuben, 1991). Because the cognitive abilities of AD patients decline in such an unpredictable fashion, it is difficult to determine when these individuals should stop operating a motor vehicle. Although investigators agree that AD patients must stop driving at some point in their disease, there is controversy as to when this should take place. This study will investigate the ability of cognitive measures to predict performance of AD patients in some basic aspects of driving. Neuropsychological and driving measures were used in an attempt to find predictors of driving ability, which was quantified by the Total Driving Index (TDI), which comprises frequency of getting lost while driving, tickets for moving violations, near misses, and crashes as reported by the subjects' collaterals. It was to be hoped that this information will provide health care providers with time effective as well as cost effective measures that will limit the number of on-the-road evaluations. The current literature on AD and how resultant deficits can affect driving ability are reviewed to provide a theoretical basis for this proposed study.
Review of the Literature

Alzheimer's Disease

Dementia of the Alzheimer's type is characterized by multiple cognitive deficits that begin with a gradual onset and then progressively decline, causing significant impairment of daily functioning. The particular cognitive functions that are affected and the severity of these dysfunctions can vary greatly, particularly in the mild stages of dementia (Butters et al., 1994). This insidious dementing process progresses until the patient becomes totally oblivious to his or her surroundings and requires constant care (American Psychiatric Association, 1994). No obvious systemic features are seen in AD until the late stages when weight loss is apparent (Katzman & Jackson, 1991). Although medical technology has allowed individuals to live longer, this progress is accompanied by the problem of prolonging the period of time patients with AD live a life flawed by significant functional impairments. AD is the leading cause of dementia and the fourth leading cause of death in the U.S. (Pendlebury & Solomon, 1994).

Prevalence

For people 65 years of age and older, the prevalence of Alzheimer's disease varies from 4.5% to 18.5% (Amaducci et al., 1992). Evans and his colleagues (1989) state that prevalence rates are strongly correlated with age, ranging from 3% in the 60-74 year old group, 18.7% for people between 75 and 84 years, and 47.2% for those over 85 years of age. Prevalence rates for females are higher in all age groups (Amaducci et al., 1992). Because the onset of AD symptoms is so insidious, it is difficult to determine incidence rates, although estimates increase exponentially with age and appear to triple for each additional 10 years after the age of 65. Currently, over four
million individuals in the United States have serious dementia, and this dementia will cause an estimated 120,000 deaths per year (Goldman & Côté, 1991).

**Description of the Disease**

**General Characteristics and Diagnosis**

The criteria endorsed by the DSM-IV (American Psychiatric Association, 1994) for AD require memory impairment in addition to one of the following problems: aphasia, apraxia, agnosia, or disturbance in executive functioning. These deficits must cause significant problems with social or occupational functioning and must reflect a significant decline from previous functioning.

AD has been divided into two diagnostic groups, pre-senile, which encompasses patients 65 years or below at the time of onset, and senile, which includes patients over 65 years at the time of onset (American Psychiatric Association, 1994). While these are often regarded as discrete categories, there is controversy as to whether the groups actually have different characteristics (Lezak, 1995). Some researchers have found greater severity as well as greater attentional problems for the younger group (Jacobs et al., 1994), while others have found greater problems with language and praxis for the early onset patients (Lawlor, Ryan, Schmeidler, Mohs, & Davis, 1994). Additionally, early onset AD has also been postulated to result in more rapid cognitive and functional decline than AD with onset after age 65 (Jacobs et al., 1994). Other studies have shown no differences between the two groups, indicating that the presenile/senile distinction may be artificial (Amaducci, Rocca, & Schoenberg, 1986). These conflicting...
findings serve to emphasize the great variability found in the presentation of AD.

Gradual onset of deficits and progressive deterioration are two of the defining characteristics that are necessary for diagnosis. Because other reversible disorders can show a similar pattern of deficits, these must be ruled out before a diagnosis of AD can be made. To eliminate other possible etiologies, assessment should include an extensive patient history, medical examination, and laboratory testing, comprising at the very least a complete blood count (CBC), blood sugar (BS), electrolytes, serum calcium, and thyroid stimulating hormone (Patterson & Clarfield, 1994). The history should be detailed, and questions should address possible stroke, head injury, infections, alcohol or drug abuse, risk factors for AIDS, endocrine dysfunction, anemia, and vitamin deficiency (Whitehouse, Lerner, & Hedera, 1993). When indicators of other forms of dementia are negative and all other criteria are consistent with AD but neuropathological verification has not been obtained, a diagnosis of probable AD is given (La Rue, 1992). A confirmed diagnosis requires verification from autopsy or biopsy findings.

Pathophysiological Changes

In AD, the cerebral cortex shows dramatic changes, including atrophy, neuronal loss, neurofibrillary tangles (NFTs), senile plaques (SPs), gliosis, and amyloid angiopathy. Atrophy in AD is shown in the greatest amounts in the temporoparietal and anterior frontal areas (Hyman, Arriagada, Van Hoesen, & Damasio, 1993). This atrophy is usually attributed to the loss of neurons in the frontal cortex (DeKosky & Scheff, 1990), corpus callosum (Vermersch, Scheltens, Barkhof, Steinling, & Leys, 1993), association cortex and certain subcortical nuclei, especially the cholinergic
cells of the nucleus basalis and the serotonergic cells of the raphe nucleus (Blass, 1993). The loss of synapses implies a decrease in connections throughout the brain, resulting in a neocortical isolation syndrome (Vermersch et al., 1993). This obviously causes a decreased potential for neuronal interaction (DeKosky & Scheff, 1990). However, some evidence suggests that at least some portion of the atrophy is due to neuronal shrinkage rather than actual cell loss (Kemper, 1994). A compensatory mechanism has been posited by some investigators (DeKosky & Scheff, 1990) that serves to offset the effects of neuronal loss. As the number of neurons decrease, the size of the synapses of the remaining neurons increases, which is effective for cell losses up to 35%. Many investigators (Amaducci et al., 1992; Blass, 1993; DeKosky & Scheff, 1990; Katzman & Jackson, 1991; Zec, 1993) have noted the importance of the size of the total synaptic area, showing strong correlations between density of synapses and mental status scores.

NFTs and SPs, two of the hallmarks of AD, are also found in normal aging; therefore, diagnostic criteria for AD require numbers in excess of specific cut-off values (Hyman et al., 1993). Neurofibrillary tangles are intracellular accumulations of straight and paired helical filaments, a major component of which is the abnormally phosphorylated protein tau which is associated with neuronal microtubules (Blass, 1993; Whitehouse et al., 1993). It has been postulated that impaired transport via altered microtubules may be a mechanism of neuronal damage in AD (Blass, 1993). NFTs are predominantly located in the pyramidal cells of the neocortex, hippocampus, and amygdala as well as the locus coeruleus and raphe nucleus (Hyman et al., 1993).
Senile plaques are spherical with a dense insoluble amyloid core surrounded by glia and distorted cell processes (Whitehouse et al., 1993), and these are mainly found in the cerebral cortex and hippocampus as well as the corpus striatum, amygdala, and thalamus (Hyman et al., 1993). These plaques in a diffuse form may be present 10 to 20 years before the development of the clinical signs and may be a precursor of the dementing process (Katzman & Jackson, 1991). Amyloid is a fibrillar protein that has a precursor called APP, or amyloid precursor protein, which is coded by a gene on chromosome 21. Although APP is necessary for daily functioning of cells, fragments of this protein have been found to be toxic to neuronal cells (Katzman & Jackson, 1991). Amyloid is also deposited in the vascular wall by microglial cells, serving to thicken the vascular wall, destroy the endothelium, and eventually obliterate the vessel (Wisniewski, Wegiel, Morys, & Bobinski, 1994).

Other Characteristics

The typical AD patient has memory problems that are temporally graded with more recent information being forgotten first (Zec, 1993). The rate of forgetting increases as the disease progresses. During recall, intrusions and perseverations are common (Butters, Granholm, Salmon, Grant, & Wolfe, 1987). Memory diminishes as the disease progresses and by the intermediate stage of AD, remote memory is affected (LaRue, 1992).

Language problems begin with word finding problems, circumlocutions, and use of vague words (La Rue, 1992; Zec, 1993). Moderate AD may be accompanied by increased verbosity but empty content, while in the severe phases, language becomes sparse and telegraphic, if the patient has not yet become mute (La Rue, 1992).
Fluency performance is related to dementia severity and is useful for tracking disease progression, regardless of modality of presentation (Mickanin, Grossman, Onishi, Auriacombe, & Clark, 1994). Word fluency for categories is worse for AD patients than letter fluency, which suggests breakdown of semantic hierarchies (Chan, Butters, Salmon, & McGuire, 1993).

Problems with spatial orientation (or geographical disorientation) may be one of the first signs in AD, and it greatly affects daily functioning. This is a form of visual agnosia and may result from impairment of visuospatial memory as well as visuoperceptual dysfunction (Zee, 1993). One study (Henderson, Mack, & Williams, 1989) found that 39% of their sample had difficulties with spatial orientation, such as getting lost on familiar streets, getting lost indoors, and inability to recognize familiar places.

Constructional/visuospatial ability may be intact in early AD, but it may decline sharply (La Rue, 1992). This is shown by difficulties with complex visuospatial discriminations, mental rotation (Lezak, 1995), and unilateral visuospatial inattention (Freedman & Dexter, 1991). A visuospatial impairment suggests parietal lobe dysfunction, and indeed, PET scans in patients with these problems demonstrate large decreases in glucose utilization in right temporal and parietal lobes (Zee, 1993).

Studies have shown that mild (Greenwood, Parasuraman, & Haxby, 1989) and moderate AD patients (Greenwood, Parasuraman, & Haxby, 1991) are impaired in the ability to reorient attention, although simple focus of attention seems relatively unimpaired. However, Lezak (1995) pointed out that even some mildly affected AD patients have difficulties concentrating.
on tasks and sustaining attention. Divided attention and shifting of attention may be the earliest signs of cortical dysfunction, progressing to difficulties with arousal and focused attention to stimulus features in the late stages of the disease (Parasuraman & Haxby, 1993).

Patients may show a lack of awareness of their deficits, an anosognosia for dementia (Green, Goldstein, Sirockman, & Green, 1993; Zee, 1993). This loss of insight can involve various degrees of awareness and can fluctuate over time and over symptoms. Anosognosia has been found in the early stages of AD (McGlynn & Schacter, 1989), and it is said to be caused by damage to parietofrontal connections in the right hemisphere (Auchus, Goldstein, Green, & Green, 1994; Reed, Jagust, & Coulter, 1993). Neither depression nor severity of dementia has been correlated with the presence of anosognosia (Reed et al., 1993).

Depression is estimated to be present in 20% to 30% of all demented patients. Accurate assessment is difficult because demented patients cannot accurately remember their symptoms, and caregivers may supply inaccurate information (Teri & Wagner, 1991). Additionally, in most cases of geriatric depression, the presenting symptoms are dysthymia, apathy, or anergy, which serves to make diagnosis difficult (Ashford & Zee, 1993).

Behavioral disturbances typically reported in AD include psychotic symptoms, apathy, aggressiveness, incontinence, and inappropriate actions (Tuokko, 1993). Additionally, "sundowners" (increased confusion and agitation in the late afternoon or evening) is a common characteristic in AD (Hofman & Swaab, 1994; Satlin, Volicer, Ross, Herz, & Campbell, 1992) and is thought to arise from the combined influence of accumulated fatigue and the reduced sensory stimulation that occurs as the day's activities wind down.
down. Psychotic symptoms early in AD predict a more rapid decline (Gilley, 1993) and usually consist of beliefs of belongings being stolen or of an unfaithful spouse (Raskind, 1993). Estimates of prevalence of psychotic symptoms range from 28% to 38% (Zubenko, Rosen, Sweet, Mulsant, & Rifai, 1992).

Etiology of AD

The cause of AD is unknown, but, because the symptoms can be so heterogeneous, many researchers believe that there are multiple underlying causes that combine in various ways in different individuals (Kay, 1991; La Rue, 1992). Blass (1993) describes this as a convergence syndrome.

Genetic Basis

The genetic theory was first supported by evidence that nearly all people with Down's syndrome, a known genetic disorder, develop the neuropathologic signs of AD, including both amyloid plaques and NFTs, by the age of 40 (Blass, 1993; La Rue, 1992; Wurtman, 1985). The neuropathology and ensuing dementia is essentially indistinguishable from classic AD (Farrer, 1994). Down's syndrome is caused by mutation of genetic material on chromosome 21, and this area is also implicated in some early onset AD cases but no late onset cases (Kay, 1991). Other chromosomes known to be involved in familial AD (FAD) are 19 and 14 (Bird, Nemens, & Kukull, 1993; Brousseau et al., 1994). The familial form of AD appears to be heterogeneous with genetic susceptibility associated with AD alterations at a number of sites. According to Blass (1993), chromosome 14 is the most common genetic abnormality in FAD. Families with this mutation are part of a relatively
small group of AD patients who inherit the disease in an autosomal dominant pattern.

However, these genetic findings are tempered by the relatively low 40% concordance rate among monozygotic twins (Kay, 1991; La Rue, 1992), and differences in age of onset that can vary from 6 to 15 years between concordant identical twins (La Rue, 1992). This argues for non-genetic factors, a position which is further supported by the fact that less than half of Down's syndrome patients have a progressive cognitive decline from young adulthood, although they have the neuropathologic characteristics (Blass, 1993).

Interest in a genetic factor for AD has increased with the finding that there is an over representation of the ε4 allele of the apolipoprotein E gene (APOE) in patients with AD when compared to controls (Brousseau et al., 1994; Petersen et al., 1995). Brousseau et al. (1994) found the risk of AD was approximately 6 times greater for patients having at least one APOE ε4 allele than for subjects without the ε4 allele. In a study to assess the predictive ability of APOE status, Petersen et al. (1995) followed patients evaluated for mild cognitive deficits, which usually involved memory problems. Their results indicated that having the ε4 allele of the APOE gene was a strong predictor of progressive dementia in those patients having mild cognitive impairments. Because the correlation of APOE status and clinical outcome is not perfect, APOE status is useful only as a risk factor and not as a diagnostic test.

Blass (1993) stated that genetics plays a variable role in the causation of AD. In some families, a genetic abnormality has a dominant role, causing the disease in any individual who lives to the age of risk, while in other
family groups, genetics may cause a predisposition, dependent upon currently unknown environmental factors. In patients without a family history of AD, genetics may not play a role at all (Blass, 1993).

Transmissible Agent Theory

An infectious disease model was proposed because other neurodegenerative diseases, such as Creutzfeld-Jacob and scrapie, were found to be transmissible (Prusiner & Hsaio, 1994). As in AD, these diseases had a late onset of clinical signs as well as distinctive neuropathological structures, although these structures were not the same as those in AD (La Rue, 1992; Wurtman, 1985). However, animal studies have not supported the possibility of transmission of AD, and there is also no evidence of human transmission in personal contact with AD patients or blood transfusions (La Rue, 1992).

Environmental Toxin Theory

Epidemiology studies have identified aluminum as an environmental toxin (Blass, 1993). The aluminum theory is based on the presence of a high concentration of aluminum within the NFTs and the knowledge that aluminum is a known neurotoxin (La Rue, 1992). For example, aluminum salts applied directly to the brain cause fibrillary degeneration, although it is not the same type of degeneration found in AD (Blass, 1993). However, AD can develop without high levels of aluminum (Blass, 1993). It may be that the association of aluminum with the tangles means that once the tangles are formed, they have an affinity for aluminum (Wurtman, 1985).

Abnormal Protein Theory

The one neuropathological abnormality required to make the diagnosis of AD is a quantity of amyloid plaques that exceeds a cut-off value,
since amyloid plaques can also occur (in lesser amounts) in the elderly without AD (Blass, 1993). A precursor for amyloid, amyloid protein precursor (APP), has become a major focus of investigation because the β-amyloid found in the dense neuritic plaques is derived from it (Katzman & Jackson, 1991). APP is coded by a gene on chromosome 21 and is necessary for daily functioning of the cells; in fact, an increase in APP during fetal brain development is necessary for maintenance of fibroblasts and hippocampal cells in culture (Katzman & Jackson, 1991). A systemic origin for cerebral amyloid is suggested by the presence of this protein in skin, subcutaneous tissue, and intestine of AD patients and of some controls (Kemper, 1994). A problem with this model is the fact that plaques are found not only in the parts of the brain affected by AD, but also in the cerebellum which is not usually considered to have neurodiagnostic changes (Katzman & Jackson, 1991). Additionally, dense plaques occur in the elderly, even those without cognitive impairment (Blass, 1993). In fact, some autopsied patients have had sufficient numbers of plaques to meet criteria for AD but were cognitively intact on repeated testing during life (Katzman et al., 1988).

Acetylcholine (ACh) Theory

In AD patients, the most characteristic neurotransmitter loss is found in the cholinergic system. This is caused by the loss of large cholinergic cells in the rostral portion of the reticular activating formation, the septum, diagonal band, and the nucleus basalis of Meynert (Blass, 1993). The specific measure of ACh in brain tissue is choline acetyltransferase, which is the enzyme necessary to synthesize ACh. Its presence can decrease from 60-90% in the cerebral cortex and hippocampus (Goldman & Côté, 1991). Since the
mid-1970s, precursors to ACh have been used in an attempt to increase cholinergic levels (La Rue, 1992). Choline and lecithin supplements have had only limited clinical success, but some improvements have been seen with use of cholinesterase inhibitors which decrease the breakdown of ACh in the synaptic cleft. Cognex is a drug that has been recently approved for patient use; however, the duration of response is unknown (Small, 1992). While the losses of ACh are certainly profound, this model does not account for lesser decrements in serotonin, norepinephrine, somatostatin, and other substances (Blass, 1993).

Inflammation Theory

An autoimmune or inflammatory component in AD has been considered, citing amyloid as an activating agent that causes an inflammatory reaction which contributes to the process of degeneration (Blass, 1993; Aisen & Davis, 1994). Aisen and Davis (1994) suggest that disruption of the blood-brain barrier (BBB) may be important in starting the process of AD. When the integrity of the BBB is disturbed, previously protected brain antigens may be exposed to the immune system which may initiate inflammatory and immune mechanisms leading to tissue destruction in the brain. The inflammatory theory is consistent with evidence that AD is less prevalent in those patients who have rheumatoid arthritis, supporting the hypothesis that medications used in the treatment of arthritis, such as non-steroidal anti-inflammatory drugs (NSAIDS), protect against AD (Broe et al., 1990; Henderson et al., 1992; The Canadian Study of Health & Aging, 1994).

Other Theories

Other models have been proposed to explain AD. One that posits that the olfactory-limbic connection may provide a route for toxins or infectious
agents (Goldman & Côté, 1991). Another model states that mitochondria are damaged, which limits the glucose oxidation in the AD brain, producing effects of hypoxia (Blass, 1993). The mitochondrion is also a major generator of oxidative radicals in the cell, and free radical damage has been shown in the AD brain (Blass, 1993).

Summary

All of these investigators have taken a specific aspect of AD and produced theories to account for the features related to that aspect. However, the current theory that AD is a convergence syndrome implies that no single event causes AD (Blass, 1993). Similarly, Amaducci et al. (1992) suggest that AD is not a single genetic entity, but that it may be caused by genetic defects on chromosome 21 and other genetic and non-genetic factors. The idea that there are multiple causes provides multiple sites for intervention that do not have to be mutually exclusive. Blass (1993) reports that subgroups of AD patients may respond differently to different treatments. It is only with further research that we will be able to develop better interventions and to determine for which groups they will be appropriate.

The Controversy Regarding Drivers with Alzheimer's Disease

The approach that investigators have used to study AD - to consider one aspect of its presentation - is due to the heterogeneity of its clinical, anatomic, and physiological characteristics. Many researchers have noted the variety of impairments of patients with AD. For example, although the time period from onset of symptoms to death is usually five to ten years, some patients have had a precipitous decline that lasts only one to two years, while others have had a slow course with plateaus that allows for survival.
greater than twelve years (Friedland et al., 1988). Similarly, AD patients may
initially present with difficulties with visuospatial functioning (Becker,
Huff, Nebes, Holland, & Boller, 1988), language impairment (Becker et al.,
1988), or focal neurological abnormalities such as astereognosis and
pseudoathetosis (Crystal, Horoupian, Katzman, & Jotkowitz, 1981). In a
longitudinal study, Mayeux, Stern, and Spanton (1985) noted that their
sample of AD patients clustered into four groups: benign (little to no
progression of symptoms), myoclonic (severe intellectual decline and
frequent mutism), extrapyramidal (severe intellectual and functional
decline and frequent psychotic symptoms), and typical (a gradual
progression of intellectual and functional decline, but without other
distinguishing features). The wide variety of clinical presentations
indicates that no two patients present in exactly the same manner nor are
patterns of deterioration identical because different abilities will decline at
different rates for the individual patient as well as for different patients
(Lezak, 1995). This means that each patient will have different areas of
intact and impaired functioning and that these will be continually
changing. This presents difficulties in trying to predict what functions an
AD patient can perform competently and for how long. This is particularly
true for driving.

It is acknowledged that at some point virtually all AD patients will
become incapable of driving safely (Drachman, 1988). However,
investigators have widely differing views on the method that should be used
to determine when a patient should cease driving. Because of the danger
involved and the fact that many individuals with AD did not stop driving
until they had at least one accident, some investigators (Lucas-Blaustein,
Filipp, Dungan, & Tune, 1988) have recommended that patients who have been diagnosed with AD should cease driving immediately upon receiving the initial diagnosis. Friedland and his colleagues (1988) made similar recommendations because their study indicated that neither severity of dementia nor duration of the disease could predict those who could drive safely. On the other hand, Drachman (1988) stated that the limitation of driving privileges should be based on a demonstration of impaired driving skills rather than a medical label such as AD. Additionally, there is an increased possibility of misdiagnosis when deficits are mild and patients are most likely to still be driving (Hunt, Morris, Edwards, & Wilson, 1993). Drachman (1988) further pointed out that decisions regarding a patient's abilities to drive are often beyond the scope of an office examination and should utilize specialized testing of driving ability, whether simulated or on-the-road.

This controversy is based on findings that have come from various studies on AD patients and their driving. Lucas-Blaustein and her colleagues (1988) found that 30% of their sample had at least one accident since the onset of dementia, and an additional 11% were reported by caregivers to have caused an accident. Forty-four percent routinely got lost while driving. Similarly, Tuokko, Tallman, Beattie, Cooper, and Weir (1995) found that drivers with dementia had 2.5 times more crashes than controls, and 65% of the patients with possible AD and 21% of the patients diagnosed with probable AD had two or more crashes. Other investigators (Friedland et al., 1988) found that the AD patients were 4.7 times more likely than controls to have had at least one crash in the last five years. These studies indicate that
AD patients present a greater driving risk than controls and that having a crash does not necessarily induce them to stop driving.

While some patients are reported to give up their licenses easily, others cling to them tenaciously. In fact, in one study, investigators (Odenheimer et al., 1994) were able to recruit subjects only by promising the prospective subjects that the results of the driving tests would not be forwarded to the state licensing department. The determination to keep their licenses is influenced by many factors. Alternate methods of transportation are not often readily available, and this may limit the quality of life for these people (O'Neill, 1992). For many people, the ability to drive allows independence and socialization (Bloedow & Adler, 1992; Carr et al., 1991; Retchin, Cox, Fox, & Irwin, 1988), while for some patients, it is essential to purchase food, clothing, and other necessities (Carr et al., 1991). If driving is limited, these duties may have to be assumed by a caretaker (Dubinsky, Williamson, Gray, & Glatt, 1992). The loss of mobility also may result in the loss of self-esteem or income (Reubin, Silliman, & Traines, 1988). Cessation of driving can be traumatic, causing a major change in lifestyle (Logsdon, Teri, & Larson, 1992), or more importantly, could force an unwanted move into an urban area, into a retirement community (Logsdon et al., 1992), or into an institution (Carr et al., 1991). Perhaps even more important to the patient is the fact that driving represents entry into adulthood as well as independence and freedom (Logsdon et al., 1992). These quality of life issues must be weighed against the potential risks of unsafe driving to the patient, family, and others (Gilley et al., 1991).

Patients often minimize these risks by saying that they will know when to stop driving or that their family will tell them. However, driving
competency cannot be reliably gauged from self-report of driving skills (Hunt et al., 1993). Some persons with dementia continue to drive regardless of their deficits and number of crashes experienced (Tuokko et al., 1995). Studies that have investigated patient and collateral ratings of recent memory, remote memory, attention, and everyday activities show a larger discrepancy for judgments of recent memory and everyday activities, a smaller one for attention, and minimal discrepancies for judgment about remote memory. (Green et al., 1993). Patient self-ratings were significantly more positive than familial ratings of patient abilities. It is likely that many AD patients cannot recognize that their driving abilities have diminished. Unfortunately, even a reliable judgment by a health care professional that the patient can operate a vehicle safely can be invalidated quickly by disease progression (Gilley et al., 1991).

**Factors Involved in Driving**

To evaluate someone's competence as a driver, it is important to know the kinds of tasks that must be performed competently to be considered a safe driver. Investigators have suggested a plethora of abilities thought to be intrinsic to safe driving. The most frequently cited ability was visual perceptual functioning (Dubinsky et al., 1992; Koepsell et al., 1994; Logsdon et al., 1992; Poser, 1993; Rebok, Keyl, Bylsma, Blaustein, & Tune, 1994). Other abilities included judgment (Dubinsky et al., 1992; Fitten et al., 1995; Gilley et al., 1991; Koepsell et al., 1994; Poser, 1993), continuous tracking (Dubinsky et al., 1992; Fitten et al., 1995), vigilance (Fitten et al., 1995; Gilley et al., 1991; Logsdon et al., 1992), route finding (Dubinsky et al., 1992; Gilley et al., 1991; Poser, 1993), rapid motor responding (Koepsell et al., 1994; Rebok et al., 1994).
ability to process multiple environmental stimuli at once (Koepsell et al., 1994), and memory (Poser, 1993).

While this list is certainly comprehensive, it can not delineate the specific cognitive abilities that are necessary for safe driving, because these are not known at the current time. However, there is agreement on some major domains, which include mental status, attention, visuospatial/visual, language, and memory. While other factors such as judgment have been proposed, their importance has not been empirically validated.

Mental status is related to accident rates with three times more accidents occurring for those AD patients with poorer mental status as opposed to those with better mental status (Owsley, Ball, Sloane, Roenker, & Bruni, 1991). The Mini-Mental Status Exam has been used in most driving studies (e.g., Odenheimer et al., 1994), and, while it is predictive of driving ability in these studies, it is not sufficient to discriminate those who pass or fail the driving examination.

Parasuraman and Nestor (1991) reported that both mild and moderate AD patients have marked difficulties with disengaging or reorienting attention, although their ability to focus attention may remain intact. This attentional shifting is crucial for safe driving (Hunt et al., 1993) in order to react to the unexpected events experienced by drivers (Parasuraman & Nestor, 1991). Even when most cognitive abilities are still in the normal range, difficulties in shifting of attention on tasks can be seen (Rees, Boyer, & Phillips, 1995).

Visuospatial confusion may be caused by abnormalities in visual scanning behavior (Donnelly & Karlinksy, 1990). Haphazard scanning patterns may lead to great difficulty with extracting relevant information
from a visual search of the patient's surroundings. In one recent study (Fittgen et al., 1995), eye movement measurements were able to distinguish between AD patients and patients with vascular dementia, with AD patients demonstrating significantly less scanning movements. Impaired visuospatial discrimination may be accompanied by a reduction in visual fields that the patient is unaware of (O'Neill et al., 1992). Another measure of vision, the Useful Field of Vision (UFOV) was failed by all subjects with multiple accidents and by those subjects who were involved in 95% of the intersection accidents (Owsley et al., 1991). Visual processing abilities are essential for driving, particularly at intersections where most accidents occur (Parasuraman & Nestor, 1991).

Language skills have been shown to be related to on-road testing, although investigators (Odenheimer et al., 1994) have noted that this may be due to the format of their test which relies on verbal instructions. Failure to follow a command could be due to lack of comprehension rather than lack of ability to perform. Hunt and her colleagues (1993) cited language difficulties as exacerbating poor road performance because it interfered with the patient's ability to understand the comments or advice of passengers, lessening the effectiveness of "co-pilots." In a study of stroke patients with language impairments, Nouri and Lincoln (1992) found that language ability did not significantly contribute to driving safety.

Those components of driving that rely on recent memory, such as following a new route, may be difficult for the AD patient (Parasuraman & Nestor, 1991). As the disease progresses, individuals may have difficulties getting lost on familiar streets and may drive more slowly to compensate for uncertainty (Bloedow & Odler, 1992). Parasuraman and Nestor (1991) suggest
that driving restricted to very familiar routes with minimal traffic may not be affected by memory impairment. However, procedural memory remains relatively intact for a period of time, and this includes the basic operations of driving, such as shifting gears or using the turn signal (Kapust & Weintraub, 1992).

**Restriction of Driving**

Self-reports of driving habits show a characteristic pattern for AD patients. They decrease their miles driven and driving frequency, implying an awareness of their driving impairment, but most denied any difficulties with driving (Cushman, 1993). Additional strategies used included avoiding rush hour traffic, avoiding highway driving, and decreasing their speed, but despite these precautions, AD patients still had a higher accident rate than controls (Dubinsky et al., 1992). This may be explained by the fact that these strategies are not sufficient to compensate for the AD patient’s deficits. Parasuraman and Nestor (1991) suggest that basic deficits such as inability to shift attention cannot be ameliorated by driving more slowly or by paying closer attention to the road.

The deficits that are incurred by AD patients as their disease progresses have been studied in relation to driving, and a summary of these investigations follows.

**Empirical Studies of Alzheimer’s Disease and Driving**

van Zomeren and Brouwer (1994) explained that there are two methods of investigating driving skills. In the first, driving ability is evaluated in a natural setting in which the subject drives in a variety of traffic situations that are meant to be representative of everyday driving. The second method uses another criterion measure such as number of
crashes or one or more critical driving subtasks or driving-related abilities. These methods will be discussed.

Hunt and colleagues (1993) evaluated 13 healthy controls and 12 subjects with very mild AD and 13 subjects with mild AD on a road test that was scored independently by two evaluators. Subjects and their collaterals were interviewed separately to obtain their opinion of the subject's driving ability. All control subjects and very mild AD subjects passed the on-road test; however, five (40%) of the mild AD subjects were impaired to such a degree that they failed the road test. Of those that failed, inappropriate driving behaviors included coasting to a stop in traffic, stopping abruptly without a cause, and simultaneously pressing the brake and accelerator while driving. Neither subject self-assessment nor collateral assessment of the subject's driving consistently predicted ability to drive safely. Driving scores were most highly correlated with attentional abilities. These investigators found that healthy elderly individuals and at least some of the very mild and mild AD subjects were considered to be safe drivers.

A study by Odenheimer and her colleagues (1994) involved an on-the-road driving test with closed course and in-traffic components which was given to 24 elderly subjects and three AD patients as well as three patients with vascular dementia. Tests that significantly correlated with driving scores included the Mini-Mental State Exam (MMSE), visual and verbal memory subtests of the Wechsler Memory Scale-Revised (WMS-R), Trails A, traffic sign recognition, and a computerized complex reaction time test. Although there was a strong correlation between the MMSE and the on-the-road test scores, the four drivers who failed the driving test had MMSE scores of 4, 16, 21, and 24, while the lowest MMSE score of a subject that passed was

23
This overlap indicates that MMSE scores are not sufficient to predict driving performance.

The most recent of these studies (Fritten et al., 1995) provided on-the-road data from an assessment of the abilities of fifteen mild AD patients, twelve multi-infarct dementia (MID) patients, fifteen age-matched controls with diabetes, and sixteen young subjects. Patients with a history of mild AD or MID performed significantly worse on the road test compared to control subjects. The three best predictors of the driving score were the MMSE, visual tracking, and a memory test. However, the MMSE score at the upper end of the range did not correlate well with the driving score, which is a limitation for the MMSE as a screening device.

The information provided by these three studies suggests that some AD patients are capable of driving in a safe manner, although many exhibit dangerous behaviors during the road test. Additionally, while the MMSE was predictive of driving scores, it was not sufficient by itself to discriminate those patients who passed the road test and those who didn't. Although these studies are difficult to compare due to differing test batteries, two of the three studies showed attention to be a significant factor in predicting driving scores.

Another method of studying driving behavior involves using a criterion measure for driving other than an on-the-road test. Two of the studies reviewed have used some form of driving status as their grouping variable. Retchin and colleagues (1988) used categories of frequent drivers, occasional drivers, and nondrivers, and they found that these categories were predicted by dynamic visual acuity, nondominant grip strength, and peripheral vision, but not cognitive impairment. Alternatively, Logsdon et
al. (1992) used groups of individuals who, by collateral report, were driving without difficulty, driving with difficulty, and those who had stopped driving due to cognitive deficits. Findings showed that mean MMSE, DRS, and visuospatial task scores were significantly different between drivers and nondrivers, but no significant difference was found between those who had a change in driving ability and those who had problems but were still driving independently. These studies demonstrate that there is no clear relationship between severity of dementia and driving status, but due to the grouping variables selected, no other conclusions can be drawn.

An alternate method of considering driving abilities in AD is to use questionnaire data from collaterals that involves number of crashes before and after onset of dementia symptoms. This strategy has been used by investigators who studied patterns of crashes in AD (Drachman & Swearer, 1993; Dubinsky et al., 1992; Gilley et al., 1991) as well as those who studied neuropsychological differences between AD drivers who were still driving and those who were not (Lucas-Blaustein et al., 1988). In the latter study, neuropsychological scores were compared between those AD patients who were still driving and those who had stopped driving.

A slightly different format was used by Rebok and his colleagues (1994) who used the Driver Performance Test (DPT; Weaver, 1985) and the Driving Advisement System (DAS; Gianutsos, 1988) as tapping driving-related abilities and compared these scores with various neuropsychological tests. They found that the visual and verbal memory scores and category fluency scores correlated highly with their driving measures and therefore suggested that these paper and pencil measures could be used to predict
driving ability, with the caveat that they lack the face validity of the driving measures.

**Consideration of Previously Used Methodologies**

In efforts to determine the effects of the deficits of AD patients in driving, investigators have been using on-road tests and survey methods. Currently most evaluations have an on-road test as the final decision factor. However, these tests have limiting factors for use with AD patients. Some investigators (Fritten et al., 1995) have suggested that these patients must be re-tested frequently because the progression of their disease may render them incapable of safe driving in a relatively short period of time. However, these on-the-road evaluations are costly and time consuming. Kapust and Weintraub (1992) estimated the cost per on-road evaluation to be $1200 per patient. Several investigators (Hunt et al., 1993; Odenheimer et al., 1994) who used on-road testing have a course that takes approximately an hour to complete in order to provide a wide variety of driving situations. Additionally, other screening measures must additionally be performed to ensure some modicum of safety before allowing road tests (Odenheimer et al., 1994). Although attempts have been made to standardize these courses (Odenheimer et al., 1994), changing traffic conditions cannot be duplicated, and closed courses do not allow for testing of the patient's interaction with other vehicles. Similarly, subjects are often closely directed and asked only to follow single commands, minimizing the effect of other factors such as getting lost (Odenheimer et al., 1994) and the ability to follow sequential directions (Drachman & Swearer, 1993). As Jones, Giddens, and Croft (1983) stated, an on-the-road test "has the disadvantages of low objectivity, low reliability, and often low safety levels." On-road driving examinations may
not be challenging enough to indicate the ability of AD patients when faced with more complex and stressful traffic situations that surpass their cognitive and decisional capabilities (Hunt et al., 1993). That information is supplied by moving violation and crash data.

An alternative to on-the-road tests are the use of simulators. However, these involve the purchase of expensive equipment (Rebok et al., 1994) and do not typically correlate well with driving performance (Dubinsky et al., 1992; Owsley et al., 1991).

Use of crash data is supported by the report of Owsley and her colleagues (1991) who argue that the use of crash data is preferable to on-road testing if the goal is to predict and eventually reduce crashes. Additionally, if an on-road test was to be used to determine who was at risk for accidents, the test would have to be validated against crash frequency. Tuokko and her colleagues (1995) reported that on-road testing and survey data show consistent findings despite variations in methods and sampling procedures. Other investigators (Gilley et al., 1991) point out that crash rates alone may underestimate the patients' difficulties. Their sample had relatively frequent tickets and rule infractions as noted by collaterals, even in those patients who had no crashes. Therefore, summation of crash data, moving violations, and rule infractions should provide comprehensive information.

**Rationale for Study**

It is evident from a review of the literature on driving and AD, that AD patients have a greater risk for automobile crashes than controls (Dubinsky et al., 1992; Friedland et al., 1988). Investigators have shown that having crashes does not necessarily change an AD patient's driving status, often
leaving the caregiver or health professional the unpleasant task of persuading the patient to stop driving (Friedland et al., 1988; Gilley et al., 1991; Lucas-Blaustein et al., 1988).

Deciding when a patient should stop driving is not an easy task. Those affected with AD may plateau in their symptom progression or may present with a pattern of deficits that allows for safe driving. Currently performance-based (on-road) tests are used to determine safe driving in individuals, but these tests are expensive and time intensive. It should also be noted that some investigators recommend these on-road tests be given repeatedly to check for possible disease progression that would affect driving safety. Brief screening measures that are clearly predictive of driving abilities need to be developed (Hunt et al., 1993; Robbins & Weintraub, 1992).

While many abilities have been suggested as being important to driving safety, research has not been done to determine the measures that would best predict safe driving. Therefore, measures indicative of driving ability should be used to ascertain the best predictors for driving ability. Determining predictors of safe driving ability in AD would allow for screening that could eliminate on-road testing for those patients that would be most dangerous on the road.

Measures that will be considered as predictors include the Mini-Mental State Examination (MMSE), Trails A and B, Boston Naming Test (BNT), Logical Memory (LM) and Visual Reproduction (VR) from the Wechsler Memory Scale-Revised, and Category Fluency. These tests have been found to correlate with driving ability in previous investigations. The Driver Performance Test (DPT) and Driver Risk Index (DRI) are videotaped tests of
driving ability. The DPT assesses knowledge of driving skills, while the DRI evaluates the patient's ability to estimate the risks inherent in driving.

This study is designed to assess the utility of various cognitive tests and measures of driving-related abilities as predictors for driving ability. Similar to many studies regarding driving in dementia, collateral report was used to provide information regarding the demented patients' driving record (Drachman & Swearer, 1993; Dubinsky et al., 1992; Gilley et al., 1991; Logsdon et al., 1992; Lucas-Blaustein et al., 1988; Wagner, Bachman, Cushman, Waid, & Hummer, 1994). Collateral report has been validated for use in studies that gather data that is subjective or cannot be obtained by other means (Logsdon & Teri, 1995; Rocca et al., 1986). Logsdon and Teri (1995) investigated AD patients' levels of depression by comparing three collateral questionnaires, a caregiver structured interview, and a patient structured interview. Correlations of the report measures were significant at the p<.0001 level, supporting the concept that caregivers can act as accurate reporters of depression in AD. This evidence for the accuracy of collateral information is important in the current study because of the limitations of the DMV records. Department of Motor Vehicles (DMV) records reflect only police-reported accidents. In a study by O'Jile (1994) that compared the driving records of head injured subjects and non-head injured controls, the self-reported records of the head injured subjects were consistent with the DMV records, but controls reported more crashes than the state records revealed. In a study that dealt with elderly patients, Tuokko and her colleagues (1995) in Vancouver, British Columbia used a combination of Motor Vehicle Branch (MVB) data and insurance company data (since there is only one insurance carrier in that province). Their paradigm was limited by the amount of time
records are kept in the MVB. In the US, many states limit their records to three years of data. Tuokko et al. (1995) found that elderly subjects may have more frequent minor crashes that may go unreported to the police. Finally, Dubinsky et al. (1991) pointed out that subjects would be less likely to participate in research if they were informed that the accident data would be obtained from the DMV. Therefore, because DMV data is limited by the type of accidents reported and the length of record-keeping, collateral data was obtained for this study. Data collected included information concerning the last six years of driving for controls or from date of onset of dementia symptoms for AD patients. Using collateral data also permits the collection of more subjective data such as quality of driving. This period of six years is based on investigations (e.g., Logsdon, Teri, and Larson, 1992) in which all AD subjects had discontinued driving by six years after onset of dementia symptoms. Therefore, data for this period of time was collected by collateral report to derive the TDI for each subject.

**Research Questions and Hypotheses**

This study compared the driving performance and predictors of that performance for subjects with AD and elderly controls. Neuropsychological tests were correlated with driving performance as measured by the TDI, comprising measures of patient confusion while driving, moving violations, and crashes. The literature in this area gives indications of results that were expected to be replicated in this study. These included: 1) more automobile crashes would be found for AD subjects than for normal elderly controls, 2) subjects with AD and elderly controls would consider themselves to be equally competent to perform on the driving-related tests, although the AD participants were expected to score significantly lower than controls, and 3)
the AD subjects would score significantly lower than controls on the DPT. However, there are issues that previous studies had not addressed.

Hypothesis 1. The first hypothesis was that predictors of driving ability as measured by the Total Driving Index will be different for the two groups. Specifically, for AD subjects, the MMSE, DPT, DRI, and Trails A and B would account for significant incremental variance in the criterion variable. For controls, only the DPT and DRI would account for significant incremental variance.

Hypothesis 2. Driving ability as measured by Total Driving Index would correlate significantly with all measures (DRI, DPT, MMSE, Trails A and B, BNT, LM, VR, and Category Fluency) for AD subjects. Significant correlations for controls would be found for DRI and DPT.

Hypothesis 3. The error scores on the DRI would be significantly higher for AD participants than for the normal controls.
Method

Subjects

A total of fifty individuals served as subjects, 25 of which were diagnosed with AD, meeting DSM-IV criteria. An additional 25 normal controls of equivalent age and education also participated, with 18 of these subjects recruited in the state of Louisiana and 7 recruited in the state of New Hampshire. AD subjects and controls were recruited from the Dartmouth Hitchcock Medical Center in Lebanon, New Hampshire; AD subjects were also recruited from a neurologic clinic in Fort Lauderdale, Florida; and control subjects were also recruited in Baton Rouge, Louisiana under the auspices of Louisiana State University. AD subjects were examined by a neurologist (FL) or a team of a neurologist and a geropsychiatrist (NH) who provisionally diagnosed these subjects with senile dementia of the Alzheimer's type. All AD subjects received physical and neurologic exams as well as blood tests (for thyroid screen, CBC, SMAC, etc.) and neuroimaging to assess for other possible causes of dementia. Control subjects were recruited from a retirement apartment complex (LA) or from a hospital Volunteer Services Department (NH). Individuals were screened for significant alcohol or drug use as well as for physical illness that could potentially compromise cognitive functioning. Controls were screened by MMSE, and scores for controls were above those scores considered to be indicative of possible dementia (above 23/30). The controls were in good health, lived independently in the community, and had no history of progressive memory or cognitive impairment. All subjects had a collateral who was familiar with the subject's driving. Additionally, all subjects have driven for at least 10 years, and AD participants had driven for at least one year after the onset
of dementia symptoms. All control subjects were currently driving, as were all but two of the AD subjects. These two subjects had stopped driving recently (one stopped one month prior to testing and the other stopped driving two months before testing). AD subjects and controls were matched by age and sex. The date of onset of dementia symptoms for the AD participants was used as the corresponding start date for the control subjects for comparison of driving events.

Measures

Demographic/Driving History Questionnaire

A questionnaire regarding demographics and driving habits was administered to all subjects and their collaterals (see Appendix A). Collateral-reported driving data was obtained for the last six years for all control subjects, while for AD subjects, data was collected for that period of time since onset of symptoms until the date of cessation of driving or the date of testing for this study. This allowed for between groups comparison of driving since dementia symptom onset (Drachman & Swearer, 1993). Additionally, both controls and AD subjects were asked to estimate how well they performed on the DPT and DRI. This provided an opportunity for AD subjects to demonstrate the accuracy with which they could assess their ability regarding driving related measures. This has a direct bearing on their ability to accurately assess their driving skills.

Mini-Mental State Exam

The Mini-Mental State Exam (MMSE; Folstein, Folstein, & McHugh, 1975) is probably the most widely used dementia screening measure. It assesses a restricted number of cognitive domains quickly (Lezak, 1995). Scores of 23 and lower are considered to be abnormal when screening for
dementia. Basic functions assessed include attention, memory, verbal functions, and construction. High twenty-four hour test-retest reliability was found in the original study, .89 for the same examiner and .83 for different examiners (Folstein et al., 1975). As stated before, this measure has been found to be correlated with driving scores in several studies, and it is expected to account for significant incremental variance.

Trail Making Test

The Trail Making Test is widely used as a measure of visual conceptual and visuomotor tracking (Lezak, 1995). Part A involves tracking sequential numbers while Part B requires alternation of numbers and letters. Errors are not counted but are pointed out by the examiner and corrected by the patient, and the time taken for correction is included in the total time of the test. Part A has been found to have the ability to document the progress of even mild dementia (Botwinick, Storandt, Berg, & Boland, 1988), and has been predictive of driving scores in several studies (Hunt et al., 1993; Odenheimer et al., 1994). Reliability coefficients of Part A were found to be .69 to .94, while Part B showed .66 to .86 for various neurological groups (Snow, Tierney, Zarzitto, Fisher, & Reid, 1988). Trails B is the more sensitive of the two tests (Spreen & Strauss, 1991), and a patient's difficulties with this test could indicate problems such as inability to shift attention during an ongoing task (Pontius & Yudowitz, 1980) or the inability to deal with more than one stimulus at a time (Eson, Jen, & Bourke, 1978). Use of Trails B as a possible predictor of safe driving is supported by the suggestion of Parasuraman and Nestor (1991) that this measure assesses the ability to shift attention between visual locations which is impaired in AD. Trails A and B
are expected to account for significant incremental variance in the Total Driving Index, the criterion variable.

Boston Naming Test

The Boston Naming Test (Kaplan, Goodglass, & Weintraub, 1978) consists of 60 line drawings which are presented one at a time for the patient to name. If the patient does not produce the word spontaneously, two prompts (semantic and phonemic) may be given (Spreen & Strauss, 1991). An original form of the test was divided into two equivalent forms, and between-forms correlations were found to be .81 for normal controls and .97 for AD subjects (Huff, Collins, Corkin, & Rosen, 1986). Williams, Mack, and Henderson (1989) used an experimental version with the current BNT divided into two forms using the odd and even numbered items. These three forms discriminate well between AD, other types of dementia, and elderly controls. While this measure has been significantly correlated with driving scores (Hunt et al., 1993), it is not expected to account for significant incremental variance in the hierarchical regression. This is due to the relatively small role of language in driving.

Wechsler Memory Scale-Revised: Logical Memory

Logical Memory (LM) from the Wechsler Memory Scale-Revised (Wechsler, 1987) assesses the ability to recall ideas from two stories that are read aloud to the patient. Immediate and delayed recall are assessed. Wechsler (1987) reported that the interscorer reliability coefficient was .99. The LM has been found to be useful for identifying and tracking dementia (Storandt, Botwinick, & Danziger, 1986). Although verbal memory is a significant problem in AD, due to the overlearned nature of the driving process and the restrictions that individuals with AD self-impose, limiting
the role of verbal memory, it is not expected to account for significant incremental variance in the final regression equation.

Wechsler Memory Scale-Revised: Visual Reproduction

Visual Reproduction (VR; Wechsler, 1987) consists of four items (three with a single figure and one with two figures), and these are shown to the subject for 10 seconds and then withdrawn. Subjects are asked to draw them immediately and again after a thirty minute delay. A reliability coefficient for scoring of .97 was reported (Wechsler, 1987). VR is very sensitive to the effects of dementia (Mitrushina, Satz, Gayer, & McConnell, 1988). The restrictions that AD drivers impose upon themselves and the ability to have someone else in the automobile help "navigate" leads to the prediction that VR will not be a predictor that accounts for significant incremental variance in the criterion variable, and it is not expected to contribute significant incremental variance.

Category Fluency

Category Fluency is a 60 second naming test in which subjects are asked to produce exemplars of a category. Monsch and her colleagues (1992) found that this test provided greater sensitivity (100%) and specificity (92.5%) than letter fluency with a sensitivity of 88.8% and a specificity of 84.9% for discriminating AD subjects from elderly controls. Although this measure has significantly correlated with measures of driving skills (Rebok et al., 1994), it is not expected to account for significant incremental variance in the criterion variable.

Driver Performance Test

The Driver Performance Test (DPT; Weaver, 1985) is a 36 minute videotaped test that consists of driving situations with questions regarding
these situations to be answered in a multiple choice format. Each situation exemplifies one of five abilities: 1) search for factors that might present danger, 2) identifying those situations, 3) predicting the effect of the dangerous factors, 4) decide the appropriate action, and 5) execute the proper response. A subscore for each of these abilities as well as a Total Score is derived from each subject's performance. Standardization data was based on 8000 experienced drivers with a mean annual driving exposure of 15,000 miles. A Total Score below 130 (out of a possible 200 points) is associated with probable collision frequency. Because of the relationship of the Driver Performance Test Total score with crash frequency, it is expected that the DPT will account for significant incremental variance in the TDI.

Driver Risk Index

The Driver Risk Index (DRI; Weaver, 1985) is a measurement of a driver's risk taking potential in a driver. Fifty risk-related scenes are shown, and a statement regarding the situation is made by the narrator, which the subjects indicate is true or false. Scores were based on a standardization sample of 600 drivers. It is expected that this measure will account for significant incremental variance in the TDI.

Procedure

AD participants and control subjects were administered a questionnaire with items consisting of demographic and driving history queries. For all subjects, experimental and controls, collaterals were asked to answer these questions for the patient. The information provided by the collaterals were used as the statistical basis for the Total Driving Index. A weighting system was used to derive the Total Driving Index for the criterion variable. The first factor in the weighting system was a Patient
Perplexity Index that is similar to one that was used by Wagner et al. (1994). These investigators used an index composite score to reflect the family’s perception of unsafe driving. Their index of general safety included five measures of frequency of unsafe behavior: episodes of getting lost, episodes of near misses, problems with attention, problems with directions, and necessity for the driver to have someone with him or her to drive safely. These resulted in a “frequency of unsafe driving behavior.” In the current study, the Patient Perplexity Factor is made more objective by limiting this factor to the number of incidents in the last year of driving of getting lost while driving and episodes of near misses as reported by the collateral. These events were added and weighted times a unit of one. Collateral report of the number of moving violations since onset of dementia symptoms for AD participants (or an analogous for controls) were weighted times a unit of two, and collateral report of the number of crashes since onset of dementia symptoms for AD subjects (or an analogous time for controls) were weighted times a unit of three. Summation of these factors provide a Total Driving Index that allows for the consideration of the incremental seriousness of these events within a total score. The Total Driving Index was computed based on subjective appraisal by the collateral of the subject’s driving behavior for a year as well as collateral report for the more objective measures (tickets and crashes) which were assessed for the length of time since onset of dementia symptoms for the AD subjects and a comparable time period for the controls. The finish date for these computations was either when the patient stopped driving or the date when the examination for this study occurred.
All subjects were administered the MMSE, Trails A, Boston Naming Test, Logical Memory I and II, Visual Reproduction I and II, and Category Fluency. All of these tests have been shown to correlate significantly with driving measures in the literature. Additionally, subjects were administered Trails B. Although this has not been correlated with driving measures in the past, its use is justified by the difficulties individuals with AD have shown in switching attention between visual locations (Grady et al., 1988; Greenwood et al., 1989). The order of neuropsychological test and driving measures were alternated to control for possible order effects. Two AD subjects fatigued quickly, and the testing was completed over two consecutive days for these subjects.

The subjects were also administered the DPT and DRI. While the DPT has been used in previous investigations with AD subjects (Rebok et al., 1994), the DRI has not. However, AD participants have been noted to have more crashes at intersections (Kaszniai, Kyls. & Albert, 1991; Owsley et al., 1991), while changing lanes (Kaszniai et al., 1991), and at traffic signals (Friedland et al., 1988). This suggests that, when presented with a complex situation, persons with AD are less able to adequately determine the risk involved in their actions. Therefore, the DRI scores should provide a reflection of the subjects' ability to make a judgment regarding risk. In addition, these two tests could be a valuable part of a screening battery for driving because they provide face validity for clinical decisions regarding driving abilities. This is important because other effective measures may not be seen by the patient as having any relationship to the driving process.
Results

Preliminary univariate tests were conducted to obtain a description of the sample characteristics. A summary of demographic data is shown in Table 1.

Comparisons of the two groups' demographic data were performed to determine if there are significant differences between the experimental groups. AD subjects and control subjects were matched by sex, with each experimental group consisting of eleven males and fourteen females. Experimental groups were also equivalent in age ($t(48)=0.82$, n.s.) and education ($t(48)=1.87$, n.s.).

Because control subjects were recruited from two separate locations (Louisiana and New Hampshire), comparisons were made to ensure that these control subjects were not significantly different for any of the parameters used. No significant differences were found between age, education, years driven, and all neuropsychological and driving measure scores for the two groups of control subjects. These results are summarized in Table 2.

Tests of Hypotheses

Hypothesis 1 which stated that predictors of driving ability would be different for the two groups was tested by stepwise regression. It was expected that the MMSE, DPT, DRI, and Trails A and B would be predictive of driving ability as measured by the Total Driving Index for the AD subjects, while the DRI and DPT were postulated to be predictive for the control group. For each group, the Total Driving Index was regressed upon the neuropsychological and driving measures (MMSE, LM1, LM2, VR1, VR2, Trails A, Trails B, BNT, Category Fluency, DPT, and DRI) using forward
stepwise regression. (See Table 3 for results.) Among the AD subjects, Trails A was the only significant predictor of the Total Driving Index, although the DRI approached significance ($p=0.06$). Changes in $R^2$ were obtained for each of these independent variables: Trails A accounted for .224 of the incremental variance ($p=0.02$), and the DRI accounted for .126 of the incremental variance ($p=0.06$). Among the control subjects only Visual Reproduction II was significantly related to TDI ($p=0.01$), accounting for .293 of the incremental variance. Therefore, Hypothesis 1 was only partially supported.

Table 1

Demographic Information

<table>
<thead>
<tr>
<th></th>
<th>AD Subjects</th>
<th>Control Subjects</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>25 (11 Males, 14 Females)</td>
<td>25 (11 Males, 14 Females)</td>
</tr>
<tr>
<td>Age</td>
<td>77.48 (6.91)</td>
<td>74.40 (4.50)</td>
</tr>
<tr>
<td>Age</td>
<td>13.72 (3.66)</td>
<td>13.04 (1.95)</td>
</tr>
<tr>
<td>Mean Months</td>
<td>Stopped Driving</td>
<td></td>
</tr>
<tr>
<td>Years Driven</td>
<td>56.76 (10.80)</td>
<td>47.52 (12.05)</td>
</tr>
<tr>
<td>Miles Driven/Week</td>
<td>53.40 (53.44)</td>
<td>115.00 (101.28)</td>
</tr>
</tbody>
</table>

Hypothesis 2 stated that driving ability as measured by the Total Driving Index will correlate significantly with all measures (DRI, DPT, MMSE, Trails A, Trails B, BNT, LM, VR, and category fluency) for all AD subjects. It was likewise hypothesized that the DRI and DPT would be significantly correlated with the Total Driving Index for control subjects. Correlations were performed between Total Driving Index and all neuropsychological and driving measures for both groups. For the AD
Table 2
Comparisons of Control Subjects by State (LA and NH)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>LA (18 subjects)</th>
<th>NH (7 subjects)</th>
<th>t</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>74.94 (4.87)</td>
<td>73.00 (3.27)</td>
<td>1.15</td>
<td>n.s.</td>
</tr>
<tr>
<td>Education</td>
<td>12.44 (1.10)</td>
<td>14.57 (2.28)</td>
<td>6.7</td>
<td>n.s.</td>
</tr>
<tr>
<td>Yrs Driven</td>
<td>46.22 (12.56)</td>
<td>50.86 (10.75)</td>
<td>-0.92</td>
<td>n.s.</td>
</tr>
<tr>
<td>MMSE</td>
<td>28.28 (1.64)</td>
<td>28.29 (1.98)</td>
<td>-0.01</td>
<td>n.s.</td>
</tr>
<tr>
<td>LM1</td>
<td>19.61 (5.64)</td>
<td>24.43 (8.12)</td>
<td>-1.44</td>
<td>n.s.</td>
</tr>
<tr>
<td>LM2</td>
<td>13.56 (6.34)</td>
<td>19.71 (8.98)</td>
<td>-1.66</td>
<td>n.s.</td>
</tr>
<tr>
<td>VR1</td>
<td>27.56 (6.09)</td>
<td>33.43 (6.40)</td>
<td>-2.09</td>
<td>n.s.</td>
</tr>
<tr>
<td>VR2</td>
<td>19.78 (8.26)</td>
<td>27.86 (9.32)</td>
<td>-2.01</td>
<td>n.s.</td>
</tr>
<tr>
<td>Trails A</td>
<td>51.72 (20.88)</td>
<td>41.71 (10.19)</td>
<td>1.60</td>
<td>n.s.</td>
</tr>
<tr>
<td>Trails B</td>
<td>108.56 (39.51)</td>
<td>82.00 (27.05)</td>
<td>1.63</td>
<td>n.s.</td>
</tr>
<tr>
<td>BNT</td>
<td>55.00 (2.17)</td>
<td>56.86 (3.72)</td>
<td>-1.24</td>
<td>n.s.</td>
</tr>
<tr>
<td>Category Fluency</td>
<td>14.72 (3.98)</td>
<td>20.71 (6.80)</td>
<td>-2.19</td>
<td>n.s.</td>
</tr>
<tr>
<td>DPT</td>
<td>115.00 (17.10)</td>
<td>119.14 (11.08)</td>
<td>-0.71</td>
<td>n.s.</td>
</tr>
<tr>
<td>DRI</td>
<td>16.22 (5.02)</td>
<td>14.71 (4.03)</td>
<td>0.78</td>
<td>n.s.</td>
</tr>
<tr>
<td>Variable</td>
<td>B value</td>
<td>Standard Error</td>
<td>B value</td>
<td>p</td>
</tr>
<tr>
<td>-------------------</td>
<td>---------</td>
<td>----------------</td>
<td>---------</td>
<td>------</td>
</tr>
<tr>
<td><strong>For AD Subjects:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MMSE 0.15</td>
<td>0.14</td>
<td>0.30</td>
<td>0.32</td>
<td>0.09</td>
</tr>
<tr>
<td>LM1</td>
<td>0.24</td>
<td>0.13</td>
<td>0.68</td>
<td>0.15</td>
</tr>
<tr>
<td>LM2</td>
<td>-0.20</td>
<td>0.13</td>
<td>-0.49</td>
<td>0.51</td>
</tr>
<tr>
<td>VR1</td>
<td>0.05</td>
<td>0.07</td>
<td>0.20</td>
<td>0.33</td>
</tr>
<tr>
<td>VR2</td>
<td>0.16</td>
<td>0.16</td>
<td>0.29</td>
<td>0.02</td>
</tr>
<tr>
<td>Trails A</td>
<td>0.03</td>
<td>0.10</td>
<td>0.49</td>
<td>0.02</td>
</tr>
<tr>
<td>Trails B</td>
<td>0.00</td>
<td>0.00</td>
<td>0.05</td>
<td>0.84</td>
</tr>
<tr>
<td>BNT</td>
<td>-0.01</td>
<td>0.06</td>
<td>-0.06</td>
<td>0.88</td>
</tr>
<tr>
<td>Category Naming</td>
<td>-0.13</td>
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<td>-0.32</td>
<td>0.30</td>
</tr>
<tr>
<td>DPT</td>
<td>-0.06</td>
<td>0.04</td>
<td>-0.35</td>
<td>0.14</td>
</tr>
<tr>
<td>DRI</td>
<td>0.20</td>
<td>0.10</td>
<td>0.37</td>
<td>0.06</td>
</tr>
<tr>
<td><strong>For Control Subjects:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MMSE -0.10</td>
<td>0.20</td>
<td>-0.14</td>
<td>0.61</td>
<td></td>
</tr>
<tr>
<td>LM1</td>
<td>-0.12</td>
<td>0.11</td>
<td>-0.61</td>
<td>0.29</td>
</tr>
<tr>
<td>LM2</td>
<td>0.10</td>
<td>0.09</td>
<td>0.61</td>
<td>0.27</td>
</tr>
<tr>
<td>VR1</td>
<td>0.04</td>
<td>0.09</td>
<td>0.20</td>
<td>0.69</td>
</tr>
<tr>
<td>VR2</td>
<td>-0.07</td>
<td>0.02</td>
<td>-0.54</td>
<td>0.01 **</td>
</tr>
<tr>
<td>Trails A</td>
<td>-0.01</td>
<td>0.02</td>
<td>-0.17</td>
<td>0.58</td>
</tr>
<tr>
<td>Trails B</td>
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<td>0.01</td>
<td>0.16</td>
<td>0.68</td>
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<tr>
<td>BNT</td>
<td>0.06</td>
<td>0.13</td>
<td>0.13</td>
<td>0.66</td>
</tr>
<tr>
<td>Category Naming</td>
<td>-0.02</td>
<td>0.08</td>
<td>-0.14</td>
<td>0.69</td>
</tr>
<tr>
<td>DPT</td>
<td>0.02</td>
<td>0.03</td>
<td>0.25</td>
<td>0.48</td>
</tr>
<tr>
<td>DRI</td>
<td>0.02</td>
<td>0.07</td>
<td>0.06</td>
<td>0.83</td>
</tr>
</tbody>
</table>

* Significant at p<0.05
** Significant at p<0.01
group, there was a significant correlation between the Total Driving Index and Trails A ($r=0.39, p=0.05$) For control subjects, Total Driving Index correlated significantly with Visual Reproduction I ($r=-0.49, p=0.01$) and Visual Reproduction II ($r=-0.54, p=0.01$). (See Table 4.) Therefore, this hypothesis was partially supported for the predictions made for the groups.

To test Hypothesis 3, a t-test was performed to compare DRI scores for both groups. It was postulated that AD subjects would score significantly higher (more errors) on the DRI than control subjects. This hypothesis was supported by the results of a two-tailed t-test ($t(48)=-2.34, p<0.02$) and lends support for the prediction that AD participants are less able to correctly determine how risky a situation might be.

**Additional Analyses**

Miles driven per week were analyzed by a t-test between the two groups, with the controls driving more than twice as far ($M=115$ miles) as AD subjects ($M=53.4$ miles) ($t(45)=2.69, p=0.01$). Because there was such a large discrepancy between the groups for miles driven per week, a Corrected Total Driving Index was devised which controlled for this discrepancy. New regressions were performed. Among the AD subjects, both Trails A and the DRI were significant predictors of the Corrected Total Driving Index. (See Table 5). Incremental changes in $R^2$ for these variables were .198 for Trails A ($p=0.01$) and .120 for the DRI ($p=0.04$). For control subjects, only Visual Reproduction I was significantly related to Corrected TDI ($p=0.02$), accounting for .218 of the incremental variance.

Comparisons were made between scores on neuropsychological measures of AD subjects and control subjects, using t-tests. On all measures,
controls scored significantly better than AD subjects. (See Table 6.) Scores for the DPT Total Score and its subtest scores were also compared by group using t-tests, which showed significant differences between the groups for the DPT Total score as well as for two subtests, search and execute. (See Table 6.)

A t-test was also used to compare years driven by the AD and control subjects, with the AD subjects having driven significantly longer than the controls ($t(58)=2.86$, $p=0.01$).

Table 4

<table>
<thead>
<tr>
<th>Measures</th>
<th>AD Subjects Correlation</th>
<th>Control Subjects Correlation</th>
<th>p</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>MMSE</td>
<td>0.02</td>
<td>0.94</td>
<td>-0.39</td>
<td>0.06</td>
</tr>
<tr>
<td>LM1</td>
<td>0.09</td>
<td>0.68</td>
<td>-0.28</td>
<td>0.17</td>
</tr>
<tr>
<td>LM2</td>
<td>-0.06</td>
<td>0.78</td>
<td>-0.17</td>
<td>0.41</td>
</tr>
<tr>
<td>VR1</td>
<td>-0.08</td>
<td>0.69</td>
<td>-0.49</td>
<td>0.01*</td>
</tr>
<tr>
<td>VR2</td>
<td>0.14</td>
<td>0.51</td>
<td>-0.54</td>
<td>0.01*</td>
</tr>
<tr>
<td>Trails A</td>
<td>0.39</td>
<td>0.05*</td>
<td>0.18</td>
<td>0.38</td>
</tr>
<tr>
<td>Trails B</td>
<td>0.01</td>
<td>0.99</td>
<td>0.32</td>
<td>0.12</td>
</tr>
<tr>
<td>BNT</td>
<td>-0.07</td>
<td>0.75</td>
<td>0.05</td>
<td>0.80</td>
</tr>
<tr>
<td>Category Fluency</td>
<td>-0.10</td>
<td>0.60</td>
<td>0.29</td>
<td>0.08</td>
</tr>
<tr>
<td>DPT</td>
<td>-0.07</td>
<td>0.73</td>
<td>-0.29</td>
<td>0.16</td>
</tr>
<tr>
<td>DRI</td>
<td>0.34</td>
<td>0.25</td>
<td>0.29</td>
<td>0.16</td>
</tr>
</tbody>
</table>

* Significant at $p<0.05$
A Kruskall-Wallis One-Way Analysis of Variance was used to compare driving styles and other driving factors. (See Table 7.) Results indicate that all subjects drove alone, and there were no significant differences between the groups for use of medication or restriction of driving (e.g., only during the day or only in the neighborhood). None of the collaterals rated a control's driving unsafe, but seven of the twenty-five AD subjects were rated by collaterals as unsafe. Discrepancies between subject and collateral report about driving information (such as whether or not the subject was a safe driver or the number of driving infractions incurred) revealed a statistically significant difference between the groups, with AD subjects showing eleven discrepancies with their collaterals and controls showing only two discrepancies with their collaterals \( \chi^2(1) = 8.25, p < 0.01 \). Likewise, significant differences were shown in driving speed between the groups with seven subjects in the AD group indicating that they drive below the speed limit, while none of the controls made this claim. (See Table 6.)

A one-tailed t-test was used to compare the Total Driving Index of the two groups, with a significant differences found at the \( p = 0.10 \) level \( (t(48) = 1.36) \). Also, a one-tailed t-test was performed on the Corrected TDI, showing a significant difference between the groups at the \( p = 0.07 \) level \( (t(48) = 1.54) \). Similarly, t-tests were performed on the factors comprising the Total Driving Index (Times Lost, Near Misses, Tickets, and Crashes), and there were no significant differences found between the groups for these factors. (See Table 7).

Discrepancies between the groups for estimated and actual scores on the DPT and DRI were assessed by use of t-tests. It was a matter of concern
Table 5

Summary of Hierarchical Regression Analysis for Predictors of Total Driving Index With Correction for Miles Driven

<table>
<thead>
<tr>
<th>Variable</th>
<th>B  value</th>
<th>Standard Error</th>
<th>B  value</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>For AD Subjects:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MMSE</td>
<td>0.15</td>
<td>0.30</td>
<td>0.32</td>
<td>0.09</td>
</tr>
<tr>
<td>LM1</td>
<td>0.24</td>
<td>0.13</td>
<td>0.68</td>
<td>0.15</td>
</tr>
<tr>
<td>LM2</td>
<td>-0.20</td>
<td>0.13</td>
<td>-0.49</td>
<td>0.51</td>
</tr>
<tr>
<td>VR1</td>
<td>0.05</td>
<td>0.07</td>
<td>0.20</td>
<td>0.33</td>
</tr>
<tr>
<td>VR2</td>
<td>0.16</td>
<td>0.16</td>
<td>0.29</td>
<td>0.02*</td>
</tr>
<tr>
<td>Trails A</td>
<td>0.03</td>
<td>0.10</td>
<td>0.49</td>
<td>0.84</td>
</tr>
<tr>
<td>Trails B</td>
<td>0.00</td>
<td>0.00</td>
<td>0.05</td>
<td></td>
</tr>
<tr>
<td>BNT</td>
<td>-0.01</td>
<td>0.06</td>
<td>-0.06</td>
<td>0.30</td>
</tr>
<tr>
<td>Category Naming</td>
<td>-0.13</td>
<td>0.12</td>
<td>-0.32</td>
<td>0.14</td>
</tr>
<tr>
<td>DPT</td>
<td>-0.06</td>
<td>0.04</td>
<td>-0.35</td>
<td>0.06</td>
</tr>
<tr>
<td>DRI</td>
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<td>0.10</td>
<td>0.37</td>
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<tr>
<td><strong>For Control Subjects:</strong></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>MMSE</td>
<td>-0.10</td>
<td>-0.14</td>
<td>0.61</td>
<td>0.29</td>
</tr>
<tr>
<td>LM1</td>
<td>-0.12</td>
<td>0.11</td>
<td>-0.61</td>
<td>0.27</td>
</tr>
<tr>
<td>LM2</td>
<td>0.10</td>
<td>0.09</td>
<td>0.61</td>
<td>0.69</td>
</tr>
<tr>
<td>VR1</td>
<td>0.04</td>
<td>0.09</td>
<td>0.20</td>
<td>0.01**</td>
</tr>
<tr>
<td>VR2</td>
<td>-0.07</td>
<td>0.02</td>
<td>-0.54</td>
<td>0.58</td>
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<tr>
<td>Trails A</td>
<td>-0.01</td>
<td>0.02</td>
<td>-0.17</td>
<td>0.68</td>
</tr>
<tr>
<td>Trails B</td>
<td>0.01</td>
<td>0.01</td>
<td>0.16</td>
<td>0.66</td>
</tr>
<tr>
<td>BNT</td>
<td>0.06</td>
<td>0.13</td>
<td>0.13</td>
<td>0.69</td>
</tr>
<tr>
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<td>0.03</td>
<td>0.25</td>
<td>0.83</td>
</tr>
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<td>DRI</td>
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<td>0.07</td>
<td>0.06</td>
<td></td>
</tr>
</tbody>
</table>

* Significant at p<0.05
** Significant at p=0.01
Table 6

**Comparisons of Results of Neuropsychological Test Scores, Driving Measures, and Total Driving Index by Group**

<table>
<thead>
<tr>
<th>Variable</th>
<th>AD Mean (SD)</th>
<th>Control Mean (SD)</th>
<th>t</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>MMSE</td>
<td>21.68 (4.72)</td>
<td>28.28 (1.70)</td>
<td>-6.58</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>LM1</td>
<td>10.00 (6.54)</td>
<td>20.96 (6.62)</td>
<td>-5.89</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>LM2</td>
<td>4.40 (5.80)</td>
<td>15.28 (7.52)</td>
<td>-5.73</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>VR1</td>
<td>16.44 (9.91)</td>
<td>29.30 (6.61)</td>
<td>-5.36</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>VR2</td>
<td>3.80 (4.21)</td>
<td>22.04 (9.15)</td>
<td>-9.05</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Trails A</td>
<td>82.48 (35.63)</td>
<td>48.92 (18.86)</td>
<td>4.16</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Trails B</td>
<td>265.24 (136.93)</td>
<td>101.12 (37.90)</td>
<td>5.78</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>BNT</td>
<td>39.56 (14.94)</td>
<td>55.52 (2.74)</td>
<td>-5.25</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Category Fluency</td>
<td>10.32 (5.74)</td>
<td>16.40 (5.51)</td>
<td>-3.82</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>DPT Total</td>
<td>10.532 (13.47)</td>
<td>116.16 (15.54)</td>
<td>-2.64</td>
<td>0.01</td>
</tr>
<tr>
<td>DPT Search</td>
<td>19.44 (7.01)</td>
<td>23.36 (5.03)</td>
<td>-2.27</td>
<td>0.03</td>
</tr>
<tr>
<td>DPT Identify</td>
<td>20.96 (5.13)</td>
<td>23.52 (5.32)</td>
<td>-1.73</td>
<td>n.s.</td>
</tr>
<tr>
<td>DPT Predict</td>
<td>19.40 (4.97)</td>
<td>19.52 (5.72)</td>
<td>-0.08</td>
<td>n.s.</td>
</tr>
<tr>
<td>DPT Decide</td>
<td>25.20 (4.92)</td>
<td>26.40 (5.78)</td>
<td>-0.79</td>
<td>n.s.</td>
</tr>
<tr>
<td>DPT Execute</td>
<td>20.32 (4.66)</td>
<td>23.28 (4.29)</td>
<td>-2.34</td>
<td>0.02</td>
</tr>
<tr>
<td>DRI</td>
<td>18.68 (4.33)</td>
<td>15.80 (4.73)</td>
<td>2.24</td>
<td>0.03</td>
</tr>
<tr>
<td>Total Driving Index</td>
<td>1.32 (2.34)</td>
<td>0.60 (1.22)</td>
<td>1.36</td>
<td>n.s.</td>
</tr>
</tbody>
</table>
Table 7

<table>
<thead>
<tr>
<th>Measures</th>
<th>AD Subjects Correlation</th>
<th>p</th>
<th>Control Subjects Correlation</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>MMSE</td>
<td>-0.18</td>
<td>.40</td>
<td>-0.21</td>
<td>.31</td>
</tr>
<tr>
<td>LM1</td>
<td>-0.09</td>
<td>.68</td>
<td>-0.30</td>
<td>.14</td>
</tr>
<tr>
<td>LM2</td>
<td>-0.06</td>
<td>.79</td>
<td>-0.17</td>
<td>.42</td>
</tr>
<tr>
<td>VR1</td>
<td>-0.17</td>
<td>.41</td>
<td>-0.44</td>
<td>.03*</td>
</tr>
<tr>
<td>VR2</td>
<td>0.18</td>
<td>.39</td>
<td>-0.37</td>
<td>.07</td>
</tr>
<tr>
<td>Trails A</td>
<td>0.27</td>
<td>.20</td>
<td>0.36</td>
<td>.08</td>
</tr>
<tr>
<td>Trails B</td>
<td>0.13</td>
<td>.55</td>
<td>0.36</td>
<td>.08</td>
</tr>
<tr>
<td>BNT</td>
<td>-0.25</td>
<td>.23</td>
<td>-0.01</td>
<td>.97</td>
</tr>
<tr>
<td>Category Fluency</td>
<td>-0.22</td>
<td>.29</td>
<td>-0.36</td>
<td>.08</td>
</tr>
<tr>
<td>DPT</td>
<td>-0.17</td>
<td>.41</td>
<td>-0.20</td>
<td>.33</td>
</tr>
<tr>
<td>DRI</td>
<td>0.29</td>
<td>.17</td>
<td>0.21</td>
<td>.31</td>
</tr>
</tbody>
</table>

* Significant at p<0.05
Table 8

Comparisons of Frequencies of Driving Characteristics by Kruskall Wallis One Way Analysis of Variance

<table>
<thead>
<tr>
<th></th>
<th>AD Subjects</th>
<th>Control Subjects</th>
<th>$\chi^2$</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drives Alone</td>
<td>637.56</td>
<td>637.50</td>
<td>0.00</td>
<td>n.s.</td>
</tr>
<tr>
<td>Restricts Driving</td>
<td>635.00</td>
<td>640.00</td>
<td>0.00</td>
<td>n.s.</td>
</tr>
<tr>
<td>Drives at Speed Limit</td>
<td>551.50</td>
<td>723.50</td>
<td>4.48</td>
<td>0.03</td>
</tr>
<tr>
<td>Taking Medications</td>
<td>587.50</td>
<td>687.50</td>
<td>1.96</td>
<td>n.s.</td>
</tr>
<tr>
<td>Safe Driver by Collateral Report</td>
<td>725.00</td>
<td>550.00</td>
<td>7.98</td>
<td>&lt;0.01</td>
</tr>
</tbody>
</table>

that scores considered as above and below the actual score could cancel the effects of both. Therefore, the absolute value of the difference scores were used for the DPT ($t(48)=-1.75$, n.s.) and for the DRI ($t(48)=-4.11$, $p<0.001$), with control subjects estimating their performance on the DRI better than the AD subjects. Additionally, for each group, the DPT Total and DRI were regressed upon the neuropsychological measures (MMSE, LM I, LM II, VR I, VR II, Trails A, Trails B, BNT, and Category Fluency). Among the AD subjects, none of the neuropsychological tests were significant predictors of the DRI. For AD subjects, LM II approached significance ($p=0.08$) as a predictor of the DPT Total. For control subjects, VR II was the only significant predictor ($p=0.02$) of the DRI, while for the DPT Total, LM I and VR II were significant predictors ($p<0.001$ and $p=0.03$, respectively).
Discussion

Support was provided for some of the proposed hypotheses. Hypothesis 1 predicted that predictors of driving ability would be different for the two experimental groups. This was found to be true, but the specific tests hypothesized to be effective did not turn out to be supported. It was postulated that the statistically significant predicting variables for the AD subjects would be the MMSE, the DPT, the DRI, and Trails A and B. Regression analysis found only Trails A and the DRI to be significant contributors to the variance for AD subjects. While the MMSE had been found to be a predictor of driving in previous studies (Rebok, Keyl, Bylsma, Blaustein, & Tune, 1994; Mitchell, Castleden, & Fanthome, 1995), other studies utilized this test only as a broad measure of dementia severity (Gilley et al., 1991; Fitten, et al., 1995). While it would be expected to show some correlation with driving simply because it is a screening measure of dementia, factor analysis has shown that the MMSE is comprised of verbal functions, memory abilities, and construction with most of the score coming from verbal items (Morris et al., 1989). This emphasis on verbal functions and construction is not consistent with the skills needed for driving and may in part account for why the MMSE was not a significant predictor in this study. Another possible factor limiting the MMSE's predictive utility here is the relatively truncated range of MMSE scores among the mild AD patients studied here. The DPT was also not a significant predictor. This test comprises questions regarding knowledge of driving, and many of the questions regarding the driving scenes could be answered without having seen the vignette (or without being able to remember the scene). Although not true for all the items, many represented retrieval of overlearned knowledge, developed
from years of driving experience. This kind of overlearned material is often relatively preserved in AD patients (Beatty et al., 1994), which may explain the failure to observe significant predicting contributions for AD subjects. Trails B, a more complex version of Trails A, provides added assessment of cognitive flexibility and set shifting that may not be pertinent to the driving skills reflected in the Total Driving Index. However, Trails A, as the variable that accounted for the most incremental variance, assesses complex visual scanning with a component of motor speed and agility (Lezak, 1995). Performance can also reflect how the subject responds to a complex visual array, which is particularly salient in driving. It is therefore not surprising that Trails A is a significant predictor. The DRI, approaching significance, provides driving situations for the subjects that require visual scanning, integration of different stimuli, and quick decisions as to the maneuvers performed that reflect the abilities that AD subjects find increasingly difficult to do.

For predicting controls' Total Driving Index, the only variable accounting for significant incremental variance was Delayed Visual Reproduction, which was an unexpected finding. However, visuospatial abilities diminish with age, with older adults five times more likely to report problems in activities involving visual search, peripheral vision, and cluttered visual scenes (Ball & Owsley, 1993). A logical conclusion is that those elderly people who have better visuospatial skills should have fewer problems driving. One reason why delayed visual reproduction was significant (rather than immediate recall) could be that those controls who can recall visual arrays of stimuli may be better able to predict hazardous situations, because they can draw from past experience and not have to
analyze similar situations anew each time. However, because there was such a large discrepancy between the number of miles driven for the two groups, a Corrected TDI was derived that controlled for this difference. New regression equations revealed, that for the AD group, Trails A still accounted for the most incremental variance, but the DRI was also a significant predictor for the Corrected TDI. For the control group, the only significant predictor was VR I. This change from VR II as the only predictor for controls on the TDI to VR I on the Corrected TDI is most likely due to the high correlation between these two tasks. For the Corrected TDI, VR I may reflect such abilities as being able to remember what someone has just seen as they visually scan their environment before crossing an intersection. This may be particularly important because, as noted before, many accidents take place at intersections, traffic lights, and when changing lanes.

It was also hypothesized that the Total Driving Index would correlate significantly with the driving measure scores as well as the results of the neuropsychological tests, but this did not occur. Nor did it occur when the Corrected TDI was used in analyses. This may be due to restriction of range, as the present study yielded scores for the Total Driving Index ranging from zero to seven. Had the patient sample been larger or the Total Driving Index higher for some individuals, significant correlations may have been found. Similarly, the lack of findings could result from poor reliability due to subjective ratings by collaterals. Although there were no significant differences between the groups for the Total Driving Index, this may also be accounted for in part by the fact that the controls drove more than twice as many miles per week as the AD subjects. In some cases reduction of mileage driven was due to pressure from their relatives, and in some cases it was due
to the AD subjects' recognition that their driving was not as good as it had been before the onset of these symptoms, although only one AD subject said she was not a safe driver, and she attributed this to her poor vision rather than any change in her driving skills. However, as expected, the collaterals of AD subjects described the subjects as unsafe more than the collaterals of controls.

In other aspects of driving, differences were not found between the groups. For example, there was no difference in the number of subjects who were taking medications, nor were there differences in the number per group that restricted their driving in some way, such as avoiding rush hour. This would seem to suggest that both groups try to minimize their exposure to hazardous situations.

In considering the test performance of subjects, control subjects performed significantly better on all neuropsychological measures as predicted. This demonstrates that the two groups were indeed different, and that the lack of significance of some analyses are not due to overlap between the groups. On driving measures, a more complex pattern of differences emerged. Controls did score significantly higher on the DRI and the DPT total score. Subtests of the DPT showed significant differences between the groups for the search and execute subtests only. The search subtest assesses ability to search the driving environment for possible hazards while the execute subtest evaluates the ability of the subject to choose appropriate actions in dangerous situations. These are the two subtests of the DPT that appear to be least reflective of overlearned material. This suggests that, for driving tests to be able to differentiate between control and AD subjects, they
must emphasize the dynamic parts of driving, not the overlearned, rote aspects.

It was surprising to find that there were no differences between the groups for the Total Driving Index or for the factors comprising it, particularly in light of the fact that many of the AD subjects' collaterals rated subjects as unsafe. Therefore, it seems as though the subjective rating must be based on more than the objective, measurable events chosen to represent the Total Driving Index in this study. It may be that, in an attempt to objectify the collaterals' opinions, assessment of the subtle qualities of the subjects' driving was eliminated. Drivers can exhibit many unsafe behaviors that are not reflected in getting lost, having near misses, tickets, or crashes. This could include having difficulty staying in their driving lane or driving so slowly that other drivers perform risky maneuvers to pass them. Additionally, even if a person with AD should execute a dangerous action (such as changing lanes without looking), other drivers may be adept enough to avoid colliding with that individual. It may be then that to more fully understand the quality of someone's driving a check-list of risky behaviors should be developed to provide a more comprehensive picture of hazardous behaviors that could be performed. It could also be that the TDI was compromised by bias in the collateral ratings. This bias could arise from faulty memory on the part of the collateral, who was generally the spouse of the subject. The spouse may also have been biased by the transportation resources available. It would be likely that, if the patient was the only source of transportation, the collateral may be more likely to deny problems that could affect the subject's driving status.
Findings regarding estimated and actual performance on the DPT and DRI indicated no difference in rating of performance between the groups for the DPT, but, on the DRI, controls subjects were able to estimate their performance better than AD subjects. It may be that AD subjects show efficacy similar to controls for their DPT estimates because they are basing their estimate on what they were able to do in the past. As said before, it may be that the DPT is a better indicator of overlearned material than the DRI, which may reflect more the ability to judge situations in a more fluid fashion. If this is the case, then the AD subjects' estimate of DPT performance could be more correctly surmised by using past standards of their driving to make estimates. However, the DRI would require more manipulation of information and judgment, requiring the AD participants to use skills they no longer have. By relying on evaluations of past abilities, AD subjects would tend to overestimate their present performance and make inaccurate predictions.

In this study, the TDI was not sufficient to distinguish between the two groups. In an effort to better understand the relationship between driving and neuropsychological tests, predictors of the driving measures were considered. For AD subjects, there were no significant predictors for the DRI, and only LM2 approached significance for the DPT. The lack of predictors for the DRI is not surprising; it is a reflection of the difficulties encountered by researchers in driving who are unable to find predictors of driving that are significant across studies. This highlights the fact that driving consists of many cognitive factors that cannot be easily assessed by our current neuropsychological measures. It is interesting that LM2 approached significance as a predictor of DPT, since this test was
hypothesized to be indicative of crystallized knowledge of driving and its "rules," accumulated over years of experience. This is consistent with the long-term memory abilities assessed by LM2. For controls, the DRI's only significant predictor was VR2, which is congruent with the premise discussed above that the more "fluid" aspects of driving are enhanced by the ability to remember other similar situations in the past and to benefit from the knowledge gained by them. For control subjects, predictors of the DPT Total were LM1 and VR2, which again emphasizes the importance of both verbal and visual memory for adequate knowledge of the "overlearned" aspects of driving.

In conclusion, these findings suggest that the best predictors of driving for both groups are visuospatial measures, requiring visual scanning, a motor response to a visual stimulus, and identification of salient visual material in a timely manner. Although predictors were different for both groups, it is evident that neuropsychological tests that are not visuospatially oriented did not predict driving ability as measured by the Total Driving Index. Although the two groups were similar in many characteristics of driving, AD subjects were shown to drive fewer miles and tend to drive slower as if to compensate for deficits, although most felt that they were safe drivers. Future studies should try to develop a better and more comprehensive criterion variable than the TDI used here - one that reflects more subtle evidence of risky driving than just the objective measures used here. Considering the number of AD subjects' collaterals who reported the subject was unsafe, it is obvious that more characteristics of dangerous driving need to be evaluated to provide a clear picture of the deficits in driving that these subjects show.
More research needs to be done to provide more sensitive measures of driving ability. Apparently some AD patients do have the knowledge and driving skills to permit them to safely drive familiar routes occasionally. But tests need to be devised to ascertain if they have the visuospatial skills, reaction time, and judgment to stop in an emergency situation. It is these uncommon, novel, and emergency situations that provide the most danger for AD patients and for others on the road.
References


62

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Vita

Judith O'Jile was born in St. Louis, Missouri, and, after graduation from high school, attended St. Louis University as a theatre major. She began employment at St. Louis University Hospitals and changed her course of study to business, continuing her studies part-time. She later attended Meramec Community College. She moved to Houston, Texas, and worked at Baylor College of Medicine, where she became interested in neuropsychology. She finished her undergraduate degree in psychology at Georgia State University, followed by a year of research work at G.S.U. and Emory University. Judith entered graduate school at Louisiana State University. Her internship was spent at the Veterans Administration Hospital in Portland, Oregon. She accepted a neuropsychological fellowship at Dartmouth College where she is currently. In May 1998, she will receive a degree of Doctor of Philosophy in psychology.
DOCTORAL EXAMINATION AND DISSERTATION REPORT

Candidate: Judith Rosemary O'Jile

Major Field: Psychology

Title of Dissertation: Predicting Driving Ability in Alzheimer's Disease Patients

Approved:

[Signature]
Major Professor and Chairman

Dean of the Graduate School

EXAMINING COMMITTEE:

[Signatures]

Date of Examination:
October 24, 1997