Predicting Age Related Changes in Mobility and Driving Habits

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PREDICTING AGE RELATED CHANGES
IN MOBILITY AND DRIVING HABITS

A Thesis
Presented to
The Faculty of the Department of Psychology
Western Kentucky University
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In Partial Fulfillment
Of the Requirements for the Degree
Master of Arts

By
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Older adults encounter many changes as they age, both cognitively and physically. These changes tend to impact one's mobility in terms of driving ability and exposure. It has been well documented that this population is increasing in number (Lyman, Ferguson, Braver, & Williams, 2002) and that they pose a higher crash risk than a younger population (Braver & Trempel, 2004; Dellinger, Kresnow, White, & Seghal, 2004; Tavris, Kuhn, & Layde, 2001). These cognitive and physical changes combined with increased crash risk lead a number of drivers to reduce the amount that they drive or cease driving altogether, thereby limiting their independence. Some studies have examined the domains on which these changes occur and have found that various medical conditions, cognitive deficits, and physical limitations lead to these changes in driving habits (Ball, Owsley, Stalvey, Roenker, Sloane & Graves, 1998; Lyman, McGwin, & Sims, 2001). The present study sought to replicate a structural equation model proposed by Vance, Roenker, Cissell, Edwards, Wadley, and Ball (in press) in which it was found that a particular battery of tests (GRIMPS and UFOV) was predictive of both increased avoidance of certain situations and decreased
exposure. Specifically, they found that the latent constructs of health and
cognitive function were predictive of both exposure and avoidance. However,
physical function appeared to make no contribution. The current study attempted
to replicate this model on a sample \( N = 299 \) that participated as part of the
driver’s licensing process at three Motor Vehicle Administration sites in
Maryland. It was found that this sample did decline over time in the areas of
health, physical, and cognitive function. Also, they reduced the amount of driving
that they did and increased their avoidance of many situations. However, the
structural equation model for this sample found the latent construct of physical
functioning to be the only significant predictor of driving avoidance and exposure.
Chapter 1

Introduction

The structure of American society is such that dependence upon the automobile is necessary. Many nonurban environments provide insufficient transportation to accomplish daily needs such as shopping for groceries, going to doctors’ appointments, or merely visiting one’s family and friends. This becomes a particular problem for the elderly, some of whom may suffer from cognitive or physical impairments that would make operating a vehicle dangerous for themselves and other drivers. These individuals face choices that are not very palatable in terms of their independence, such as giving up driving altogether and becoming dependent upon a second party for the majority of their needs. Many attempts have been made to understand these problems, their origins, and the impact that they have on society. Briefly, it is known that older drivers constitute a greater percentage of drivers and that they crash more frequently than younger drivers even when adjustments are made for differences in driving exposure. Also, it is known that many factors (e.g., cognitive, physical, medical) may play critical and overlapping roles in these crashes. An examination of the literature on these factors will provide a background for the central question of this thesis – an examination of the longitudinal changes in these factors and their effect on general mobility.

Driving Accidents and Older Drivers

The number of older drivers is increasing, and they have more crashes per mile driven than any other age group. Lyman, Ferguson, Braver and Williams
(2002) found that a greater number of older adults now possess a license and that the rate is increasing steadily. For example, from 1983 to 1995, the percentage of individuals over 65 possessing a driver’s license increased from 63% to 75%. Among the overall licensed population, their numbers grew from 11% to 14% of the total driving population during this period. Not only is the number of older drivers increasing, but also they are driving more. During the same interval, total miles per year increased by 25% for the total driving population, whereas it increased 44% for those drivers over the age of 65. This age group also saw their death rates from vehicle crashes increase from 12% to 18% of the total driving fatalities per year. Although drivers over 75 were found to have the lowest crash rate per capita, fatal crash involvement in the over-70 age group increased 34% while all other age groups saw a 4% decline during this interval. Currently, older drivers represent 8% of police reported crashes. Lyman et al. (2002) also found that the projected crash rate for those over 65 is expected to be 9% of all police reported crashes by 2010 and increase steadily to 13% by 2020 and 16% by 2030.

Lyman et al. (2002) examined current data in an effort to estimate the future crash risk posed by older adults. Using national databases such as the Fatality Analysis Reporting System (FARS), Nationwide Personal Transportation Survey (NPTS), the General Estimates System (GES), and the US Census Bureau, they examined fatal crashes, self-reported miles per year, police reported crashes, and population estimates in order to predict likelihood of crash involvement for older drivers in the years 2010, 2020, and 2030. They found that, in 1995, those individuals 65 and older comprised 14% of those owning a license and were
responsible for only 8% of the total miles per year driven by US drivers. Of crashes reported to the police, they comprised 8% of that population and 13% of those elderly drivers were involved in fatal crashes. Overall, Lyman et al. (2002) projected that between the years 1999 and 2030 there would be a 155% increase in fatal crashes and a 178% increase in all crashes reported to police for this population. However, they went on to say that these crashes do not constitute over-involvement when compared to all drivers as they still account for fewer crashes per capita. Bedard, Stones, Guyatt, and Hirdes (2001) also examined FARS data to predict future crash trends based on age and projected that, by the year 2015, older drivers would be involved in 27% of fatal crashes, matching the same projected percentage for those under the age of 30.

Dellinger, Kresnow, White and Sehgal (2004) sought to explore the role of age in traffic accidents resulting in injury to self and others. They looked at two-vehicle crashes, defined as a collision between a car and another car, bicycle, motorcycle, or pedestrian. After correcting for the number of miles driven, the authors found that older drivers were over-represented in two-vehicle crashes and were more likely to be involved in crashes where someone other than themselves was injured. However, when looking at older drivers as a percentage of all licensed drivers, older drivers were found to be a greater danger to themselves than to others.

Tavris, Kuhn, and Layde (2001) examined data from the Wisconsin Office of Health Care Information (OHCI) regarding patient demographics, diagnoses, and procedures for those individuals injured in car crashes in 1997. They used
these data along with estimated 1997 population statistics to calculate rates of crash occurrence by gender and age. Seventy-two percent of crashes could be classified as either “collision with another vehicle” or “loss of control.” They found that, at age 70, the likelihood of colliding with another car increased sharply, especially for males. When looking at the rates for loss of control crashes, there was a bimodal distribution showing the age groups that have the most crashes of this type to be males between the ages of 20 and 24 and males between the ages of 85 and 89. Older females were most likely to be injured passengers.

Braver and Trempel (2004) compared drivers aged 30-59 to those over the age of 75 in an analysis of crash injuries and fatalities using the FARS and the GES, as well as examining insurance bodily injury and property injury claims. They found that drivers over the age of 75 were more likely to be involved in both fatal and nonfatal injurious crashes. Looking at those individuals over the age of 70, the authors found that, if examined in 5-year age groups, claim rates for bodily injury liability increased steadily. Those over the age of 85 had property damage liabilities similar to adolescents.

Cooper, Tallman, Tuokko, and Beattie (1993) undertook a study with the Insurance Corporation of British Columbia to examine the risks posed by elderly drivers. They found that, with respect to total crash involvement, older drivers do not appear to give much reason for concern. However, when one examines the trend in at fault crashes according to age, those drivers over the age of 75 are responsible for more crashes than those aged 16-20. They did find, however, that
those drivers over the age of 65 had fewer crashes when the weather was
inglement or the traffic was heavy and that this difference was likely due to
avoidance of those situations.

When one examines accident involvement as a function of age, it becomes
apparent that particular problems increase with age. In crashes attributed to
“failure to yield right of way,” Cooper et al. (1993) found 13% of these crashes
were caused by those aged 55-64. However, as age increased so did the
likelihood of being involved in this type of crash.

As an indicator of frailty, Evans (1988) found that those age 70 and older
had a three times greater risk of dying from a car accident than did a 20-year-old
when the accidents were equal in severity. Bostrom, Wladis, and Nilsson (2001)
found similar fatality risks for older drivers in a Swedish sample. Safih, Norton,
Rogers, Gardener, and Judson (1999) looked at a New Zealand sample to examine
differences in injury severity due to age from trauma associated with traffic
accidents as well as falling. They found that hospital admissions due to falling
were more common than admissions arising from traffic crashes and that the most
typical injury from both was sustained to the head and neck of the patient. Also,
their injuries were more severe than those of younger patients. They found that
when injury severity was comparable between young and old, the older patients
had a mortality rate twice that of the younger patients. Peek-Asa, Dean, and
Halbert (1998) studied those over 65 with the goal of determining the manner in
which injury profile changes as people age. Previously, research had looked at
those over 65 as one group. However, this study looked at changes as the elderly
advance in age. They found that as people age past 65, severe injury due to a traffic accident became more common. For individuals in the 65-69 age group, 24.5% of patients were admitted with severe injury, whereas for those over 85 37.8% were admitted with severe injury. McCoy, Johnstone, and Duthie (1989) found that, regarding older pedestrians, they were more likely than younger pedestrians to sustain injury or death from stepping into traffic. It was often the case that these individuals were suffering from confusion and/or visual/hearing impairment. They also found that older drivers, while receiving injuries similar to those in younger age groups, sustained more severe injuries. One exception to the frequency of injury between young and old was that sternum fractures as a result of wearing a seatbelt were seen more frequently in the elderly. They also found that with equivalent injury, those over 65 were admitted more often, stayed for a longer duration, and suffered higher mortality rates than younger patients. Those under 20 had a mortality rate of approximately 1%, whereas those over the age of 70 had a rate of almost 11%. Given comparable severe injury, 87% of those over 65 died while only 22% of those under 65 suffered mortality. Morris, Welsh, Frampton, Charlton, and Fildes (2003) found similar patterns of fatality risk and chest injury due to seatbelt use in a sample of UK elderly.

Incurring more severe injury from crashes takes a toll on older drivers’ mobility, both physically and mentally. Many times, crashing is a step on the road to decreased mobility whether the crash occurs prior to the mobility reduction or vice versa. Marottoli et al. (1993) surveyed 1,445 noninstitutionalized men and women over the age of 65 in an effort to determine
the factors that cause elderly individuals to change their driving habits in the form of driving cessation and mileage changes. In 1982, 1985, and 1988, these individuals participated in in-home interviews with follow-up telephone interviews for the intervening years. In order to predict these changes, interviewers gathered data regarding demographic characteristics, medical conditions, and psychosocial features such as mental status, depression, and social support network. They also assessed the degree of social/physical activity participation such as how well they performed fundamental activities of daily living like dressing, bathing, and eating. This study found that physical (i.e., disease and disability) and social factors (i.e., retirement) were most predictive of driving cessation. Factors most predictive of a reduction in mileage were age and reduced physical ability in areas such as stair climbing and performing heavy housework.

Reduction in mobility leads to a number of consequences for elderly drivers. They feel as though they have lost their independence if they do give up driving; if they do not cease driving, that decision may cause family conflict in addition to personal discomfort with being on the road. Researchers have studied the personal and social consequences perceived by older drivers when they ceased to drive. Jette and Branch (1992) looked at the influence of age on alteration of driving habits in a large sample (N=1,625) of older adults. Participants were interviewed in three different waves in the years 1976, 1980, and 1985 and were asked two questions pertaining to their driving patterns. These questions were asked in order to assess the participants’ reliance on a car regardless of whether or
not they drove as well as to assess how much they actually drove the car. The authors examined the demographic characteristics of those who changed their driving patterns from wave to wave against those who did not. They found that, even into one’s 80’s and 90’s, a car is the primary mode of transportation regardless of driving status. They theorized that this dependency may reflect sociocultural necessity independent of health and mobility. However, the ability to continue driving a car was significantly related to health factors. They also stated that this change in driving pattern implies some degree of self-regulation on the part of the driver.

*Driving Cessation and Older Adults*

Persson (1993) studied older drivers who had, in the last five years, ceased driving and examined the contributing factors in one’s decision to stop driving as well as the degree of influence by the family and physician. A guided interview had participants discuss aspects of driving such as their feelings, experiences, problems, and what lead them to give up driving. Most stopped driving based on advice from their doctor, anxiousness when driving, difficulty seeing, or medical conditions. In this sample, the conditions most likely to cause difficulty driving were arthritis, cataracts, and macular degeneration. However, Owsley et al. (2002) found that those who had cataract surgery posed half the crash risk of those who did not elect to have the surgery. It was also found that driving cessation typically took one of two paths. The first was a gradual change based on decline taking the form of avoidance of certain situations and reduction in mileage. Second, it seems as though a significant event eventually convinces the
person to stop driving altogether such as an accident, getting lost, or worsening health problems or “sudden disabling event” (i.e., stroke) that renders the individual incapable of operating a vehicle (Persson, 1993).

Persson (1993) also looked at how the participants felt about driving and giving up their licenses. One particularly poignant quote stated, “Driving is a way of holding on to your life...it was like losing my hand to give up driving” (p. 90). Others stated that driving was a way of maintaining independence and that they missed its convenience. In fact, a number of the participants came to retirement communities specifically because they offered transportation. Participants also stated that they were less willing to accept the advice of family members who suggested they stop driving but would be more accepting of that advice from a physician. However, Persson noted that physicians are often reluctant to make that suggestion because they know the patient often cannot compensate for the cost of not driving, and there are no specific guidelines for recommendation of driving cessation. Participants did agree that they would be most likely to stop if the physician made the suggestion and the family was in agreement.

Dellinger, Schgal, Sleet and Barrett-Connor (2001) attempted to discover why older drivers voluntarily give up driving. They found only 12.1% (141 participants) of the participants who gave up driving reported a crash in the last five years and that there were gender differences as to the reasons. Women were more likely to cite licensing difficulties, cost, and the availability of another person to drive them. Reasons as to why men stopped were not given. This study found that the main reasons for giving up one’s license were medical problems
and age-related changes, with the most common being poor vision and slowed reaction times. Regarding medical problems, most of these participants cited poor vision as the main reason. A traffic accident was given by only two people as the reason for driving cessation. When those who gave up driving were compared with those still driving, they found that the non-drivers were older and in worse health. There was, however, no difference regarding the number of traffic accidents or number of illnesses.

In general, the literature shows that older drivers are increasing in number, mileage, and crashes. Furthermore, they are more likely to suffer severe injury or death as a result of crashing, but driving cessation is something they avoid. There have been at least two attempts to deal with this increase in older driver problems: 1) identify the factors that lead older adults to self-restrict their driving and 2) identify the factors that place older drivers at risk for crashes. In the latter case, such a detection system would then provide the basis for an early intervention system. The search for mobility reduction factors is examined first followed by a discussion of risk factors for early detection.

Driving Avoidance and Mobility Reduction

Older adults, even those who do not crash, still reduced driving mobility over time. Owsley et al. (2000) defined mobility as a “person’s purposeful movement through the environment from one place to another….to accomplish some task or achieve some goal that cannot be reached where one already resides” (p. 305).
Lyman, McGwin and Sims (2001) examined the relationship among chronic medical conditions, impairments on various functional, cognitive, and physical domains, and mobility reductions and problem driving in the elderly. Data were collected from 901 participants over the age of 65. Functional limitations were assessed by asking if they encountered difficulty with such daily tasks as climbing stairs, moving heavy objects, dressing or bathing. Chronic medical conditions were assessed by asking if they had ever been diagnosed with various conditions such as arthritis, cataracts, heart disease or high blood pressure, for example. Visual functioning was assessed by asking how much difficulty was encountered when performing visual tasks like reading a newspaper. Cognitive impairment was assessed through the use of the Short Portable Mental Status Questionnaire (SPMSQ) and indicated by three or more errors. Problems with three or more driving situations were taken as an indication of high-level difficulty. They were also asked about the number of falls they had incurred and if they used a hearing aid. In order to assess driving habits, they asked for a self-report on driving quality, amount of driving (i.e., annual mileage, days per week), and if the participant had difficulty driving in particular situations such as nighttime, bad weather, or heavy traffic. The most difficulty was reported with driving in the rain (45%) and fog (35%). Those who had difficulty moving heavy objects were also most likely to drive fewer days in a week. These were also the individuals that had difficulty climbing stairs, walking a quarter mile, and feeding themselves and displaying near vision impairment. Those individuals reporting difficulty also had more reports of falling and stroke. Those with high blood
pressure and cataracts were most likely to reduce the number of days per week they drove. Those who reduced number of days per week were also more likely to have greater near and far visual impairment. Low annual mileage was associated with cognitive impairment and poor far visual scores.

Ball et al. (1998) studied driving avoidance and its relationship with objectively measured visual and cognitive abilities. Two-hundred fifty-seven non-institutionalized drivers were stratified by age with categories ranging from 55-59 to over 85 and crash frequency ranging from 0 to 4 or more. Visual acuity, contrast sensitivity, and visual field sensitivity were assessed and each participant received an eye examination in order to determine the degree of clinical defects. Cognitive function and useful field of view were also determined. A driving habits questionnaire was used to assess exposure (i.e., days per week) and avoidance habits (i.e., night driving, high traffic). The Alabama Department of Public Safety also provided records of at-fault crashes in which three independent raters had to determine fault.

Drivers were categorized into six groups based on a combination of the number of visual problems and Useful Field of View (UFOV) score. UFOV is an assessment of visual speed of processing. The cognitive assessment was dropped from the analysis because UFOV scores were closely associated with cognitive impairment. They found that most of their sample avoided rush hour or night driving, at least sometimes. This avoidance might be due to the fact that this set of drivers had flexibility in their schedule such that they did not have to drive at these times. They found that those drivers avoiding more situations were most
likely to display visual and/or cognitive deficiencies plus eye health problems. All assessments were correlated with avoidance of high traffic/speed and rain. These assessments were also related to a reduction in driving exposure. Those with one or more vision problems and impaired UFOV avoided heavy traffic, driving alone, and interstate highways and expressways. Those having three or four visual problems and impaired UFOV tended to avoid rush hour more than the other groups. Regarding driving in the rain, they found that as visual impairment and UFOV impairment increased, so did avoidance. Regarding eye conditions, the most common in this sample were cataracts and age related macular degeneration (AMD). Those with cataracts specifically avoided high traffic, rush hour, expressways, driving alone, and driving in the rain. Those having AMD avoided all situations equally.

Ball et al. (1998) also found that those who avoided rain, rush hour, and left turns were more likely to have a higher crash record for the previous five years. In a prospective analysis, they found that almost 80% of the drivers who reported driving cessation or became deceased were from the functional impairment groups. However, this sample limitation hindered the ability to examine the connection between avoidance and crash prediction.

Thus, the literature is mixed regarding precisely which factors influence driving restriction. Older adults avoid more situations than younger drivers and seem to select the situations that they avoid. However, this increased avoidance of difficult situations is not sufficient to eliminate their elevated crash risk.
Following is a review of the literature regarding risk factors for crashes involving older adults.

**Older Adult Crash Risk Factors**

Older drivers crash more and such crashes are often fatal. As driver’s age, they adjust driving and some ultimately cease driving altogether. Some have asked the question whether or not this trajectory can be delayed with early detection. Is the early detection of such individuals possible? If so, what factors have been identified as predictors of crash? The search for risk factors for driving failure can be summarized in three categories: vision, cognition, and medical conditions and medication.

**Visual Factors**

Clearly, driving is a highly visual task. Declines in visual skills that accompany aging have been the target of numerous studies to determine the impact of visual function on crash risk. Despite the clear visual nature of the driving task, several large sample studies (e.g., Henderson & Burg, 1974; Hills & Burg, 1977; Shinar, 1977) have failed to find a useful relationship between standard measures of visual function (e.g., static and dynamic acuity, disability glare). However, Ball et al. (1998) reviewed earlier work leading to the conclusion that older adults often report visual difficulties that would be difficult to assess with standard vision assessments. Also, individuals have often no knowledge of their impairments. It is theorized that many of the standard visual
tests (i.e., static acuity, contrast sensitivity) are conducted under optimal conditions in which the patient has enough time to fixate on the target so that it may be easily identified. In real world situations, it is necessary to process moving stimuli and attend to more than one thing at a time under varying conditions of visibility. Ball et al. (1998) undertook the development of a task that would more adequately capture the visual and attentional demands of driving. The UFOV refers to the “working visual field” or the degree of visual field that is required to perform a specific task. This task was developed in order to assess three things: (1) speed of visual processing, (2) ability to divide attention between centrally and peripherally presented targets, and (3) selective attention abilities (i.e., the ability to identify both a centrally and peripherally presented target when visual distracters are present). This task is more thoroughly detailed in the Methods section. Essentially, this task assesses one’s ability to identify objects that are rapidly presented in one’s central and peripheral visual fields. As an example of how this test might relate to actual driving situations, if a car was approaching from the left and did not get the attention of the driver, it may not be noticed in time to avoid a crash. Ball et al. discovered that, in their sample, overall age was associated with deficits on this measure, but there were still a number of participants who experienced no difficulty. In an effort to compare those with impaired UFOV to those without, the participants were categorized according to which dimension was impaired (i.e., processing speed, divided attention, or selective attention) or a combination of the three (i.e., divided and selective, selective and processing, or all three). The effects of impairment
proved to be additive such that the more domains on which a person was impaired, the greater the reduction in their useful visual field. For example, one who was impaired on all three domains showed a loss of approximately 85% of his or her visual field. This constriction in visual field might impact driving in that certain visual information may not be seen by the driver at the same rate as one who is without impairment.

The authors also examined whether or not the UFOV could be used in crash prediction and administered a battery of tests designed to assess visual function, visual attention, cognition, and driving habits. Crash data were collected from state records. They found that eye health (i.e., cataracts, AMD) and visual function were not related to crashes. However, UFOV and mental status were related to crashing, especially crashing at intersections. With regard to predicting crashes, the UFOV accurately identified 26 of 27 who did not crash but made 15 errors of prediction when identifying those who did crash. The authors theorized that those older drivers with poor UFOV (10 of 14 of whom had bad eye health) may be self regulating, perhaps based on a worsening eye condition. These individuals did, in fact, report more avoidance with respect to difficult driving situations.

Owsley, McGwin, and Ball (1998) conducted a study in order to determine the role that visual impairment and eye conditions may play in crashes that result in injury. They assembled a sample of 294 individuals to determine if crash frequency could be predicted from visual and cognitive functioning. Crash frequency was sorted into three categories: 0, 1-3, and 4+ crashes in the previous
five years. Those who experienced a crash were sorted into those resulting in an injury and those that did not. The visual processing tests used in this study included tests designed to assess sensory functioning, visual processing speed, and visual attention. Participants also received an eye examination to determine eye health. Cognitive functioning data and driving exposure data were also collected. They found that those drivers exhibiting difficulty in the areas of stereoacuity, visual field sensitivity, UFOV, glaucoma, and AMD were the ones most likely to be involved in crashes resulting in an injury. Upon multivariate logistic regression analysis, the only two variables significantly and independently predicting injurious crashes were impaired UFOV and glaucoma. Those individuals showing a greater than 40% UFOV reduction were also 20 times more likely to have a crash resulting in an injury. Even for those crashes not resulting in an injury, those with that degree of UFOV impairment were still 5.5 times more likely to be involved than those not exhibiting this impairment.

Goode et al. (1998) conducted a study in order to compare an established battery of neuropsychological/cognitive (i.e., mental status, attention, and memory) tests to the UFOV when used to predict at fault crashes of older drivers over the age of 55. Again, the sample was sorted according to age and crash frequency. Crash data were provided from state driving records, and three independent raters were assigned the task of choosing which person was at fault. All raters were blind as to the identity of the participant. They found that, although the neuropsychological tests were predictive, they were not as predictive as UFOV alone, which exhibited the most sensitivity (86.3%) and specificity
(84.3%). None of the other measures, either together or separately, predicted crash frequency as well as UFOV alone, although all measures showed a significant relationship with UFOV. In an effort to make this assessment clinically useful, the authors, using their previous work, set the cut point at a 40% reduction in visual field as the point where optimal classification can be made. In further predictive analysis, the authors found that the predicted probability of incurring at least one traffic accident in a given five-year period was .59 for those individuals obtaining a failing score.

In a prospective follow-up, Owsley et al. (1998) evaluated 294 drivers aged 55-87 upon enrollment over a period of three years in an effort to determine those visual characteristics that might be used to predict future crash involvement. The test battery was similar to the one mentioned in the last study. However, a questionnaire regarding driving habits, demographics, and health was included in the present study. Of the drivers they studied, they found that 70% of those who crashed were involved in accidents involving not yielding right-of-way, running a traffic stop device, or incorrectly judging the distance it would take to stop. They also found that those participants who did not pass the UFOV were 2.1 times more likely to suffer a crash during the follow-up than those who passed. In an effort to determine if any one UFOV subtest was more predictive of crashes than the others, the authors analyzed them separately and found that only Subtest 2 (the divided attention task) was predictive of crash risk. Failing this subtest was related to a 2.3 times greater risk of being involved in a motor vehicle accident. Further research involving the UFOV (Roenker, Cissell, Ball, & Edwards, 2003)
found that the attentional skill required to perform the UFOV tasks can be improved with training, that the training transfers to better choice reaction time scores, and that trained participants made fewer hazardous maneuvers while driving as compared to control groups not receiving training. These benefits were shown to last at least 18 months. Richardson and Marottoli (2003) also found that visual attention was associated with the majority (25 of 36) of driving behaviors (i.e., yielding right of way, turning, and merging) performed by older drivers that they assessed, and that the tests of executive function and visual memory that were correlated with particular driving performance/maneuvers were also those that overlapped with visual attention. Clay et al. (in press) conducted a meta-analysis of studies using UFOV to predict state-reported crashes and driving performance in an effort to determine the predictive utility of this measure. They found that the effect size was extremely large ($d = 0.945$), indicating that it was a reliable predictor of poor driving performance. Also, the effect sizes were relatively stable across the various studies, indicating that the measure is stable across testing environments.

Recall that in the Owsley et al. (1998) study the only visual factor other than UFOV that was found to be predictive of crashes was the presence of glaucoma. McGwin et al. (2004) examined the impact of glaucoma on crash risk and found that those with glaucoma posed a significantly lower crash risk than those without. It is also noteworthy that those drivers diagnosed with glaucoma avoided more difficult driving situations (i.e., night, fog, rain, etc.) than the glaucoma-free group. However, further analysis found that their reduced crash
risk was not due to avoidance; thus, the authors posit that perhaps these drivers modify their driving behaviors in other ways as yet unmeasured such as undertaking more scanning of the environment.

Cognitive Factors

Normal Age Related Declines

Lundberg, Hakamies-Blomqvist, Almkvist, and Johansson (1998) wanted to examine the issue from a different angle. They note that most research has sampled cognitively impaired individuals to ascertain their performance on certain driving tasks. In their study, they sampled older drivers having crashes and citations and compared them to a matched control sample of older adults without crashes or citations. Their hypothesis was that there would be more cognitive impairment in those individuals in the crash or citations groups than the control group. Each group underwent a battery of neurological tests designed to detect cognitive impairment as well as multiple eye and vision tests.

In the analysis, the authors divided their traffic incident involved drivers into four categories: (1) violating traffic rules (i.e., failure to yield, running stop signs) which may or may not have resulted in a crash, (2) losing control of the car that did not result in a crash, (3) speeding, and (4) crashing without a rules violation. In this way, they were able to examine the differences between those drivers who had crashed, those who had incurred a violation only, and control participants. They found that those who were involved in crashes were significantly older than the control group. They found that those involved in crashes had impaired performance in the domains of visuoconstructive ability and
visuospatial memory, psychomotor speed, verbal and visuospatial episodic memory, and verbal learning. The groups did not differ, however, on tests of reaction time, divided attention, verbal ability, or mental flexibility. No real differences were found between rules violators and control participants.

Stutts, Stewart, and Martell (1998) sought to examine the connection between performance on cognitive tests and crashing and driving avoidance/mileage in the elderly and also to evaluate the usefulness of certain tests for crash prediction. The tests they administered were the Trailmaking Test parts A and B, AARP Reaction Time, Short Blessed Orientation-Memory-Concentration, and a Traffic Sign Recognition Test. No single test was deemed to be useful for prediction, although overall performance was associated with crash risk even when controlling for exposure. They found that the Trailmaking Tests A and B were the ones that were most significantly associated with crash risk. However, the only tests entered into the full analysis were these and the Short Blessed Test due to the fact that the reaction time test and the traffic sign test were still considered to be experimental.

Dobbs, Heller, and Schopflocher (1998) attempted to discover the exact driving errors that could indicate declines in competence for older drivers. They used three groups for comparison: young ‘normal’ drivers, old ‘normal’ drivers, and cognitively impaired older drivers. They evaluated the groups on a number of possible errors (i.e., positioning errors, turning errors) and found that the cognitively impaired older group performed significantly worse on minor positioning errors, turn position errors, and over cautiousness. They also found
that the most accurate indicator of one who was in the cognitive decline group was the commission of a hazardous error defined as one that was clearly dangerous and required the driving evaluator to assist in regaining control of the car or required the traffic to “adjust to accommodate the error.” Those suffering from cognitive decline were much more likely to commit these types of errors.

*Dementia*

Cognitive impairment takes many forms, from mild cognitive impairment (MCI) to fully developed dementia such as that experienced with Alzheimer’s disease. The research on this latter group will now be discussed. Hunt, Morris, Edwards, and Wilson (1993) examined the ways in which varying levels of dementia severity impacted driving performance. Participants were divided into three groups: those who were healthy older adults, those with very mild dementia, and those with mild dementia. These participants completed various attention switching tasks as well as tasks designed to assess memory and visuospatial performance. They were also examined for physical conditions that might hinder their driving performance. Prior to on-the-road testing, they completed a questionnaire in which they self-assessed their driving capabilities. Caregivers also completed a questionnaire in which they rated the safety of the participant as a driver. The on-road test consisted of one hour spent driving in typical traffic situations (i.e., encountering stop signs, making left turns) and was conducted under good weather conditions in low density traffic. They found that the greater the severity of dementia, the poorer the driving performance. The specific significant driving behaviors that were impaired were the ability to follow driving
instructor directions, signaling, and checking blind spots prior to a lane change, and using good judgment in traffic. Those with mild dementia performed significantly worse on these tasks as well as on the attention switching and traffic sign recognition assessments. It is noteworthy that 62% of the patients with mild dementia were still categorized by the driving evaluators as safe, whereas 100% of the very mild dementia subjects were categorized as safe. They cautioned against using diagnosis of dementia as the sole criteria for license revocation.

In a longitudinal follow-up study, Duchek et al. (2003) used a very similar design and evaluated the same group types every six months during a two-year period of time. The results were similar to the previous study in that poor signaling and poor lane changing increased with severity of dementia. However, the only behaviors that declined from time one to time two (six months later) were the ability to make good judgments in traffic, reactions to the surrounding traffic, and control speed. Cooper et al. (1993) also found that those drivers suffering from dementia had more accidents and were responsible for a greater proportion of accidents that they were part of (92%) than non-demented matched control subjects (66%).

Rizzo, Reinach, McGehee and Dawson (1997) used a realistic driving simulator (Iowa Driving Simulator or IDS) to assess the relationship between Alzheimer’s dementia and driving behaviors associated with increased crash risk. The simulator was realistic in that it was able to reproduce much of the movement and sounds experienced when actually driving. They used two groups, those with dementia and those without dementia. Afterwards, the participants were
evaluated on certain cognitive, visual, and demographic characteristics. It was found that visuoconstructual ability, executive functioning, nonverbal intellect, and structure-from-motion were most predictive of crashes. They also found that a 50% or greater reduction in UFOV was related to simulated crash risk. With regard to driving performance measures, lane deviations and lateral accelerations above 0.1g were found to be most predictive of simulated crash risk. They also found that, regarding near misses, those in the Alzheimer’s group were more likely to experience near misses (74%) than those in the non-Alzheimer’s group (35%). Visual and cognitive declines (i.e., digit span, structure-from-motion) were also predictive of this phenomenon. Again, these authors caution license revocation based solely on diagnosis of dementia and note that the majority of their patients with Alzheimer’s Disease (AD) had not crashed and had performed satisfactorily on the driving performance assessment.

Rizzo, McGehee, Dawson, and Anderson (2001) conducted a follow-up study using the same driving simulator (IDS) to determine the intersection crash risk posed by older adults with Alzheimer’s dementia. They also looked again at the associated visual and cognitive impairments common to AD patients to see if they could be used to predict these events. In this study, the simulator had the participants encounter a vehicle incursion at an intersection, which means that a car pulled out in front of them illegally. The object for the participant was to undertake necessary steps to avoid a collision. They found that 33% of the AD participants would have incurred a crash, whereas none of the non-AD patients would have experienced that phenomenon. Reasons for failing to avoid the
collision ranged from failing to take any action to taking inappropriate action to responding too slowly. When results were combined with those of the above 1997 study, they found again that impairments in visuospatial skills, attention, and motion perception were most predictive of these simulator crashes.

However, Lucas-Blaustein, Filipp, Dungan and Tune (1988) suggest that, although not all demented drivers crash, they are still a risk on the road. Their study found that 30% of their patients diagnosed with dementia had had one or more accidents since the diagnosis, 44% routinely “got lost,” and 75% always drove below the speed limit. The concern over licensing lies in the fact that, given the clinical tests used here, there was no way to distinguish between the crash involved and non-crash involved demented older drivers.

Health Factors

Medical conditions and medications may also impact the driving abilities of older adults. Many illnesses have both cognitive and physical aspects, and the medications associated with many illnesses impact these domains as well. Campbell, Bush, and Hale (1993) compared 276 individuals who had been drivers in the past but were not currently driving with 1,380 individuals who had never given up driving in order to assess the differences in medical conditions between the two groups. They also assessed reasons for driving cessation as well as any traffic accidents. They found that age and gender were significantly associated with driving cessation in that those who were older and/or female were more likely to give up driving. A number of eye conditions such as retinal hemorrhaging or detachment and macular degeneration were significantly related
to driving cessation as were Parkinson’s Disease, stroke, frequent dizzy spells, memory loss, and limitations on daily activities such as housework or shopping requiring assistance from a second party. Glaucoma and cataracts were found to be unrelated to driving cessation. Interestingly, when predicting driving cessation through multiple logistic regression, the authors found different predictive models for males and females. Age, limitations on daily activities, and macular degeneration were shared, but males also had stroke as a factor while females had retinal hemorrhaging and Parkinson’s in the equation. They also found that individuals with three or more of these conditions were 60 times more likely to report driving cessation. However, when asked, most participants reported that they decided on their own to stop driving and did not refer to any medical conditions.

Koepsell et al. (1994) adopted a matched case-control study of adults over the age of 65 to ascertain the impact of certain chronic medical conditions on crash risk. They attempted to match by age, gender, and county of residence two control participants for each case participant. However, in a few cases, only one matched control participant could be obtained. Medical records up to three years prior to crash date were examined and control subjects were matched by that date as a reference date. Surveys were completed either by mail or telephone and yielded information regarding driving habits, mileage, health habits and demographics.

They found that about half of those crash involved drivers were responsible for a traffic violation during the accident. More cases (21%) than
controls (16%) had a history of heart disease as well as a history of falls, depression, and alcohol abuse. Diabetes was also present in 11.1% of the cases but only 4.5% of the controls. Additionally, those treated with insulin were at six times greater risk for crash involvement and those treated with oral diabetes medication had a three times greater risk than controls. Those having comorbid heart disease and diabetes were at a significantly higher risk than those participants having neither illness.

McGwin, Pulley, Sims, and Roseman (1999) also conducted a matched case-control study to determine the role of diabetes and/or diabetes related complications in risk of at-fault crash involvement. The authors looked at three groups: (1) at least partially at fault, (2) not at fault, and (3) non-crash involved; these were frequency matched to the other two groups on the basis of age and sex. In addition to police records regarding the crashes, data were collected via telephone interview regarding various medical conditions including diabetes, in which case, severity and method of treatment were assessed. They were also asked about their mileage, quality of driving, and comfort level in particular situations. Questions designed to assess visual impairment and mental status were also asked. They found, again, that over half (57.2%) of those who had had crashes were at least somewhat at-fault and that those at-fault were older than those participants who were involved in crashes but not at-fault. Also, those at fault were more likely to report poor driving quality, driving more miles, and being involved in more crashes in the four prior years, and were more likely to have vision impairments, heart disease and stroke. They did, however, find no
evidence for differences between groups based on diabetes or type of diabetes treatment. However, those who were diabetic and involved in a crash in the four years prior to the study were at a higher crash risk than those non-crash involved participants.

In a study using the same data set, McGwin, Sims, Pulley, and Roseman (2000) found that women with arthritis had a 20% greater at-fault crash rate than those without. Also, those crash involved, not at-fault participants showed a greater frequency of heart disease, stroke, and arthritis than those who were crash free. This study also looked at the role of medication usage as it related to crashing and found a relationship between at-fault crashes and nonsteroidal anti-inflammatory drug (NSAID) use, angiotensin converting enzyme (ACE) inhibitors, anticoagulants, and benzodiazepines. Benzodiazepines were also related to not at-fault crashes. Calcium channel blockers and vasodilators were negatively related to at-fault crashes. One interesting finding was noted when looking at two-way interactions between medication classes. It was found that NSAIDs and ACE inhibitors were related to crash involvement when taken together, such that those individuals exhibited a 3.4 times greater crash risk. Use of NSAIDs alone was related to a 50% increase in crash risk, whereas ACE inhibitors had no association. The effect of heart disease and stroke on crash risk appeared to be independent of the medications taken for those diseases. However, ACE inhibitors and anticoagulants appeared to make independent contributions to crash risk regardless of their associated conditions. This study did not make it clear whether or not risk increased with dosage.
Foley, Wallace, and Eberhard (1995) interviewed 1,791 individuals over the age of 68 (206 of whom had incurred crashes) living in a rural setting to gain information regarding physical, cognitive, and vision/hearing in addition to health conditions and medications used in order to predict crash risk. Crash histories were obtained for the years 1985 through 1989. In this study, men had a higher crash rate than women but age was insignificant. It was found in this study, like the previous study, that about half of those involved in crashes also incurred a citation as a result of the crash. Unlike a previous study (i.e., McGwin et al., 2000), which found a strong link between crash risk and diabetes, this study found no relationship. The only significantly associated medical conditions were current back pain or having had an episode of back pain in the last year and impaired recall memory. The only medication class significantly associated with crash risk was nonsteroidal antiinflammatory agents. However, this association was not investigated with respect to whether or not this risk increased proportionally with increases in dosage. Also, for whatever reason, they did not adjust the significance level even though they tested multiple hypotheses.

Sjogren, Eriksson, and Ostrom (1996) attempted to determine the influence of existing disease processes on fatal car crashes. They examined 480 autopsied Swedish drivers (autopsies in crash related fatalities are common in Sweden) over the age of 18 who were deceased within 72 hours after the crash between the years 1977 and 1989. In addition to autopsy reports, they also obtained police records in order to determine responsibility for the crash. Internal medical factors (IMF) were rated on a scale of 0 to 4 based on their risk of
causing sudden incapacitation sufficient to lead to a crash. They found that IMF’s occurred more in males and those over 60. In fact, for those over the age of 70, 85% of the group had IMF’s whereas the proportion of 18-24 year olds having IMF’s was only 3%. They also found that those drivers having IMF’s were more likely to be involved in crashes involving the driver crossing into the oncoming traffic lane than those without existing medical conditions, independent of age. However, they did admit that the relationship between IMF’s and crash initiation could only be talked about in terms of probabilities as they found no instances in which they could say for certain that an existing medical condition caused the accident. Also, in many cases, they had no information regarding vision, hearing, or possible dementing illnesses.

Forrest, Bunker, Songer, Cohen, and Cauley (1997) studied 1,768 community dwelling, ambulatory women over the age of 70 in order to look at the relationship between driving patterns and medical conditions. They were asked whether or not they currently drive and for those current drivers, questions about frequency, mileage, avoidance and difficulty with certain traffic situations, and whether or not they had reduced their driving in the last five years followed. All participants answered questions regarding demographics, lifestyle (i.e., physical activity, smoking), and medical history including falls, fractures, vision/hearing difficulties and muscle pain experienced over the previous seven days. Memory and cognitive functioning were also assessed. They found that former drivers more often reported the presence of medical conditions and had much higher comorbidities. They also found that driving cessation increased with age as did
avoidance of certain driving situations. Older women in this group were also more likely to report a reduction in mileage as well as driving slower than the rest of the traffic. The presence of medical conditions, broken bones, angina, diabetes, and poor vision were most associated with the decision to give up driving altogether. Reduction in mileage over the last five years was most closely linked to falls, impaired hearing, and muscle pain whereas taking trips of only less than 100 miles was related to fractures and myocardial infarction. Comorbidity of conditions was related to driving reduction in current drivers such that, as number of conditions increased, the likelihood that the driver would cease or reduce driving also increased.

Guibert et al. (1998) studied 2,504 crash involved and 2,520 non-crash involved men between the ages of 45 and 70 in a case-control design in order to determine what impact chronic medical conditions might have on crash risk. These men were randomly chosen from the database of a large insurance company in Quebec and data were provided regarding driver category, medical conditions, and crash involvement. These individuals were mailed a survey containing questions about mileage, avoidance, demographics, driving behavior routine car maintenance, and lifestyle (i.e., smoking, drinking). The response rate was relatively low (35%) with non-responders tending to be younger and crash involved. The groups did not differ on the basis of having a medical condition(s) versus not having a medical condition(s). They found that the presence of medical conditions went up with age. They also found that drivers having medical conditions drove less with respect to accomplishing daily errands and
that, the older the driver, the more likely they were to avoid driving in poor weather conditions and decrease driving in all circumstances. Overall, they found no significant relationship between medical conditions and crash risk. It should probably be kept in mind that the upper age range of the sample was only 70. It might be more likely that one would find a relationship as age increased.

DiStefano and Macdonald (2003) examined data obtained from road tests as well as medical information reported to the licensing bureaus in Victoria, Australia, in order to better understand the relationship between age, medical conditions and hazardous maneuvers on the road. Ultimately, 496 individuals’ records were examined. Although ages in this study ranged from 24 to 100, the average age was 76, indicating a relatively old sample. The overall fail rate for the road tests in this sample was 49% and increased with age. The biggest predictors of test outcome were how well the participant negotiated intersections, maintained appropriate position and speed, and their safety margin (i.e., failure to maintain adequate distance from a parked car). The relationship between driver age and performance was significant; however, no associations between number or type of medical condition and performance were noted. In order to examine the role of type of illness, they grouped varied conditions together into those representing either physical, cognitive, or a mixture of the two. They postulated that this lack of relationship may be due to varying severity of conditions and differences in type of impairment associated with individual conditions. Also, documented major illnesses were relatively low in this sample, indicating that declines may be simply age related.
The data regarding medications and medical conditions is varied and not always in agreement. Some studies find diabetes to be a risk factor whereas others do not. The same is true for various eye conditions, heart conditions, and inflammatory illnesses. More research is needed to establish conclusions regarding these factors.

**Summary and Hypotheses**

So far, a variety of factors related to older driver crash risk have been observed. Multiple factors seem to play into this risk. Visual deficits in the form of cataracts, macular degeneration, and glaucoma as well as visual attention and processing deficits all pose problems for the older driver. In the area of cognition, many studies found that those suffering from cognitive deficits were more likely to make risky maneuvers on the road and be at a higher risk for driving simulator crashes. Stutts (1998) examined the extent to which those older adults with visual or cognitive impairments regulated their driving by reducing their amount of mileage and avoiding certain situations. She found that those with lower functional ability in these two domains were indeed likely to reduce their driving exposure. With regard to medical conditions and medications, the evidence is not conclusive and yields several different results, especially regarding diabetes.

Given the vicissitudes reflected in this body of literature, is it possible to locate these risky older drivers prior to crash involvement? In an attempt to answer this question, Staplin, Lococo, Gish, and Decina (2003) and Ball et al. (Under Review) selected the functional measures with the greatest likelihood of detecting risk factors in older adults and subjected them to a field test.
Participants were recruited at the time of license renewal at the Maryland Motor Vehicle Administration (MVA) and asked to complete a brief battery of physical and cognitive measures. This particular battery examined several cognitive dimensions including visual search, memory, information processing speed, and physical dimensions such as limb strength mobility and flexibility. These assessments consisted of the UFOV and a battery of tests known as the Gross Impairments Screening Battery (GRIMPS), which are detailed in the Methods section of this paper. They found that administration of this short battery was indeed feasible, resulting in complete data and accurate administration for each participant 98% of the time. The best predictors of at-fault crashes appeared to be the visual closure subtest of the Motor Free Visual Perception Test (MVPT) and the UFOV. The results of these studies indicated that older drivers who are at risk for future crashes can be identified through this brief battery of tests even when the tests are administered in a non-laboratory setting.

A second part of the project involved yearly interviews with these participants for up to five years following MVA testing. The telephone interviews consisted of questions regarding employment status, average mileage driven per week and per year, as well as driving situations with which the participant had difficulty or avoided. In addition, there was a self report section assessing number of falls, crashes, citations, illnesses and medications used in the last year. Vance et al. (in press) further analyzed this data set. In this study, they used data from the GRIMPS and UFOV screening battery as well as follow-up telephone interviews regarding health and driving habits in order to create a
causal structural equation model of driving avoidance and exposure. The study was based on data collected during the first MVA screening in 1999 and the interviews conducted within six months thereafter (N = 815). They found that the latent constructs of health (comprised of number of reported illnesses and number of reported medications taken) and cognitive function (indicated by performance on the UFOV and other GRIMPS cognitive measures detailed in the Methods section of this paper) were predictive of driving avoidance and exposure. However, they found that physical functioning (indicated by number of self-reported falls in the last year and the physical measures in the GRIMPS detailed in the Methods section of this paper) was not predictive of these driving outcomes. Also, health status was not significantly related to either physical or cognitive function.

Vance et al. (in press) examined these data at only one point in time – during year one. Since the time of the initial functional assessment at the Motor Vehicle Association office in 1999, yearly mobility interviews have been collected from this sample. In addition, a second functional assessment of these individuals, using the same screening battery, was performed at license renewal five years later (2004). It is these data that form the basis for this thesis. These data permit the assessment of several important questions about changes in older adult mobility over time, and that is the aim of the current study. The specific questions this study is designed to answer are:

1. Absent significant illness or dementia, what is the time course of normal changes in mobility?
2. Did the factors predicting mobility and exposure remain constant over time for a sample of individuals?

Many studies have used a variety of methods to assess older drivers in an effort to predict those factors that are related to crash involvement and mobility reductions. Ball et al. (Under Review) evaluated one particular battery of tests in an effort to determine their effectiveness at predicting at-fault crashes and the ease with which these methods may be used in a Motor Vehicle Administration licensing setting. The battery under evaluation was the Gross Impairments Screening Battery (GRIMPS) along with the UFOV subtest 2 (Ball, Roenker, & Bruni, 1990). GRIMPS is an assessment of performance based abilities representing both physical and cognitive domains, and UFOV is a measure of visual attention and visual processing speed. This battery, in addition to yearly follow-up telephone interviews, was the one adopted for this study and is described in the following methods section.
Chapter 2

Methods

Participants

Participants age 55 and over were recruited from three Motor Vehicle Administration (MVA) offices in Maryland and one retirement community after renewal of their driver’s licenses in 1999 and again in 2004. As part of the license renewal procedure, individuals’ visual acuity was tested and those meeting state standards (20/40 or better) qualified for recruitment. In the 1999 sample, 4,484 individuals were asked if they would be interested in participating in a research study to evaluate a battery of tests. Informed consent was waived by the IRB under rule CRF § 46.116. Individuals participated on a volunteer basis and were assured that participation did not affect their licensing status.

Two-thousand, one-hundred and seventy individuals consented to participate in the screening measures. Ages ranged from 55-99, with the mean age being 70.34 and included 1,139 males and 1,029 females. Gender information was not obtained for two individuals. 91% of the sample was Caucasian with 6% African-American. Those choosing to participate did not demographically differ significantly from those who refused participation. Afterwards, participants were asked if they would consent to yearly follow-up telephone interviews for the next four years. Informed consent for the phone interviews which would be conducted in the intervening years was then obtained. One-thousand, five-hundred and fifty initially consented to participate in the follow-up telephone interviews. Of that number, 815 were selected randomly and successfully contacted for interviews.
Ages ranged from 55-99, with the mean age being 71.62 and included 385 males and 430 females. Ninety-one percent of the sample was Caucasian with 5% African-American.

Five years after the initial assessment, participants were re-recruited for participation in a second wave of the study upon license renewal at the MVAs but not at the retirement community. One thousand and fifteen individuals completed the second screening. The data set was then filtered for individuals who met four inclusion criteria: mobility interviews from both 1999 and 2004 and functional assessment at 1999 and 2004. Remember that of the original screening sample of 2,170 individuals, 815 completed telephone mobility interviews. Thus the potential pool of participants for this analysis was limited to those individuals from the original 815 who met the remaining two criteria – screening and mobility assessments in 2004. Because individuals from a retirement community (n = 176) who completed the initial telephone interview were not included in the reassessment of functional skills in 2004, they were removed from the sample. An additional 340 participants were not included in this analysis for the following reasons: their licenses were revoked by the Medical Advisory Board (n = 2), they were unable to be contacted (n = 79), they had quit driving (n = 21), had died (n = 62), or declined to participate in the second screening (n = 176). Thus, the final sample for the present data analysis consisted of 299 participants.

The participants in this sample ranged in age from 55-86 with their mean age being 68.63. Females comprised 52.2% of the sample (n = 162) and males (n = 137) made up 45.8%. They were also overwhelmingly Caucasian (n = 278;
African Americans were 6.3% of the sample ($n = 19$) while Asians ($n = 1$) and American Indians/Alaskan Natives ($n = 1$) made up less than one percent of the sample.

**Materials and Procedure**

Participants underwent a screening battery consisting of visual, motor and cognitive assessments. The first several tests administered were part of the GRIMPS battery of general physical and cognitive abilities (Staplin et al., 2003) followed by subtest 2 of the UFOV. Those that consented to follow-up telephone interviews were contacted within six months of screening and then once per year for the next five years.

**Gross Impairment Screening Battery (GRIMPS)**

Rapid Pace-Walk: In this assessment of lower extremity function, participants were required to walk a distance of ten feet, turn, and return to their starting point (for a total of 20 ft) as quickly as possible (Marottoli et al., 1994). A stopwatch was used to record time measured in seconds needed to complete the task.

Head/Neck Rotation: In this second assessment of upper body flexibility, participants were required to turn their head either left or right in order to read a clock positioned directly behind them without rotating their torso. Participants were placed in a seat equipped with a seat belt. This test was scored as pass/fail. The Head Neck Rotation subtest simulates being able to turn and scan to the rear as one would do when backing out of a parking spot and are predictive of future crash risk (Marottoli et. al., 1998).
Visual Closure Subtest of the Motor Free Visual Perception Test (MVPT):
This measure of cognitive ability asked participants to visually observe a complete object and choose the most appropriate object from four partially complete objects that, when completed, would best represent the whole object. There were 11 such trials and the number of errors was recorded. This task was used to simulate conditions in which street signs might be obstructed (i.e., a stop sign obstructed by a tree limb). This task resembles the ability to understand a road sign, even though it may be obscured by a tree branch, for example.

Trails A: In another test of cognitive ability, participants were required to connect lines between eight numbered circles in a numerical order as quickly as possible (Goode et al., 1998; Spreen & Strouss, 1991; Stutts, 1998; Tarawneh et al., 1993). Time in seconds was recorded.

Trails B: Participants were required to connect lines between 26 numbered circles containing either numbers or letters and had to alternate from number to letter in both numerical and alphabetical order. Time to complete the task was measured in seconds (Goode et al., 1998; Spreen & Strouss, 1991; Stutts, 1998; Tarawneh et al., 1993). Trails A and B are measures of how well one visually searches and processes information. Trails B is a measure of how well one simultaneously divides his or her attention while searching and processing information.

Useful Field of View (UFOV)

The Useful Field of View is a computerized test assessing visual processing speed. The UFOV is composed of three subtests which ask
participants to identify and locate rapidly presented objects on a computer monitor and allows them to respond by touching the computer screen. Subtests one, two, and three measure identification, divided attention, and selective attention respectively. Out of these three subtests, Subtest 2 (measuring divided attention) has been found to be the best predictor of past and future crash involvement and was used for brevity (Owsley, Ball, et al., 1998).

Participants completed subtest 2 of the UFOV in which they were required to undergo several trials identifying a 2 cm by 1.5 cm centrally positioned target (car or truck) while also specifying the location of a peripherally positioned target (car only). After each of the images was rapidly presented, a visual mask appeared in order to erase any after images left on the screen and/or the retina of the participant. Participants then indicated their responses by touching either a car or truck pictured on the screen. Immediately following that presentation, numbered spokes appeared on the screen and the participant indicated the point at which the peripheral target was previously located. Presentation speeds ranged from 16 ms (fastest) to 500 ms (slowest). Scores were based on the average time in milliseconds required for the participants to attain 75% accuracy on both the central and peripheral targets.

Telephone Interview

Participants who agreed to participate in a yearly follow-up telephone interview were initially contacted within six months of their screening and were asked about their current work status, followed by a variety of questions pertaining to driving habits and health. The participants were then asked whether
or not they were currently driving and asked reasons for driving cessation if necessary. A self report of driving ability was then obtained which asked participants to compare themselves to the general flow of traffic as well as their opinion of their overall driving. Next, driving exposure was assessed through a series of questions pertaining to frequency and distance of driving on a weekly and yearly basis. Participants were asked how many days per week they normally drive, how many miles per week and per year were typically driven, and the farthest distance driven from their home in the past year (i.e., more than 25 miles away, outside the state of Maryland out of the Mid-Atlantic region). This particular set of questions will be referred to as Drive Space in the results section. Participants were then asked if they had engaged in specific driving behaviors/situations (including rain, unprotected left-hand turns, rush hour, and night driving) within the past three months and rated the amount of difficulty they had in performing these tasks on a four-point Likert scale ranging from no difficulty to extreme difficulty. Participants were asked if, in the last three months, they had avoided specific driving situations such as high traffic roads, making lane changes, bad weather, etc. Participants answered on a five-point Likert Scale ranging from always to never. Composites on the avoidance and exposure measures were formed by standardizing and summing the scores. Participants were also asked to self-report the number of crashes and/or citations incurred within the past year.

Health and mobility were assessed through a series of questions regarding number of falls in the past year, internal/external factors contributing to the fall(s),
and any injuries resulting from the fall(s). Self-report items assessing vision and hearing were also administered. General physical health was assessed through a questionnaire asking participants to report diagnosis and/or treatment of specific medical conditions. Finally, participants were asked to list any prescription medications currently taken at the time of the interview. Total number of medications and total number of health conditions were summed to yield a composite of overall health and overall medication use. Follow-up interviews were conducted on a one-year basis for the following three years. The full battery of questions used in the telephone interview can be found in Appendix A.
Chapter 3

Results

This longitudinal study examined mobility changes in drivers over the age of 65 for a period of five years. The analysis first compared the characteristics of the 299 people who participated in functional screening in 1999 and again in 2004 (participants) and the 340 people (nonparticipants) who completed only the screening in 1999. Secondly, this analysis examined changes over time among the 299 individuals in the participant group. Based upon the model by Vance et al., (in press), a factor analysis was conducted on the driving avoidance and driving exposure items in order to determine whether or not those same factors held up across time (i.e., 1999 – 2004). Ultimately, a Structural Equation Model was completed for the participant group in order to determine whether or not the model observed in 1999 would stay consistent five years later in 2004.

Comparison of Participants to Nonparticipants

First, it was necessary to determine whether or not the participants ($n = 299$) differed from the nonparticipants ($n = 340$) on the basis of demographic characteristics (see Table 1), functional screening measures (i.e., GRIMPS and UFOV, see Table 2), driving avoidance, driving exposure (see Table 3), and health (see Table 4). In order to examine demographic characteristics, an Analysis of Variance (ANOVA) on age and Chi Square ($\chi^2$) tests of race and gender were performed (see Table 1). Participants ($M = 68.63$) were younger than nonparticipants ($M = 71.04$), $F (1, 637) = 15.81, p < .00$. The percentage of females in the participant group (54%) did not differ from the percentage of
Table 1

Demographic Comparisons at Initial Screening (1999)

<table>
<thead>
<tr>
<th></th>
<th>Participants</th>
<th>Nonparticipants</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>*Age (yrs)</td>
<td>68.63 (7.02)</td>
<td>71.04 (8.11)</td>
<td>.000</td>
</tr>
<tr>
<td>Gender</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>% female</td>
<td>54.2</td>
<td>47.9</td>
<td>.067</td>
</tr>
<tr>
<td>Race</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>% Caucasian</td>
<td>92.9</td>
<td>94.7</td>
<td>.634</td>
</tr>
<tr>
<td>% Black</td>
<td>6.3</td>
<td>5.0</td>
<td></td>
</tr>
<tr>
<td>% Other</td>
<td>0.8</td>
<td>0.3</td>
<td></td>
</tr>
<tr>
<td>N</td>
<td>299</td>
<td>340</td>
<td></td>
</tr>
</tbody>
</table>

SD in parentheses
females in the non-participant group (47.9%), $\chi^2(1, N = 639) = 2.48, p > .05$. Similarly, the proportion of Caucasians in each group were comparable (participants 92.9%, nonparticipants 94.7%), $\chi^2(3, N = 639) = 1.71, p < .634$.

Multivariate ANOVAs (MANOVAs) were performed on the screening, avoidance/exposure items, and the health related items. Significant effects were found (all $F$'s > 1.93, all $p$'s < .02) and univariate ANOVAs were examined. Univariate ANOVAs were performed on the functional screening with the participants scoring significantly better on all measures than the nonparticipants (see Table 2), all $F$'s $(1, 580) \geq 3.90, p < .05$. It should be noted that, due to the binary nature of the Head/Neck Rotation measure (i.e., Pass/Fail), it was analyzed using the Chi-Square statistic. Fewer participants (11.4%) than nonparticipants (18.9%) failed that task, $\chi^2(1, n = 363) = 3.88, p < .049$.

In terms of Driving Avoidance, participants were less willing to drive alone ($M = 1.25$) than were nonparticipants ($M = 1.13$), $F(1, 637) = 4.38, p \leq .037$. There were no significant differences between the two groups on any other avoidance items, all $F$'s $(1, 637) \leq 2.88, p$'s $\geq .090$. Regarding driving exposure, participants ($M = 3.92$) drove further from home than nonparticipants ($M = 3.64$), $F(1, 637) = 11.79, p < .002$. A composite measure of driving exposure including days per week, miles per week, and miles per year as well as the driving space variable was developed (see below), and it was found that participants ($M = .30$) experienced significantly more driving exposure than nonparticipants ($M = .26$), $F(1, 637) = 5.19, p < .023$. In other words, participants differed significantly from nonparticipants in that they drove greater
Table 2

*Functional Measure Comparisons at Initial Screening (1999)*

<table>
<thead>
<tr>
<th></th>
<th>Participants M (SD)</th>
<th>Nonparticipant M (SD)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>GRIMPS</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Walktime (ms)</td>
<td>6.32 (1.78)</td>
<td>6.77 (2.21)</td>
<td>.007</td>
</tr>
<tr>
<td>MVPT (# wrong)</td>
<td>1.24 (1.46)</td>
<td>1.98 (1.96)</td>
<td>.000</td>
</tr>
<tr>
<td>Trails A (s)</td>
<td>10.70 (5.58)</td>
<td>12.25 (6.80)</td>
<td>.003</td>
</tr>
<tr>
<td>Trails B (s)</td>
<td>95.45 (37.54)</td>
<td>114.98 (51.60)</td>
<td>.000</td>
</tr>
<tr>
<td>Recall (# wrong)</td>
<td>0.48 (0.71)</td>
<td>0.60 (0.83)</td>
<td>.049</td>
</tr>
<tr>
<td>Head/Neck (% fail)</td>
<td>11.4</td>
<td>18.9</td>
<td>.049</td>
</tr>
<tr>
<td><strong>UFOV (ms)</strong></td>
<td>151.22 (138.25)</td>
<td>200.25 (152.36)</td>
<td>.000</td>
</tr>
<tr>
<td><strong>N</strong></td>
<td>290</td>
<td>292</td>
<td></td>
</tr>
</tbody>
</table>

Head/Neck based on n = 196 Non-Participant Group and n = 167 Participant Group due to missing data.
distances than nonparticipants when all of the exposure measures were combined. Although the overall composite measure was significant, a look at the individual items seems to suggest that it is the driving space measure that is responsible for the significance here. Other items proved to be nonsignificant with all $F$'s $(1, 637) \leq 3.11, p's \geq .078$ (see Table 3).

With respect to overall health, participants did not differ significantly from nonparticipants in terms of total number of health conditions, $F(1, 616) < 1.00$, total number of medications taken, $F(1, 616) < 1.00$, and proportion in each group reporting a fall in the last year, $F(1, 616) < 1.00$. At initial screening, both participants and nonparticipants reported having an average of one or two medical conditions for which they both took an average of one or two medications, and about 11% of the members in each group experienced at least one fall (see Table 4).

**Participant Changes Over Time**

The participant group ($N = 299$) was further examined for changes over time (i.e., 1999 – 2004) using repeated measures ANOVAs in the areas of functional screening, driving avoidance, driving exposure, and health. With respect to the screening measures, participants became significantly worse on all measures, all $F$'s $(1, 284) \geq 12.03, p's \leq .001$, with the exception of UFOV which did not change over the period of time from 1999 to 2004. $F (1, 284) = 3.51, p \leq .062$ (see Table 5).

Regarding changes over time in the areas of driving avoidance and driving exposure, there were several significant changes that occurred between
Table 3

*Avoidance and Exposure Item Comparison at Initial Screening (1999)*

<table>
<thead>
<tr>
<th></th>
<th>Participants</th>
<th>Nonparticipants</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>(SD)</td>
<td>M</td>
</tr>
<tr>
<td><strong>Avoidance</strong>¹</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>opportunities</td>
<td>1.15</td>
<td>(0.57)</td>
<td>1.19</td>
</tr>
<tr>
<td>unfamiliar areas</td>
<td>1.68</td>
<td>(1.13)</td>
<td>1.84</td>
</tr>
<tr>
<td>heavy traffic</td>
<td>1.78</td>
<td>(1.23)</td>
<td>1.78</td>
</tr>
<tr>
<td>interstate travel</td>
<td>1.63</td>
<td>(1.18)</td>
<td>1.70</td>
</tr>
<tr>
<td>driving alone</td>
<td>1.25</td>
<td>(0.80)</td>
<td>1.13</td>
</tr>
<tr>
<td>lane changes</td>
<td>1.38</td>
<td>(0.95)</td>
<td>1.46</td>
</tr>
<tr>
<td>bad weather</td>
<td>2.28</td>
<td>(1.27)</td>
<td>2.36</td>
</tr>
<tr>
<td>left turn</td>
<td>1.51</td>
<td>(1.09)</td>
<td>1.47</td>
</tr>
<tr>
<td>rush hour</td>
<td>1.90</td>
<td>(1.34)</td>
<td>2.09</td>
</tr>
<tr>
<td>night</td>
<td>1.88</td>
<td>(1.32)</td>
<td>2.03</td>
</tr>
<tr>
<td>composite</td>
<td>-0.15</td>
<td>(6.88)</td>
<td>0.15</td>
</tr>
<tr>
<td><strong>Exposure</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>days/week</td>
<td>5.35</td>
<td>(1.81)</td>
<td>5.09</td>
</tr>
<tr>
<td>miles/week</td>
<td>136.49</td>
<td>(129.48)</td>
<td>127.62</td>
</tr>
<tr>
<td>miles/year¹</td>
<td>4.71</td>
<td>(2.45)</td>
<td>4.44</td>
</tr>
<tr>
<td>driving space¹</td>
<td>3.92</td>
<td>(1.04)</td>
<td>3.64</td>
</tr>
<tr>
<td>composite</td>
<td>0.30</td>
<td>(2.99)</td>
<td>-0.26</td>
</tr>
</tbody>
</table>

N  
299     340

¹ See Appendix A for Scaling Information
Table 4

**Total Number of Health Conditions, Medications, and Percent Falling in 1999 for Participants and Nonparticipants**

<table>
<thead>
<tr>
<th></th>
<th>Participants</th>
<th>Nonparticipants</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Health Conditions</strong></td>
<td>1.43 (1.22)</td>
<td>1.52 (1.36)</td>
<td>.372</td>
</tr>
<tr>
<td><strong>Medications</strong></td>
<td>1.86 (1.67)</td>
<td>1.98 (1.97)</td>
<td>.391</td>
</tr>
<tr>
<td><strong>Falls (% falling)</strong></td>
<td>11.0</td>
<td>12.1</td>
<td>.727</td>
</tr>
<tr>
<td><strong>N</strong></td>
<td>295</td>
<td>323</td>
<td></td>
</tr>
</tbody>
</table>

Table 5

**Functional Measure Comparisons of Participants Over Time**

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>GRIMPS</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Walktime (s)</td>
<td>6.31 (1.77)</td>
<td>7.03 (2.47)</td>
<td>.000</td>
</tr>
<tr>
<td>Head/Neck (fail)</td>
<td>0.11 (.318)</td>
<td>0.60 (0.490)</td>
<td>.000</td>
</tr>
<tr>
<td>MVPT (# wrong)</td>
<td>1.25 (1.47)</td>
<td>2.54 (1.98)</td>
<td>.000</td>
</tr>
<tr>
<td>Trails A (s)</td>
<td>10.65 (5.52)</td>
<td>12.49 (7.63)</td>
<td>.000</td>
</tr>
<tr>
<td>Trails B (s)</td>
<td>95.68 (37.79)</td>
<td>114.76 (57.91)</td>
<td>.000</td>
</tr>
<tr>
<td>Recall (# wrong)</td>
<td>0.48 (0.72)</td>
<td>0.67 (0.86)</td>
<td>.001</td>
</tr>
<tr>
<td>UFOV (ms)</td>
<td>151.18 (137.27)</td>
<td>167.55 (138.25)</td>
<td>.062</td>
</tr>
<tr>
<td><strong>N</strong></td>
<td>285</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Head Neck based on n = 167
1999 and 2004 (see Table 6). With respect to driving avoidance, participants were significantly more likely to report avoiding opportunities to visit family or friends, avoid driving in unfamiliar areas, heavy traffic, interstate travel, rush hour, and night driving, all $F$’s $(1, 298) \geq 3.98, p \leq .047$. The composite measure was also significant, $F(1, 298) = 7.63, p < .006$ meaning that they avoided more difficult driving situations overall than they had five years before. Other avoidance measures proved nonsignificant, all $F$’s $(1, 298) \leq 2.12, p \geq .146$. In the area of driving exposure, participants showed significant declines in all areas except miles per week, $F(1, 298) = 3.77, p \leq .053$. Overall, however, they drove fewer days per week, miles per year and did not travel as far from home as they had in 1999, all $F$’s $(1, 298) \geq 9.13, p \leq .003$. Also, if one examines the composite of all of these items, it is shown that participants decreased their overall exposure significantly, $F(1, 298) = 22.68, p \leq .000$ over the five year interval.

Regarding health, participants saw a decline in overall health (see Table 7) with significant increases in total number of health conditions, $F(1, 260) = 45.07, p \leq .000$ and total number of medications taken, $F(1, 260) = 112.27, p \leq .000$. The percentage of people falling, however, did not significantly change over time with 11% falling in 1999 and 13.2% reporting falls in 2004, $F(1, 260) = 2.85, p \leq .093$.

*Factor Analysis*

In order to determine whether or not the driving avoidance and driving exposure measures held up as constructs over time, two separate factor analyses
Table 6

Avoidance and Exposure Item Comparisons of Participants Over Time

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>(SD)</td>
<td>M</td>
<td>(SD)</td>
<td>p</td>
</tr>
<tr>
<td>Avoidance¹</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>opportunities</td>
<td>1.15</td>
<td>(0.58)</td>
<td>1.31</td>
<td>(0.82)</td>
<td>.001</td>
</tr>
<tr>
<td>unfamiliar areas</td>
<td>1.68</td>
<td>(1.31)</td>
<td>1.88</td>
<td>(1.28)</td>
<td>.004</td>
</tr>
<tr>
<td>heavy traffic</td>
<td>1.78</td>
<td>(1.23)</td>
<td>1.94</td>
<td>(1.32)</td>
<td>.026</td>
</tr>
<tr>
<td>interstate travel</td>
<td>1.63</td>
<td>(1.18)</td>
<td>1.83</td>
<td>(1.33)</td>
<td>.004</td>
</tr>
<tr>
<td>driving alone</td>
<td>1.25</td>
<td>(0.80)</td>
<td>1.24</td>
<td>(0.77)</td>
<td>.850</td>
</tr>
<tr>
<td>lane changes</td>
<td>1.38</td>
<td>(0.95)</td>
<td>1.44</td>
<td>(0.99)</td>
<td>.423</td>
</tr>
<tr>
<td>bad weather</td>
<td>2.28</td>
<td>(1.27)</td>
<td>2.39</td>
<td>(1.30)</td>
<td>.146</td>
</tr>
<tr>
<td>left turn</td>
<td>1.51</td>
<td>(1.09)</td>
<td>1.53</td>
<td>(1.10)</td>
<td>.698</td>
</tr>
<tr>
<td>rush hour</td>
<td>1.90</td>
<td>(1.34)</td>
<td>2.07</td>
<td>(1.34)</td>
<td>.047</td>
</tr>
<tr>
<td>night</td>
<td>1.88</td>
<td>(1.32)</td>
<td>2.05</td>
<td>(1.45)</td>
<td>.017</td>
</tr>
<tr>
<td>composite</td>
<td>-0.15</td>
<td>(6.88)</td>
<td>0.92</td>
<td>(7.76)</td>
<td>.006</td>
</tr>
<tr>
<td>Exposure</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>days/week</td>
<td>5.35</td>
<td>(1.81)</td>
<td>5.08</td>
<td>(2.05)</td>
<td>.003</td>
</tr>
<tr>
<td>miles/week</td>
<td>136.49</td>
<td>(129.48)</td>
<td>124.81</td>
<td>(111.89)</td>
<td>.053</td>
</tr>
<tr>
<td>miles/year¹</td>
<td>4.71</td>
<td>(2.45)</td>
<td>4.34</td>
<td>(2.35)</td>
<td>.001</td>
</tr>
<tr>
<td>driving space¹</td>
<td>3.92</td>
<td>(1.04)</td>
<td>3.66</td>
<td>(1.16)</td>
<td>.000</td>
</tr>
<tr>
<td>composite</td>
<td>0.30</td>
<td>(2.99)</td>
<td>-0.31</td>
<td>(3.22)</td>
<td>.000</td>
</tr>
</tbody>
</table>

¹ See Appendix A for Scaling Information
Table 7

*Total Number of Health Conditions and Medications at Time 1 (1999) and Time 2 (2004) for Participation Group*

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Health Conditions</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>M        (SD)</td>
<td>1.51</td>
<td>2.01</td>
<td>.000</td>
</tr>
<tr>
<td>Medications</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>M        (SD)</td>
<td>1.99</td>
<td>3.18</td>
<td>.000</td>
</tr>
<tr>
<td>Falls (% falling)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>n</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>261</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
of the items comprising these scales were performed for the participants \((N = 299)\) who completed them in 1999 and again in 2004. The four items comprising driving exposure (i.e., days per week, miles per week, miles per year, and drivespace) and the 10 items composing the driving avoidance measure (i.e., avoiding unfamiliar areas, night driving, rush hour) were factor analyzed. Principal components analyses with Varimax Rotation yielded two factors \((\lambda > 1.31; \text{Lautenschlager, 1989})\) at both Time 1 (1999) and Time 2 (2004).

In 1999, all of the exposure and avoidance items loaded onto two separate constructs. The items on factor one, which was the Avoidance factor, shared 33.19% of their variance in common based on the rotation loadings; while the items on factor two, which was the Exposure factor, shared 19.57% of their variance for a total of 52.76% of the shared variance explained. The same analysis was repeated for those variables at Time 2 (2004) and again these two factors were found \((\lambda > 1.31)\). The items on factor one, which was the Avoidance factor, shared 25.49% of their variance in common based on the rotation loadings; while the items on factor two, which was the Exposure factor, shared 20.14% of their variance for a total of 45.64% of the shared variance explained.

In the Vance et al. (in press) model, composite scores of the avoidance and exposure items were used to form the outcome variables in that model. Therefore, for the present analysis raw scores of each of the driving avoidance and driving exposure items were transformed into \(z\) scores using the means and standard deviations from the full sample of 639 people \((n = 299\) in the participant group; \(n = 340\) in the non-participant group) and summed to create composite
scores. These composites were constructed separately for the 1999 and 2004 data sets using the means and standard deviations from the full sample in 1999. It is these composites that form the outcome measures driving avoidance and exposure for the following models.

*Structural Equation Model*

The ultimate objective of this analysis was to use a subset of the participants used in the Vance et al. (in press) model to determine whether or not the significant causal paths found were maintained over time. Vance et al. found that the observed variables of total number of illnesses and medications loaded onto the health construct (albeit weakly), walktime and falls loaded onto the physical functioning construct, and MVPT, UFOV, and Trails A and B loaded onto the latent construct of cognitive functioning. Vance et al. found direct causal paths from health and cognitive functioning to driving avoidance and exposure. However, the path from physical functioning to driving avoidance and exposure was not significant. Age and gender, considered as dummy latent variables, also had direct paths to health, physical functioning, cognitive functioning, driving exposure and driving avoidance (see Figure 1).

The models proposed for this thesis sought to replicate this model for the subsample \(n = 299\) in 1999 and 2004 (see Figure 2). In addition to the direct causal paths specified by Vance et al., (in press), the direct path between physical functioning and driving avoidance and exposure was proposed and retested to determine if the role of physical function changed over time. Also, additional measures of physical functioning (i.e., Head/Neck Rotation) and cognitive
Figure 1  Vance et al. model of the full sample in 1999. Paths in bold represent significant relationships that were of interest. Broken lines represent nonsignificant paths. Other solid, non-bold lines represent significant paths that were not specified as being of interest in the study.
Figure 2  Proposed model for the 1999 and 2004 subsample.
functioning (i.e., Recall) were available and added to the models presented as a part of this thesis.

The covariance matrix was used in order to generate the analyses and causal paths presented in the models that follow (see Tables 9 and 11). Correlation matrices are also presented in Tables 8 and 10. Diagonally weighted least squares as a method of estimation was used (as opposed to the more common maximum likelihood estimation) due to the fact that some variables appeared to have both skewed and kurtotic distributions. Figure 3 shows the standardized solution path diagram based on this sample (n = 299) in 1999. Standardized coefficients are the ones most commonly used in an analysis of this type where the sample is comprised of the same people over time. Paths were trimmed from the initial model by deleting, one at a time, those with the least significant t-values. Health as a latent variable fell out of the model altogether, as did age and sex. The only significant predictor of both driving avoidance and driving exposure was physical functioning, $\chi^2(18, N = 299) = 10.60, p \leq .05$. This model did seem to be a good fit as indicated by the fit indices (e.g., GFI = .95, AGFI = .90). Cognition was predictive of neither outcome. Analyzing the data for 2004 yielded a very similar model (see Figure 4) with physical functioning being the only significant predictor of both driving exposure and driving avoidance, $\chi^2(25, N = 299) = 36.16, p \leq .05$. This model, though a good fit (GFI = .98, AGFI = .96), would appear to be very different from the Vance et al. (in press) model since the only nonsignificant paths found in this analysis involved physical function.
Table 8

*Correlation Matrix of Model Variables (1999)*

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(8) FALLS 3.030 0.252
(9) MEDS 27.287 -0.007 2.866
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(11) HEALTH 8.584 0.057 1.172 -0.104 1.508
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Table 10

*Correlation Matrix of Model Variables (2004)*

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Table 11

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<td>(10) MEDS</td>
<td>30.29</td>
<td>0.04</td>
<td>5.14</td>
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<td>(11) SEX</td>
<td>-13.14</td>
<td>-0.06</td>
<td>0.07</td>
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<tr>
<td>(12) HEALTH</td>
<td>33.20</td>
<td>0.16</td>
<td>1.75</td>
<td>-0.18</td>
<td>1.89</td>
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<tr>
<td>(13) EXPOSE</td>
<td>-114.65</td>
<td>-0.34</td>
<td>-0.33</td>
<td>1.17</td>
<td>-0.59</td>
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<tr>
<td>(14) AVOID</td>
<td>306.81</td>
<td>1.07</td>
<td>0.08</td>
<td>-1.51</td>
<td>1.13</td>
<td>-11.02</td>
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</table>
Chi-Square = 10.60, df = 18, p-value = 0.91072, RMSEA = 0.000

Figure 3  Trimmed model from 1999 (Time 1).
Chi-Square = 36.16, df = 25, p-value = 0.06923, RMSEA = 0.039

Figure 4  Trimmed model from 2004 (Time 2).
Chapter 4

Discussion

Participants were significantly younger and performed better on all physical and cognitive measures in the screening battery than nonparticipants. However, they were not significantly different from nonparticipants on any of the Avoidance measures except willingness to drive alone. In this case, participants proved slightly less willing to do so. Perhaps, given the significant differences in age, the nonparticipants may have been the only driver in their household, whereas the younger drivers may have had a spouse with whom they preferred to travel. The participant group also traveled greater distances and more miles than the nonparticipant group with the greatest difference being in how far they had traveled from their home in the last year. Perhaps, again, the participants still had a spouse with whom they traveled and took more vacations. Another possibility, perhaps to be considered in conjunction with the idea posited above, is that a greater number of these individuals were currently employed and drove more days and miles per week than those who were older and perhaps retired.

Additionally, nonparticipants appeared to be as healthy as participants at the beginning of the study. Their health status may have changed, however, in the intervening years leading them to decline participation in 2004. Regardless of the possible reasons, it is clear that the sample of individuals who returned was more cognitively intact and physically better off than those who did not return.

Examining the changes that did occur over time in our somewhat younger, more mobile sample, it was found that participants declined on all screening
battery measures with the exception of the visual speed of processing task (UFOV) although the decline in this measure approached significance. Over time, this group also increased their avoidance of certain difficult driving situations and decreased their exposure. For example, the avoidance of unfamiliar areas, heavy traffic, and night driving was characteristic of this sample in 2004 as was a reduction in exposure (i.e., miles and days per week). This reduction could be indicative of several things. Possibly, the change in driving habits resulted from lifestyle changes that come with aging. For example, these participants may have begun to retire. This change would make it easier to avoid driving in unpleasant situations and would give ample opportunity to avoid those less pleasant conditions than in earlier years. These participants also declined significantly in the overall health area with significant increases in total number of health conditions and medications. This decline in health, too, may be a reason for the reductions in exposure and increases in avoidance.

However, when one turns to the path analysis of factors that are related to a reduction in driving exposure and an increase in driving avoidance, health does not seem to play a role. Possibly, the measures of health included here are simply not sensitive enough to allow a path to be specified. In models created at both testing times (1999 and 2004), physical function was the only significant predictor of both measures of driving habits. Here, again, it is possible that measures of cognitive function and health were just not sensitive enough to contribute to the model. It should be noted that the signs on the path coefficients for the physical latent construct changed from 1999 to 2004. To date, the reasons for the change
in direction are unknown since the correlation matrix among the variables is essentially unchanged over time. An interesting point to note is that UFOV, which is one of the best predictors of mobility decline and loads highly on the cognitive construct, did not change significantly over time.

Future directions for research might focus on using more sensitive measures of each construct. It would also be of use to examine data in the intervening years and determine when the first significant mobility declines begin to occur. It might also be useful to covary employment status when looking at changes in days and miles per week driven. Another area of interest is change in cognitive status. Possibly the reduction in exposure and increase in avoidance could be due to level of cognitive decline. Perhaps, in this sample, some people experienced more significant cognitive decline than others. It is possible that running a model with those who declined the most would yield a significant path from cognitive function to avoidance and exposure. Alternatively, future evaluations of this data set might attempt to gauge changes in each construct over time and relate these changes to changes in mobility and exposure. It is possible that changes in these measures may be more sensitive than a measurement of the current value of the variable. By way of illustration, it should be possible to calculate the change in cognitive and physical measures from 1999 to 2004 and then use this information to develop a structural equation model of Avoidance and Exposure in 2004.

While such ideas are intriguing, they are beyond the scope of this thesis. In summary, this thesis did show that those who returned and participated in the
study five years later were those who performed better initially on the measures. Also, even those that returned for participation declined over time in all areas other than UFOV. Interestingly, although decline occurred in all areas, this model was different from the one presented by Vance et al. (in press) in that physical functioning was the only significant predictor. It is possible that the characteristics of this particular sample (i.e., community dwelling, relatively healthy) are influencing the model and that they naturally yield a model different from that of Vance et al. for a more diverse sample. Obviously, capturing the factors that contribute to declines in mobility is more elusive than previously thought.
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General Information

1. Work/Employment Status:
   ______ (1) unemployed  ______ (3) working full time
   ______ (2) working part time  ______ (4) retired

1a. Education Status: How far did you go in school? Record number of years ______

Mobility/Driving Habits Interview

Current Driving

2. Do you currently drive?
   ______ (1) yes (go to question 2a.)
   ______ (0) no  (answer questions #3 and #4, then continue with page 7)

2a. Are you the only driver for your household? (If a spouse, child, or other routinely drives you places, other than trips, you should answer no.)
   ______ (1) yes (go to question #5, page 2)
   ______ (0) no  (answer question 2b.)

2b. Are you the primary driver for the household? (Primary is defined as driving 50% or more of the time for routine household driving.)
   ______ (1) yes (go to question #5, page 2)
   ______ (0) no  (go to question #5, page 2)

3. Why did you stop driving?

__________________________________________________________________________

__________________________________________________________________________

__________________________________________________________________________

__________________________________________________________________________

__________________________________________________________________________

__________________________________________________________________________

__________________________________________________________________________

__________________________________________________________________________
4. When is the last time you drove? (month/day/year)

5. How fast do you usually drive compared to the general flow of traffic? Would you say: (circle one)

   (5) Much faster
   (4) Somewhat faster
   (3) About the same
   (2) Somewhat slower
   (1) Much slower

6. Has anyone suggested over the past year that you limit your driving or stop driving?

   (circle one)

   (0) no
   (1) yes

6a. Have you decided over the past year to limit your driving?

   (circle one)

   (2) no
   (3) yes

7. How would you rate the quality of your driving? Would you say:

   (circle one)

   (5) Excellent
   (4) Good
   (3) Average
   (2) Fair
   (1) Poor

Driving Exposure

8. How many days per week do you normally drive? (circle one)

   1 2 3 4 5 6 7
9. How many total miles do you drive in a normal week?  

10. About how many miles per year do you drive? (circle one)

<table>
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<td>7</td>
<td>8</td>
<td>9</td>
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</table>
Driving Space

11. Do you live in: (circle one)
   1) the city
   2) the suburbs
   3) a rural area

The answer to this question will determine the next question to answer.

12. Main idea - During the past year, have you driven to places beyond your neighborhood?

   If #11 = City - During the past year, have you driven to places beyond the surrounding 5 blocks?
      (1)_______ yes
      (0)_______ no

   If #11 = Suburb - During the past year, have you driven to places beyond 3 streets of your home?
      (1)_______ yes
      (0)_______ no

   If #11 = Rural area - During the past year, have you driven to places beyond your closest neighbors?
      (1)_______ yes
      (0)_______ no

13. During the past year, have you driven to places more than 10 miles away such as neighboring towns?
      (1)_______ yes
      (0)_______ no

14. During the past year, have you driven to places more than 25 miles away such as more distant towns?
      (1)_______ yes
      (0)_______ no
15. During the past year, have you driven to places outside the state of Maryland?

(1)______ yes  
(0)______ no

16. During the past year, have you driven to places outside the mid-Atlantic region?

(1)______ yes  
(0)______ no

Driving Difficulties

17a) During the past 3 months, have you driven when it is raining?

     _ _ Yes (1) (go to 17b)  _____ No (0) (go to 18a)

17b) Would you say that you drive when it is raining with:

     1_____ No difficulty at all
     2_____ A little difficulty
     3_____ Moderate difficulty
     4_____ Extreme difficulty

18a) During the past 3 months, have you made left turns across oncoming traffic?
[This would include situations when you have to judge if it’s OK to make the turn when other vehicles are approaching, such as at green lights (you have the solid green light, but no green arrow), turning onto other streets, and turning into parking lots, driveways, etc.]

     _____ Yes (1) (go to 18b)  _____ No (0) (go to 19a)

18b) Would you say that you make left turns across oncoming traffic with:

     1_____ No difficulty at all
     2_____ A little difficulty
     3_____ Moderate difficulty
     4_____ Extreme difficulty
19a) During the **past 3 months**, have you driven in rush hour traffic?

   _____ Yes (1)  (go to 19b)       _____ No (0)  (go to 20a)

19b) Would you say that you drive in rush hour traffic with:

   1. No difficulty at all
   2. A little difficulty
   3. Moderate difficulty
   4. Extreme difficulty

20a) During the past 3 months, have you driven at night?

   _____ Yes (1)  (go to 20b)       _____ No (0)  (go to 21)

20b) Would you say that you drive at night with:

   1. No difficulty at all
   2. A little difficulty
   3. Moderate difficulty
   4. Extreme difficulty

---

**Driving Avoidance**

21. These next questions are also based on your driving habits within the **last 3 months**. Please respond to each question with one of these answers. ‘**Always, Usually, Sometimes, Rarely, Never**’. For each question, circle the chosen frequency estimate.

21a. Do you pass up opportunities to go shopping, visit friends etc. because of concerns about driving?

   Always   Usually   Sometimes   Rarely   Never

21b. Do you avoid driving in unfamiliar areas?

   Always   Usually   Sometimes   Rarely   Never

21c. Do you avoid driving on high traffic roads?

   Always   Usually   Sometimes   Rarely   Never
21d. Do you avoid driving on interstate highways / expressways?
   Always  Usually  Sometimes  Rarely  Never

21e. Do you avoid driving alone?
   Always  Usually  Sometimes  Rarely  Never

21f. Do you avoid making lane changes?
   Always  Usually  Sometimes  Rarely  Never

21g. Do you avoid driving in bad weather (rain, snow, fog, etc.)?
   Always  Usually  Sometimes  Rarely  Never

21h. Do you avoid making left turns across oncoming traffic?
   Always  Usually  Sometimes  Rarely  Never

21i. Do you avoid driving in rush-hour traffic?
   Always  Usually  Sometimes  Rarely  Never

21j. Do you avoid driving at night?
   Always  Usually  Sometimes  Rarely  Never
Crashes and Citations

22. How many accidents have you been involved in over the past year when you were the driver? Please tell me the number of all accidents, whether or not you were at fault.

   \[ \text{Note: If answer} = 0, \text{ go to } \# 24. \text{ If answer is equal to or greater than 1, answer } \#. \]

23. How many accidents have you been involved in over the past year when you were the driver and the police were called to the scene? __________

24. How many times in the past year have you been pulled over by the police, regardless of whether you received a ticket? __________

   \[ \text{Note: If answer is} = 0, \text{ go to } \# 25b. \text{ If answer is equal to or greater than 1, go to } \# 25, \text{ then answer } \# 25b. \]

25. How many times in the past year have you received a traffic ticket (other than a parking ticket) where you were found to be guilty, regardless of whether or not you think you were at fault? __________

25b. How many times in the past year have you received a traffic ticket from a traffic camera (by mail) where you were found to be guilty, regardless of whether or not you think you were at fault? __________

   \[ \text{Note: If answer is} = 0, \text{ go to the next page. If answer is equal to or greater than 1, answer } \# 25c. \]

25c. How many times were you the driver when you received the traffic ticket(s) from a traffic camera? __________
Mobility/Falls

In the next few questions we’re interested in finding out whether you’ve fallen down in the last **12 months**. Falling includes accidentally losing your balance and falling on the ground or falling against something such as furniture.

26. Have you fallen in the past 12 months?

1 ______ Yes 0 ______ No (if No, go to page 8)

IF YES TO NUMBER 26:

26A. How many times have you fallen in the last 12 months? _____

26B. Did something such as a rug, stairs, a curb, or ice contribute to your (most recent) fall?

1 ______ Yes 0 ______ No

26C. Did anything else contribute to the fall?

1 ______ Yes 0 ______ No

26D. If yes, specify what

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

26E. Did any of your falls in the last year:

1) result in an injury? Yes = 1 No = 0

If yes, specify what

________________________________________________________________________

2) require medical attention? Yes = 1 No = 0
3) result in hospitalization?  Yes = 1  No = 0

4) involve a loss of consciousness?  Yes = 1  No = 0
(did you pass out?)

Self Evaluation of Vision and Hearing

Vision
27. Do you wear glasses? (circle one)  Yes = 1  No = 0

If yes, all of the next question pertains to you. If no, answer the BOLD part of the question.

When you wear your glasses (if you use them) do you have trouble reading the newspaper? (circle one)
1 = no difficulty
2 = some difficulty
3 = much difficulty
4 = stopped doing this because of my eyesight

Hearing
28. Do you feel you have a hearing loss (even with the use of a hearing aid, if you use one)? (circle one)  1 = yes  0 = no

Health History Questionnaire
29. In the past year have you been diagnosed and/or treated (includes being prescribed medication) by a physician for any of the following medical conditions? (circle one)

29a. Arthritis  yes=1  no=0
29b. Bursitis     yes=1  no=0
29c. Breathing Difficulties yes=1  no=0
29d. Muscular Dystrophy yes=1  no=0
29e. Multiple Sclerosis yes=1  no=0
29f. Cerebral Palsy     yes=1  no=0
29g. Parkinson’s Disease yes=1  no=0
29h. Diabetes        yes=1  no=0
29i. Persistent back pain
   yes=1  no=0
29j. Cancer
   yes=1  no=0

30a. Stroke
   yes=1  no=0
   Stroke Date: year  month
30b. Epilepsy
   yes=1  no=0
30c. Alzheimer’s Disease
   yes=1  no=0
30d. Heart Disease/Irregular
   yes=1  no=0
30e. High Blood Pressure
   yes=1  no=0
30f. Depression
   yes=1  no=0
30g. Anxiety Disorders
   yes=1  no=0
30h. Any type of addictions (alcohol/drug)
   yes=1  no=0
30i. High cholesterol
   yes=1  no=0
30j. Thyroid problems
   yes=1  no=0

31. Have you been diagnosed and/or treated for any of these eye diseases in the past year?
31a. Glaucoma
   1 = Yes  0 = No
31b. Cataracts
   1 = Yes  0 = No
31b. Cataract Surgery
   1 = Yes  0 = No
   Cataract Surgery Date (year  month )
31c. Diabetic Retinopathy
   1 = Yes  0 = No
31d. Macular Degeneration
   1 = Yes  0 = No
31e. Retinal Detachment
   1 = Yes  0 = No
31f. Optic Neuritis
   1 = Yes  0 = No
31g. Dry Eye Syndrome
   1 = Yes  0 = No
This is the last set of questions. Do you take any prescription medications?

32.  1 = Yes   0 = No

If answer #32 = yes, please list any prescription medications you take.”

32a.  
32b.  
32c.  
32d.  
32e.  
32f.  
32g.  
32h.  
32i.  
32j.  
32k.  
32l.  
32m.  
32n.  
32o.  
32p.  
32q.  
32r.  