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# Driving Decisions and Vehicle Crashes among Older Drivers

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# DRIVING DECISIONS AND VEHICLE CRASHES AMONG OLDER DRIVERS

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# ABSTRACT

American society is undergoing a major demographic transformation. A larger proportion of the population is becoming older. Moreover, an increasing number of older individuals are licensed to drive and they drive more than their age cohort a decade ago. This trend poses a problem because older drivers have higher vehicle crash rates.

Much research has been devoted to examining older drivers' driving behavior, age-related physiological and psychological changes, crash patterns, and their rate of involvement in traffic crashes. However, little has been done to establish scientific evidence that links age-related functional and mental limitations to traffic crashes and moving violations.

The objectives of this study were to identify risk factors that increase older drivers' involvement in crashes, and factors that influence older drivers' decisions on driving.

This report summarizes results of cross-sectional/time-series analyses of a panel data base that we developed using the data from the Iowa 65+ Rural Health Study. Factors that significantly contribute to older drivers' decisions to stop driving or to change their driving behavior, and factors that increase the likelihood of older drivers being involved in vehicle crashes are reported. Finally, future research needs are presented.

# CHAPTER 1. INTRODUCTION

American society is undergoing a major demographic transformation that is resulting in a larger proportion of older individuals in the population. Moreover, recent travel surveys show that an increasing number of older individuals are licensed to drive and that they drive more than their same age cohort a decade ago. However, they continue to take shorter trips than younger drivers and they avoid driving during congested hours [1]. This recent demographic transformation in our society, the graying of America, coupled with the increasing mobility of the older population, impose a potentially serious highway safety issue that cannot be overlooked. Some of the major concerns are the identification of "high-risk" older drivers based on conclusive scientific evidence and the establishment of licensing guidelines and procedures for the identified drivers.

Much research has been devoted to examining older drivers' driving behavior, age-related physiological and psychological changes, crash patterns, and their rate of involvement in traffic crashes. However, little has been done to establish scientific evidence to link age-related functional and mental limitations to driving performance in terms of traffic crashes and moving violations. Oak Ridge National Laboratory's (ORNL) objectives in this research project are to:

- ❒ Review and evaluate the 1980 American Association of Motor Vehicle Administrators (AAMVA) and National Highway Traffic Safety Administration (NHTSA) licensing guidelines. Determine whether the license restriction recommended in the 1980 AAMVA and NHTSA guidelines was based on scientific evidence or on judgement of medical advisors. Identify in the scientific literature any medical conditions which are found to be highly associated with highway crashes, and which are not mentioned in the 1980 guidelines. Summarize States' current licensing practices for drivers with age-related physical and mental limitations. Identify potential data sources to establish conclusive evidence on age-related functional impairments and highway crashes.

- ❒ Develop an analytical approach that uses epidemiological and/or medical data bases to establish the feasibility of statistically linking age-related functional impairments to increased highway risk.

- ❒ Conduct statistical analyses of data bases which are identified by ORNL as having sufficient information and adequate sample sizes; and

- ❒ Recommend future data needs should statistical analysis prove to be possible.

The assessment of various licensing guidelines suggests that much of the existing guidelines are based on consensus and professional judgement, rather than on scientific evidence [1]. Waller in his 1992 paper summarizes obstacles to establishing statistical linkages between older drivers and highway crashes [2]. He identified several methodological and administrative issues that contribute to the inconclusiveness in research involving older and medically impaired drivers. They include:

diagnostic inaccuracy, small sample size, selection bias, inconsistent definition of criteria for excessive crash risk, the lack of research on the effect of combinations of medical conditions, and the subtle nature of the interaction between driver and environment.

To determine the statistical relationship(s), if any, between age-related disease and highway crashes of older drivers, we proposed that the following two questions be addressed:

| | |
|---|---|
| **Question No. 1.** | **What are the statistical relationship(s), if any, between functional impairments, resulting from age-related medical conditions, and increased highway crash rate**? |
| | **and** |
| **Question No. 2.** | **How do these impairments change the driving behavior of the afflicted individuals**? |

To address these questions adequately, any data base should at minimum contain:

❶ the medical conditions afflicting individual older drivers, **and** the severity and the onset of these medical conditions;

❷ the amount of driving; driving behavior (driving frequency at daytime and night time, driving on different types of road, and driving in unfamiliar areas); changes in the amount of driving and driving behavior; reasons for these changes; and when these changes took place.

❸ crashes, moving violations, and license restrictions; and when these events took place.

Furthermore, all these pieces of information need to be aligned **chronologically**. With this critical data requirement in mind, existing data bases were evaluated to determine the extent to which they satisfied these requirements. None of them fully met these requirements without any augmentation. Furthermore, the **chronological** order of various events, such as vehicle crashes, driving cessation, and the onset of chronic conditions was not readily available in anyone of the data bases.

Five data bases emerged as the most promising candidates in that they can be augmented to meet the data requirements with relatively small effort -- "small" in a relative sense when compared to other data bases. They were: **Established Populations for Epidemiologic Studies of the Elderly's (EPESE) 65+ Rural Health Study** and **Yale Health and Aging Project**, **Study of Physical Performance & Age Related Changes in Sonomans**, **Health and Functioning in Marin County**, and **Quebec's Epidemiological Study of Elderly Drivers**. Steps needed to augment these data bases were outlined in [3].

Based on our evaluation, we recommended a multi-center study in which the organizations responsible for each of the five data bases be invited to participate and, funds permitting, to augment their data base. These extensions of their data bases would be done according to the action plans outlined in [3]. It was further recommended that once their data bases are augmented, each organization will address the two questions using an analysis method proposed by the ORNL and generally agreed upon by all organizations involved. Unfortunately, due to budget constraints, this multi-center study will be carried out in phases. The first phase is a study to determine the feasibility of constructing a panel data base and to develop a statistical framework to analyze this panel data base. Since data from Iowa EPESE program covers the longest time period (1981 - 1993) and contains relatively more information than other data sources, it was decided that they will be the basis for the feasibility study.

This report summarizes results of the cross-sectional/time-series analyses of a panel data base that we developed using the survey data from the Iowa 65+ Rural Health Study. Chapter 2 summarizes a review of the literature that uses multivariate analysis approaches to identify risk factors in crash involvement of older drivers and in their decisions to stop driving. Chapter 3 reports the construction of the panel data base, the major obstacles in the process, and the chronological characteristics of the study participants. Risk factors that significantly contribute to older drivers' decisions to stop drive or to change their driving behavior are reported in Chapter 4. Factors that increase the likelihood of older drivers being involved in vehicle crashes are presented in Chapter 5. Chapter 6 concludes the report by summarizing the findings and by suggesting future research needs in determining the relationship(s), if any, between age-related chronic conditions and highway crashes of older drivers.

# CHAPTER 2. LITERATURE REVIEW

## 2.1 INTRODUCTION

Much of the research on the relationships between chronic conditions in elderly drivers (e.g., arthritis, cataracts, diabetes, stroke, Parkinson's disease), changes in driving behavior, and the occurrence of vehicle crashes uses simple descriptive or bivariate analysis [1]. There is little research on the **joint** impacts of several risk factors. Although multivariate analysis techniques have been widely used in different scientific disciplines, only in the past few years have these methods been used to quantify the impacts of various risk factors on driving cessation and on vehicle crash patterns among elderly drivers [4-8].

Rather than **separately** examine the impacts of individual risk factors, and ignore the joint impacts of several risk factors, multivariate analysis techniques **concurrently** evaluates the effect of multiple risk factors. Thus, a multivariate approach overcomes many of the limitations in previous research. In essence, a multivariate analysis examines the impact of a specific risk factor on the outcome of interest (either crashes or driving cessation) by statistically holding the remaining risk factors constant.

Four of the aforementioned references [4-7] studied the relationship between driving cessation and chronic conditions, while [7] and [8] examined the impacts of medical conditions among elderly drivers on vehicle crashes. The designs of these studies from which data were collected are detailed in [3] and will not be repeated here. This chapter summarizes the status of current research which employs a multivariate analysis approach to model the relationships of both driving behavior and vehicle crash involvement as a function of chronic health conditions, functional limitations, and sociodemographic factors.

## 2.2 CHANGES IN DRIVING AND DRIVING CESSATION

### 2.2.1 Changes in Driving Behavior and Health Factors

*"Driving Cessation and Changes in Mileage Driven Among Elderly Individuals,"*

by Marottoli et al., 1993

Marottoli et al. [4] studied a cohort of 595 individuals 65 years and older living in New Haven, Connecticut. These 595 individuals were part of the cohort for the Yale Health and Aging Project who either continued to drive or had stopped driving between 1983 and 1989. Bivariate approaches were first used to assess factors individually that may contribute to these individuals' decisions to stop driving or to change their driving behavior. The factors examined in this study were categorized into the following groups:

1. Demographics, including age, gender, education, income, and housing arrangement.
2. Physical features, including the presence or absence of chronic conditions (e.g., angina, arthritis, diabetes, cataracts, glaucoma, Parkinson's disease), vision and hearing impairment, hospitalization or institutionalization status.
3. Psychosocial characteristics, such as mental status, depression, social support, social network size, marital status, the availability of alternative transportation.
4. Activity participation, consisting of the capability to perform daily living activities such as dressing and bathing; instrumental activities of daily living such as cooking and shopping; and physical activities such as exercise and gardening. Employment status is also included in this category.

By using a binomial logistic regression model, the authors concluded that the probability of <u>ceasing</u> to drive is the highest among older, poor, and unemployed individuals who are diagnosed with either neurological diseases (Parkinson' s or stroke) or cataracts, who participated in fewer physical activities, and who were unable to perform high level functions such as climbing stairs and performing heavy housework (Table 2.1). Almost half of the individuals who exhibited three or more of these risk factors stopped driving.

**Table 2.1. Predictors[1] of Recent Driving Cessation[2], [Based on data from the Yale Health and Aging Project, by Marottoli et al.]**

| Predictors | Adjusted Odds Ratio[3] | 95% Confidence Interval |
|---|---|---|
| Gender (F vs. M) | 1.26 | 0.77 - 2.07 |
| Public Housing Complex (vs. Community) | 1.33 | 0.59 - 3.00 |
| Private Housing Complex (vs. Community) | 1.52 | 0.87 - 2.66 |
| Age (increasing) | **1.17** | 1.11 - 1.23 |
| Working (no vs. yes) | **3.50** | 1.60 - 7.67 |
| Income (decreasing) | **1.21** | 1.01 - 1.46 |
| Neurologic disease (yes vs. no)[4] | **2.90** | 1.04 - 8.11 |
| Cataract (yes vs. no) | **2.29** | 1.28 - 4.10 |
| Physical activities (increasing number) | 0.73 | 0.56 - 0.94 |
| Rosow-Breslau (increasing disability)[5] | **2.13** | 1.48 - 3.06 |

[1] Data on predictors are from 1982 baseline interview.
[2] Stopped driving between 1983 and 1989.
[3] Bold typed face indicates that the adjusted odds ratio is significantly different from 1 at $\alpha$=0.05.
[4] Parkinson's disease or stroke.
[5] High level functions, such as climbing stairs, performing heavy housework.

source: [4].

Subjects who were still driving in 1989 (n=456) were the basis for addressing the question of what factors dictate these drivers' decisions to change their driving behavior in terms of the number of miles driven and changes in miles driven. Results from a binomial logistic regression model suggested that younger employed males who are socially active and who are able to perform higher level functions are more likely to drive more miles than their counterparts in the cohort (Table 2.2). Aging and increasing disability to perform high level physical functions were the only two factors that significantly contributed to the decision to reduce driving (Table 2.3).

**Table 2.2. Predictors[1] of Low (< 5,000 miles per year) vs. High (> 5,000 miles per year) Mileage Drivers[2] [Based on data from the *Yale Health and Aging Project*, by Marottoli et al.]**

| Predictors | Adjusted Odds Ratio[3] | 95% Confidence Interval |
|---|---|---|
| Gender (F vs. M) | **3.84** | 2.21 - 6.69 |
| Public Housing (vs. Community) | 0.92 | 0.31 - 2.72 |
| Private Housing (vs. Community) | 1.67 | 0.91 - 3.09 |
| Age (Increasing) | **1.18** | 1.10 - 1.26 |
| Employment (no vs. yes) | **2.03** | 1.08 - 3.80 |
| Income (decreasing) | **1.28** | 1.04 - 1.56 |
| Social Activities (increasing) | **0.67** | 0.53 - 0.83 |
| Rosow-Breslau (increasing disability)[4] | **1.49** | 1.04 - 2.11 |
| Instrumental ADL (increasing) | **1.84** | 1.07 - 3.17 |

[1] Data on predictors are from 1988 home interview.
[2] Among individuals still driving in 1989.
[3] Bold typed face indicates that the adjusted odds ratio is significantly different from 1 at $\alpha$=0.05.
[4] High level functions, such as climbing stairs, performing heavy housework.

Source: [4].

Marottoli et al. noted that many of their findings are consistent with the literature, except those that pertain to demented individuals. The authors attributed the lack of association between cognitive impairment and driving cessation in their work to subjects' lack of awareness of their impairments, the inability of the test used to detect cognitive impairment, and the lack of a sufficient number of cognitively impaired subjects included in the analysis.

**Table 2.3. Predictors[1] of Reduced Driving Compared to Five Years Ago[2]**
**[Based on data from the *Yale Health and Aging Project*, by Marottoli et al.]**

| Predictors | Adjusted Odds Ratio[3] | 95% Confidence Interval |
|---|---|---|
| Gender (F vs. M) | 1.36 | 0.85 - 2.06 |
| Public Housing (vs. Community) | 1.85 | 0.86 - 3.99 |
| Private Housing (vs. Community) | 1.11 | 0.69 - 1.80 |
| Age (increasing) | **1.10** | 1.04 - 1.16 |
| Rosow-Breslau (increasing disability)[4] | **1.63** | 1.32 - 2.02 |

[1] Data on predictors are from 1988 home interview.
[2] Among those still driving in 1989.
[3] Bold typed face indicates that the adjusted odds ratio is significantly different from 1 at $\alpha$=0.05.
[4] High level functions, such as climbing stairs, performing heavy housework.

Source: [4].

Driving-cessation models developed in [4] are true prediction models in that they model individuals who stopped driving between 1983 and 1989 based on risk factors in 1982. Similarly, individuals' decisions to change their driving behavior (e.g., driving more, the same or less) in 1989 was modeled based on data on potential predictors collected in the 1988 home interview. Unfortunately, this New Haven cohort consists only of individuals residing in urban areas. The accessibility of various services by walking and the availability of public transportation in urban areas greatly reduce the need to drive. Also, the proportion of this cohort living in restricted housing units was greater than that normally observed in the general population (>50% vs. 17%). This characteristic further reduces the need to drive because this type of housing arrangement usually has transportation services arranged for its residents. As a result, the findings from this study have limited applicability to the general population.

*"Sociodemographic and Health Factors in Driving Patterns after 50 Years of Age,"*

by Kington et al., 1994.

In 1990, a supplemental questionnaire was sent to households that took part in the nationally representative Panel Study of Income Dynamics. The questionnaire contained questions on driving habits and was sent to 3,277 eligible household heads and their spouses more than 50 years of age. Of these individuals, 2,429 (74%) completed the survey. Of those who completed the survey, 1,716 (71%) were driving in 1989 and 1,442 (84%) drove after dark. Using these data, Kington et al. [5] addressed the question: What sociodemographic, economic, and health factors among the elderly are associated with their driving and with their driving after dark?

Sociodemographic variables studied in Kington et al. [5] included age, gender, race, education, marital status, household income, number of adults in the household, place (urban vs. rural) and geographic region of residence. Employment status, which has been proven to be a key determinant of driving habits in other studies, was not included in the analysis. Three types of information summarizing an individual's health and functionality were studied: **health status**, **functional status**, and **chronic medical conditions**. Health status was measured based on scales on general health perceptions, and physical and emotional functioning were measured by using a RAND 36-Item Health Survey. Functional status was measured by self-reported limitations in activities of daily living (ADL's) and in instrumental activities of daily living (IADL's). ADL's include personal care activities such as bathing, dressing, toileting, eating, and transferring. IADL's refer to home-management activities such as meal preparation, shopping, money management and telephone use. Self-reported information on the presence of chronic medical conditions was also used, such as arthritis, hypertension, visual and hearing impairment, heart disease, diabetes, and major neurological impairment.

Similar to Marottoli et al. [4], Kington et al. developed a logistic regression model to estimate the likelihood of a respondent reporting that he/she drove, and a separate model to estimate the likelihood of driving after dark. Table 2.4 presents the significant coefficients of predictors that determine the likelihood of a respondent reporting that he/she drove in 1989. Aging, being a female, and living in a household with more adults in an urban area contribute to a lower likelihood of respondents reporting that they drive. On the other hand, being better educated, being married, and residing in North Central or West regions led to a greater likelihood of driving. Also, individuals who perceive that they have better health are more likely to drive. Individuals who have difficulty in taking medication and in preparing meals, and who have major neurological conditions and visual impairments are less likely to drive. However, those with arthritis are more likely to drive than those without. The authors attributed this unusual finding to the possible difficulty that arthritic elderly have in using poorly-suited alternative transportation modes (e.g, buses), and that continuing to drive is the least difficult mode of transportation.

Kington et al. concluded that the elderly population's need to drive and restrictions on driving after dark are not solely based on health factors. Instead, a combination of sociodemographic factors, self-perceived health, and three medical conditions - visual impairment, neurological disability and arthritis - explained much of the variation between those who drove in 1989 and those who stopped driving. However, there is some ambiguity about when some of these events occurred. Former drivers could have stopped driving anytime prior to 1989 and after they became 50 years of age. Physical impairments could have occurred after the driving ceased. Also, driving cessation that could have occurred much earlier than 1989 was correlated with a host of health factors measured in 1989. Thus, the impact of this temporal ambiguity on the conclusions about driving cessation needs further investigation. Significant factors for "predicting" driving after dark were similar to those found in the analysis of the likelihood of continuing to drive. However, self-perceived good health, being married, and having a larger number of adults in the household were not significant predictors of driving after dark. Diabetic elderly whose vision might be impaired as a result of their diabetes, and those who scored low in emotional functioning, tended to restrict their driving after dark. The authors concluded that their findings on driving behavior after dark are generally consistent with those found in other studies (Table 2.5).

**Table 2.4. Predictors of Continuing to Drive after 50 Years of Age [Based on data from the Panel Study of Income Dynamics, by Kington et al.]**

| Predictor | Adjusted Odds Ratio[1] | 95% Confidence Interval |
|---|---|---|
| Age | | |
| 60-70 | **0.070** | 0.02 - 0.03 |
| 70-80 | **0.030** | 0.006 - 0.012 |
| 80-90 | **0.004** | 0.001 - 0.019 |
| > 90 | **0.002** | 0.0002 - 0.014 |
| Female | **0.300** | 0.17 - 0.53 |
| Married | **3.060** | 1.59 - 5.92 |
| Education ( > 12 years) | **2.240** | 1.21 - 4.17 |
| No. of adults in household | **0.640** | 0.42 - 0.98 |
| Residence in urban area | **0.990** | 0.98 - 1.00 |
| Region | | |
| West | **2.760** | 1.30 - 5.88 |
| N. Central | **2.330** | 1.16 - 4.65 |
| Health perceptions | **1.180** | 1.10 - 1.27 |
| Emotional role functioning | 0.860 | 0.64 - 1.17 |
| Functional limitation | | |
| Preparing meals | **6.450** | 1.87 - 22.22 |
| Taking medications | **0.070** | 0.01 - 0.45 |
| Using phone | 1.200 | 0.34 - 4.23 |
| Visual impairment | **0.470** | 0.27 - 0.81 |
| Major neurological impairment | 0.100 | 0.04 - 0.25 |
| Arthritis | **3.080** | 1.82 - 5.23 |
| Diabetes | 0.840 | 0.93 - 1.83 |
| *Pseudo* $R^2$ | 0.5113 | |

[1] Bold typed face indicates that the adjusted odds ratio is significantly different from 1 at $\alpha$=0.05.

Since one cannot calculate an $R^2$ for multinomial logit models, a pseudo $R^2$ is calculated as a goodness-of-fit measure based on the likelihood ratio test statistic.

Source: [5].

**Table 2.5. Predictors of Driving after Dark after 50 Years of Age**
**[Based on data from the Panel Study of Income Dynamics, by Kington et al.]**

| Predictor | Adjusted Odds Ratio[1] | 95% Confidence Interval |
|---|---|---|
| Age | | |
| 60-70 | **0.360** | 0.18 - 0.71 |
| 70-80 | **0.090** | 0.05 - 0.19 |
| 80-90 | **0.030** | 0.01 - 0.07 |
| > 90 | **0.020** | 0.002 - 0.21 |
| Female | 0.170 | 0.10 - 0.29 |
| Education ( > 12 years) | **3.390** | 1.95 - 5.92 |
| Emotional role functioning | 1.390 | 1.06 - 1.82 |
| Functional limitation- | | |
| Shopping | 0.300 | 0.10 - 0.90 |
| Telephone use | 17.320 | 1.00 - 300.67 |
| Visual impairment | **0.270** | 0.16 - 0.47 |
| Major neurological impairment | 0.260 | 0.08 - 0.80 |
| Arthritis | **1.760** | 1.08 - 2.86 |
| Diabetes | 0.340 | 0.18 - 0.66 |
| *Pseudo $R^2$* | 0.3464 | |

[1] Bold typed face indicates that the adjusted odds ratio is significantly different from 1 at $\alpha$=0.05.

Since one cannot calculate an $R^2$ for multinomial logit models, a pseudo $R^2$ is calculated based on the likelihood ratio test statistic as a goodness-of-fit measure .

Source: [5].

"*Medical Conditions Associated with Driving Cessation in Community-Dwelling, Ambulatory Elders,"*

by Campbell et al., 1993.

Campbell et al. [6] examined a group of 1,954 elderly individuals who participated in the eighth visit of the Florida Geriatric Research Program to determine the prevalence of medical conditions among those who no longer drive and those who have continued to drive. In order to participate in this program, individuals needed to be ambulatory, 65 years or older, and reside in Dunedin, Florida. During the eighth visit, a set of driving-related questions were administered, such as: driver's license status; whether still driving, the reasons for stopping driving, driving regularity in the past; licenses revoked; and involvement in vehicle crashes in the past. Of the 1,954 participants, 298 (15.3%) never drove and were excluded from the analysis, 276 (14.1%) drove regularly in the past but stopped driving, and 1,380 (70.6%) continued to drive.

Based on the results from logistic regression models, Campbell et al. reported that the likelihood of stopping to drive increased with age, and in women. Compared to drivers 70-74 years old, those 85 years or older are 11 times more likely to stop driving. Controlling for the impacts of age and gender on the decision to stop driving, the analysis showed that conditions that result in sensory impairments, such as retinal hemorrhage, retinal detachment, and macular degeneration, were significantly more prevalent among former drivers than current drivers. Furthermore, Parkinson's disease, syncope, stroke, or activity limitations (defined in this study as having someone help with shopping, housework, bathing, dressing, or getting around) was also associated with the decision to stop driving.

Hearing impairment, and diagnosis of cataracts or glaucoma were not significantly associated with stopping driving. Also unrelated to the decision to stop driving were medical conditions that result in mild disabilities that do not hamper a driver's capability to drive. These include arthritis, diabetes, myocardial infarction, and malignant neoplasms.

Many of the risk factors identified in the bivariate analysis became statistically insignificant in the multiple logistic regression models. Models were developed separately for male and for female drivers, and for all genders combined. Factors attributable to driving cessation were somewhat different for male than for female drivers (Table 2.6). While stroke sequelae contributed to male drivers' decisions to stop driving, it was not significant for female drivers. On the other hand, Parkinson's disease and retinal hemorrhage were significant factors in female drivers' decisions to stop driving, but not in male drivers. Table 2.7 shows the odds ratios of the significant risk factors in the combined model, and the associated 95% confidence intervals. The risk factors that were significantly associated with the decision to stop driving included age, gender, daily activity limitations, and five medical conditions - macular degeneration, stroke sequelae, syncope, Parkinson's disease, and retinal hemorrhage. All of these health-related risk factors result in impairments in gross motor or visual skills.

**Table 2.6. Significant Predictors of Driving Cessation[1] by Gender**
**[Based on data from the Florida Geriatric Research Program, by Campbell et al.]**

| Predictors | Male | | Female | |
|---|---|---|---|---|
| | Odds Ratio | 95% Confidence Interval | Odds Ratio | 95% Confidence Interval |
| Age | 1.20 | 1.1 - 1.3 | 1.18 | 1.1 - 1.2 |
| Activity limitations | 11.84 | 5.9 - 23.9 | 2.42 | 1.6 - 3.6 |
| Syncope | 3.20 | 1.4 - 7.2 | 1.75 | 1.0 - 3.0 |
| Macular degeneration | 7.01 | 3.1 - 15.9 | 3.67 | 2.0 - 6.8 |
| Stroke sequelae | 3.33 | 1.2 - 9.5 | - | - |
| Parkinson's disease | - | - | 8.45 | 1.8 - 39.0 |
| Retinal hemorrhage | - | - | 4.70 | 1.2 - 17.8 |
| *Number of Observations* | *n=615* | | *n=833* | |

[1] Those stopped driving one year, 1-5 years, 6-10 years or 11 or more years prior to the eighth visit in 1987.

Source: [6]

**Table 2.7. Significant Predictors of Driving Cessation[1]**
**[Based on data from the Florida Geriatric Research Program, Campbell et al.]**

| Predictors | Odds Ratio | 95% Confidence Interval |
|---|---|---|
| Age | 1.18 | 1.1 - 1.2 |
| Gender (male=1) | 0.39 | 0.3 - 0.6 |
| Activity limitations | 3.37 | 2.4 - 4.8 |
| Syncope | 1.91 | 1.2 - 3.0 |
| Macular degeneration | 4.25 | 2.6 - 7.0 |
| Stroke sequelae | 3.02 | 1.3 - 6.9 |
| Parkinson's disease | 6.36 | 1.9 - 21.2 |
| Retinal hemorrhage | 3.86 | 1.4 - 10.4 |
| *Number of Observations* | *1428* | |

[1] Those stopped driving one year, 1-5 years, 6-10 years or 11 or more years prior to the eighth visit in 1987.

Source: [6]

Two-thirds of the former drivers had one or more of the six health-related conditions (i.e., daily activity limitations, macular degeneration, stroke sequelae, Parkinson's disease, retinal hemorrhage, and syncope), while only 27% of the current drivers did. Campbell et al. further examined the probability of driving cessation as a function of the increase in the number of the six health-related conditions to which an individual was exposed. They concluded that the odds of giving up driving increased with each additional condition. For example, those with three or more of these conditions are 60 times more likely to give up driving than someone without any of these conditions. Based on the odds ratios derived from their multiple logit models and on the prevalence rates of the six health-related conditions, the authors estimated that 57% of decisions to stop driving are attributed to these six conditions in the general population. Among these six conditions, acquiring a limitation in daily activity was responsible for a quarter (26%) of the decisions to cease driving, followed by visual impairment (17%).

Several limitations in Campbell et al. were acknowledged by the authors. First, participants in this study were thought to be healthier than the general population and to be in lower-income categories. Thus, results from this study cannot be readily generalized to the older population. Second, driving behavior was self-reported, no information was available on the distance driven and on the severity of disease, and inconsistency in reporting medical conditions was observed from one visit to the next. This missing information and recall bias inevitably biased the results. Lastly, the exact year when former drivers stopped driving was unknown. It could be 12 months or a decade prior to the eighth visit (1987). The lack of detail about the temporal order of conditions and driving cessation adds uncertainty to the results.

The consequence of this lack of temporal detail is difficulty in interpretating the results. This is because the models were developed by relating changes, that occurred sometime during the period from 12 months to a decade prior to 1987, to a set of potential risk factors that existed in 1987. In essence, the models tested physical, mental and other characteristics of older drivers, as observed in 1987, to determine which ones of these characteristics influenced their decisions to stop driving a decade prior to 1987.

"*Driving Cessation and Accidents in the Elderly: An Analysis of Symptoms, Diseases, Cognitive Dysfunction and Medications,*"

by Stewart et al., 1993.

A parallel analysis of the participants in the Florida Geriatric Research Program was conducted by Stewart et al. [7]. In their study, the authors examined the relationship between driving cessation and 31 diseases, 26 symptoms, 34 clinical tests, the 50 most frequently used drug ingredients, and the 15 most frequently used therapeutic drug categories. Despite the fact that both [6] and [7] studied the same group of subjects, it is not clear why some of the descriptive statistics on the subjects from these two studies are different. For example, Stewart et al. reported that there were 1,229 subjects who continued to drive in 1987, compared to 1,380 reported by Campbell et al.

Stewart et al. performed their analysis in several sequential steps. First, bivariate analysis identified individual factors that were significantly associated with driving cessation. Significant factors identified in the previous step were then categorized into four groups: (1) reported symptoms, (2) reported diseases, (3) drug ingredients used and therapeutic drug categories, and (4) laboratory/clinical examinations (e.g., systolic and diastolic blood pressures, height, and weight). A stepwise logistic regression model was developed on each of the four groups to identify risk factors that are significantly associated with driving cessation. Finally, factors found to be significant in each group were used together to develop a final stepwise logistic regression model.

The final model suggested that increasing age; being a female; having macular degeneration, a stroke, eye problems caused by poor health, and Parkinson's disease; being hospitalized in the past year; and the use of alcohol increased the likelihood of stopping driving. The regular use of magnesium hydroxide decreased the likelihood of stopping driving (Table 2.8). The impact of magnesium hydroxide on driving cessation was unclear to the authors, Stewart et al., and was suggested as a topic for future study.

Although this study made considerable progress by taking into account the impacts of drug use on driving cessation in a multivariate framework, several data limitations similar to those observed by Campbell et al. in [6] are likely to limit the results. Among them, the greatest limitation is probably the lack of temporal detail between driving cessation and medical conditions. How to interpret the effect of currently observed risk factors on driving cessation, that could have occurred a decade ago, is unclear.

**Table 2.8. Significant Factors Correlating with Driving Cessation**
**[Based on data from the Florida Geriatric Research Program, by Stewart et al.]**

| Factor | Adjusted Odds Ratio | 95% Confidence Interval |
|---|---|---|
| Age | 2.31 | 1.91 - 2.78 |
| Gender (men) | 0.26 | 0.18 - 0.39 |
| Macular degeneration | 3.32 | 1.91 - 5.77 |
| Stroke | 2.70 | 1.54 - 4.65 |
| Parkinson's disease | 4.95 | 1.19 - 20.6 |
| Eye problems by poor health | 1.98 | 1.16 - 3.39 |
| Hospitalized past year | 1.75 | 1.19 - 2.58 |
| Drink alcohol | 0.51 | 0.37 - 0.74 |
| Use magnesium hydroxide | 0.40 | 0.19 - 0.81 |

Source: [7]

### 2.2.2 Summary of Changes in Driving Behavior and Health Factors

Among the aforementioned four papers ([4]-[7]), only models reported by Marottoli et al. [4] have any real predictive content in that the authors correlated the occurrence of driving cessation/changes to risk factors observed at an earlier date. Although some of the former drivers in Kington et al. [5] may have ceased driving in 1989, when the risk factors were observed, it is unclear how many of these former drivers had ceased to drive prior to 1989. Both Campbell et al. [6] and Stewart et al. [7] used basically an identical group of subjects. They used risk factors observed in 1987 to "determine" the probability of driving cessation, which may have occurred a decade ago.

Data from only one of the four studies, Kington et al. [5], can be used to assess the impacts of land use patterns on driving behavior and to apply its results to the general population. This is because subjects studied in Kington et al. [5] were from a national panel. This characteristic imparts sufficient variation in data so that the authors can study the impacts of household location (e.g., urban vs. rural), and the availability of public transportation on the decision to cease driving. This characteristic also allows the possibility of generalizing the results from [5] to the U.S. population as a whole.

The undertaking of trying to draw a consensus from these studies ([4] - [7]) that influence an older driver's decision to stop driving is complicated for two reasons. First, risk factors are almost always defined and/or grouped differently from one study to the next. Second, as mentioned earlier, the temporal relationship between driving cessation, driving changes and medical conditions is different among these studies -- while Marottoli et al. [4] predicts the probability of driving cessation/changes that occurred between 1983 and 1989 based on a set of risk factors observed in 1982, the others ([5] - [7]) used risk factors observed at a later date to "correlate" the occurrence of driving cessation/changes during an earlier time period. Table 2.9 strives to provide an overall view of significant factors in older drivers' decisions to stop driving. However, it should be noted that a direct comparison among these studies is inappropriate. In general, increasing age, being a female, being diagnosed with Parkinson's disease or having a stroke, and impairments in vision and motor skills surface as the most common risk factors in the probability to stop driving.

Although much research in the past decade has attempted to gain better insight as to why an older driver made her/his decision to stop driving, all of them addressed this issue using a bivariate approach and none of them studied the problem from a multivariate analysis framework, until the work by Stewart et al. [7] was published in 1993. By approaching the driving-cessation problem from a multivariate framework, Stewart et al. extended the understanding of the process underlying decisions to stop driving beyond the traditional two-dimensional perspective. Despite this progress, research on the driving-cessation problem needs to continue due to two major drawbacks. The first problem is the lack of temporal detail on driving cessation and medication conditions. The second

**Table 2.9. Summary of Significant Factors Correlated with Driving Cessation**

| | Sources | | | | |
|---|---|---|---|---|---|
| | | | Campbell et al.[2] | | |
| **Factor** | **Marottoli et al.** | **Kington et al.[1]** | **Female** | **Male** | **Stewart et al.[3]** |
| Demographics and Household Characteristics | | | | | |
| Age (increasing) | ✛ | ✛ | ✛ | ✛ | ✛ |
| Gender (male) | ✗ | — | na | na | — |
| Race | ✗ | ✗ | -- | -- | -- |
| Employment (yes) | — | -- | -- | -- | -- |
| Income (increasing) | — | ✗ | -- | -- | -- |
| Housing arrangement | ✗ | -- | -- | -- | -- |
| Education (increasing) | ✗ | — | -- | -- | -- |
| Marital status | ✗ | — | -- | -- | -- |
| No. of adults in HH | -- | ✛ | -- | -- | -- |
| Urban area | -- | ✛ | -- | -- | -- |
| Geographic region (West and N. Central) | -- | — | -- | -- | -- |
| Public transit available | -- | ✗ | -- | -- | -- |
| Chronic conditions | | | | | |
| Arthritis | ✗ | — | ✗ | ✗ | ✗ |
| Diabetes | ✗ | ✗ | ✗ | ✗ | ✗ |
| Parkinson's disease | ✛ | ✛[4] | ✛ | ✗ | ✛ |
| Stroke | ✛ | -- | ✗ | ✗ | ✛ |
| Stroke sequelae | -- | -- | ✗ | ✛ | ✗ |
| Heart diseases | ✗ | ✗ | ✗ | ✗ | ✗ |
| Hypertension | -- | ✗ | ✗ | ✗ | ✗ |
| Syncope | -- | -- | ✛ | ✛ | ✗ |
| Cataract | ✛ | -- | ✗ | ✗ | ✗ |
| Glaucoma | ✗ | -- | ✗ | ✗ | ✗ |
| Macular degeneration | -- | -- | ✛ | ✛ | ✛ |
| Retinal hemorrhage | -- | -- | ✛ | ✗ | ✗ |

| Factor | Sources | | | | |
|---|---|---|---|---|---|
| | Marottoli et al. | Kington et al.[1] | Campbell et al.[2] | | Stewart et al.[3] |
| | | | Female | Male | |
| Physical capability | | | | | |
| Activity limitation (increasing) | ✢ | ✗ | ✢ | ✢ | -- |
| High-level function limitation (increasing) | ✢ | ✢ | -- | -- | -- |
| Visual impairment | ✗ | ✢ | ✗ | ✗ | ✢ |
| Hearing impairment | ✗ | ✗ | ✗ | ✗ | ✗ |
| Cognition and Attitudes | | | | | |
| Health perception (good) | -- | — | -- | -- | -- |
| Mental status | ✗ | -- | -- | -- | -- |
| Depression | ✗ | -- | -- | -- | -- |
| Memory loss | -- | -- | ✗ | ✗ | ✗ |
| Emotional function | -- | ✗ | -- | -- | -- |
| Drugs | | | | | |
| Drug ingredients | -- | -- | -- | -- | —[5] |
| Therapeutic drug | -- | -- | -- | -- | ✗ |
| Behavioral factors[6] | | | | | |
| Drinking alcohol | -- | -- | -- | -- | — |
| Hospitalization | ✗ | -- | -- | -- | ✢ |
| Institutionalization | ✗ | -- | -- | -- | -- |
| Social support | ✗ | -- | -- | -- | -- |

-- = not included in the study.
✢ = increased the likelihood of driving cessation.
— = decreased the likelihood of driving cessation.
✗ = nonsignificant.

1 Predictors of driving cessation of older drivers after 50 years of age.
2 For combined model.
3 Due to the large number of individuals factors tested in the analysis, not all the factors are listed.
4 Neurological impairment.
5 Included the 50 most frequently used drug ingredients, and only one drug ingredient, magnesium hydroxide, is a significant risk factor.
6 Other behavior factors examined in [7] included smoking, drinking coffee, exercise regularly.

problem are the interaction effects among different risk factors and the fact that the impacts of co-morbid conditions have never been fully addressed.

In terms of changes in driving behavior, Marottoli et al. [4] concluded that aging and increasing disability to perform high level physical functions were the only two factors that significantly contributed to the decision to reduce driving. Aging, being a female, having visual impairment, and being diagnosed with diabetes and arthritis increased the likelihood of restricting driving after dark (Kington et al. [5]).

## 2.3 VEHICLE CRASHES

### 2.3.1 Risk Factors for Vehicle Crashes in Elderly Drivers

"*Driving Cessation and Accidents in the Elderly: An Analysis of Symptoms, Diseases, Cognitive Dysfunction and Medications*,"

by Stewart et al., 1993.

Using the same group of subjects as in their analysis of the risk factors in driving cessation, Stewart et al. [7] investigated the risk factors for vehicle crashes in older drivers. As in their analysis of the decision to stop driving, the authors first tested individual risk factors as to whether the proportions of drivers in both the control (have not been involved in crashes in the past 5 years, $n=1,289$) and the case (have been involved in crashes in the past 5 years, $n=142$) groups who exhibited a given risk factor were statistically different. They did this analysis using either a 2-sample $z$ test or a $\chi$-square test. To avoid potentially important factors from being excluded from the final model, the Bonferroni inequality was used to ensure that the overall significance level for all of the tests is less than 0.10.

Once significant risk factors were identified, they were categorized into four factor groups: (1) reported symptoms, (2) reported diseases, (3) drug ingredients used, and (4) laboratory/clinical tests. A stepwise logistic regression procedure was used on each factor group to select factors that were highly correlated with being involved in a traffic crash. Finally, factors found to be significant in each factor group, as well as age, gender, and behavioral factors (e.g., hospitalization, drinking and smoking habits, and exercise), were combined to calibrate the final logistic regression model. Age, gender and the most commonly used drug ingredients were found to be not correlated with being involved in vehicle crashes. Among the diseases that were studied extensively in the literature (such as stroke, Parkinson's disease, eye problems, diabetes, arthritis, cataract, and glaucoma), none of them was found to be significantly related to vehicle crashes. The only medical condition that was significantly correlated to vehicle crashes is bursitis. Table 2.10 lists factors found to be correlated with vehicle accidents [7].

**Table 2.10. Factors Correlated with Vehicle Accidents**
**[Based on data from the Florida Geriatric Research Program, by Stewart et al.]**

| Factor | Adjusted Odds Ratio[1] | 95% Confidence Interval |
|---|---|---|
| Age | 1.12 | 0.90 - 1.36 |
| Gender (men) | 1.11 | 0.75 - 1.62 |
| Bursitis | **2.26** | 1.43 - 3.57 |
| Cold in feet and legs | **1.90** | 1.22 - 2.98 |
| Protein in urine | **1.79** | 1.18 - 2.71 |
| Irregular heartbeat | **1.57** | 1.05 - 2.35 |

[1] Bold typed face indicates that the adjusted odds ratio is significantly different from 1 at $\alpha$=0.05.

source: [7].

In Stewart et al. [7], the question pertinent to being involved in a traffic accident was phrased as "*Have you been involved in a traffic accident in the past: (1) year, (2) 1 to 5 years, (3) 6 to 10 years), (4) 11 years or longer, (5) no accident*, and *(6) unknown*." This question was addressed to all participants of the eighth visit of the Florida Geriatric Research Program. Based on the answer to this question, Stewart et al. related physical and functional characteristics, drug use and other behavioral factors collected in the eighth visit to traffic accidents that occurred at any time during the period from the past 12 months to 11 years prior to the eighth visit. As a result of this temporal ambiguity, the interpretation of the study's results can be questioned. Moreover, no data on the amount of driving were available to test the hypothesis that individuals who drive more are more likely to be involved in crashes than those who drive less.

"*Risk Factors for Motor5 Vehicle Crashes Among Older Drivers in a Rural Community,*"

by Foley et al., 1995.

A group of 1,854 individuals aged 68 and older who were still driving as of 1988 were the basis of a study on vehicle crashes by Foley and his colleagues [8]. These 1,854 confirmed licensed drivers were participants in the third follow-up (in 1985) of the Iowa 65✢ Rural Health Study, one of the four Established Populations for Epidemiologic Studies of the Elderly (EPESE). The 1985 in-person household interview included questions on:

- physical functioning, including three Rosow and Breslau gross-mobility items, and 5 activities of daily living by Katz et al.;
- hearing and vision function;
- chronic diseases and chronic symptoms, including heart disease, cancer, stroke, diabetes,

arthritis, cataracts, glaucoma, and back pain;
- prescription and over-the-counter medications used during the two-week period prior to the interview; and
- tests for depression (measured by an 11-item version of the 20-item Center for Epidemiologic Studies Depression scale), cognitive impairment (using a modified version of the short portable mental status questionnaire (SPMSQ)), and memory loss (using a twenty-word recall test).

From the Iowa Department of Motor Vehicles, the crash histories of these drivers from 1985 to 1989 was assessed. During this period, 206 drivers were involved in 242 reported crashes. Based on the total number of person-years of driving, Foley et al. calculated the estimated annual crash involvement rate to be 28 per 1,000 person-years of driving (= 206/7,300).

Foley et al. used a Cox proportional hazards regression model to calculate the age and gender adjusted odds ratio for each of the selected risk factors [8]. The dependent variable in their model was the number of months from the 1985 interview until the first reported crash (or December 1989 for those for whom no crash was reported, or the day of death for those deceased prior to December 1989, or the mid-year for those who quit driving or were institutionalized).

Gender was a more important risk factor than age in the likelihood of having a crash. Men were 60% more likely to be involved in crashes than women. After controlling for this gender effect, increasing age did not contribute to a significantly higher risk of crashing [8]. Based on the results from Cox proportional hazards regression models, those who exhibited severe depression symptoms (i.e., who scored in the highest quintile), scored low (in the lowest one-third) on the memory test, or had a recent history of back pain had higher risk of crashing than the remaining members of the cohort (Table 2.11). However, the contribution of depression to the likelihood of being involved in crashes became negligible in a multivariate model. None of the chronic diseases (such as heart attack, stroke, diabetes, and arthritis) was significantly correlated with being involved in vehicle crashes.

Among all of the prescription and over-the-counter medications taken by the drivers two weeks prior to the 1985 interview, drivers who reported taking non-steroidal anti-inflammatory agents were 80% more likely to be involved in crashes than those who did not. No association was found between the total number of medications used and the risk of being involved in crashes.

The finding of no association between medications used and the risk of crashing may not be surprising since medications used during a two-week period in 1985 may well not have any significant impacts on the risk of crashing four to five years later. Furthermore, using the number of person-years of driving as the proxy for crash exposure might mask the impact of aging on the

**Table 2.11. Predictors of Being Involved in Vehicle Crashes**
**[Based on data from the Iowa 65+ Rural Health Study, Foley et al.]**

| Predictor[1] | Crash Involvement Rate[2] | Adjusted Odds Ratio | 95% Confidence Interval |
|---|---|---|---|
| **Physical Disability** | | | |
| Functional limitation[3] | 25 | 0.9 | 0.6 - 1.3 |
| ADL limitation | 30 | 0.9 | 0.5 - 1.7 |
| **Vision Status** | | | |
| History of cataracts | 25 | 0.9 | 0.6 - 1.2 |
| History of glaucoma | 41 | 1.6 | 0.9 - 2.8 |
| Cannot read newspaper | 41 | 1.2 | 1.5 - 2.9 |
| Cannot recognize friend | 26 | 1.0 | 0.4 - 2.2 |
| **Hearing Status** | | | |
| Wears a hearing aid | 37 | 1.3 | 0.9 - 1.9 |
| Cannot hear normal voice | 26 | 0.9 | 0.5 - 1.5 |
| Has singing in the ears | 26 | 0.9 | 0.6 - 1.3 |
| **Mental Status** | | | |
| Over 80% depressive score | 39 | **1.5** | 1.1 - 2.0 |
| > 2 errors on mental test | 30 | 1.0 | 0.5 - 1.5 |
| < 5 words (1st recall)[4] | 34 | 1.2 | 0.9 - 1.6 |
| < 3 words (2nd recall)[4] | 36 | **1.4** | 1.0 - 1.8 |
| **Chronic Symptoms** | | | |
| History of back pain | 35 | **1.5** | 1.1 - 2.2 |
| Chest pain (ever had) | 36 | 1.3 | 0.9 - 1.8 |
| Chest pain ( > 30 min.) | 20 | 0.6 | 0.3 - 1.2 |
| Respiratory symptoms | 32 | 1.1 | 0.8 - 1.4 |
| Urinary symptoms | 29 | 1.0 | 0.8 - 1.4 |

[1] Based on 1985 in-person home interview.
[2] Number of drivers per 1,000 estimated person years of driving.

[3] Unable to do heavy work, walk half a mile, climb stairs and no ADL limitation..
[4] In a 20-word recall test.

Source: Table 2 of [8]

likelihood of being involved in crashes. It is well known that the amount of driving decreases nonlinearly with aging. A female driver 85 years or older drives, on the average, less than one-third of a female driver 20 years her junior while the corresponding rate is less than 40% for male drivers. Using the person-years of driving as a measure of crash exposure suggests that one person-year of driving by either a 85 year old or 65 year old driver carries the same weight in the crash analysis. In fact, a 65 year old driver may have a significantly small probability of being involved in crashes compared to a 85 year old driver, other things being equal.

Foley et al. [8] also recognized several other limitations of the data or method, and claimed that their findings were preliminary. One of the limitations in the analysis was that it did not control for the overall significance level of the large number of comparisons (e.g., Bonferroni inequality). Consequently, some of the observed significant associations may not be genuine and may simply be due to chance.

### 2.3.2 Summary on Vehicle Crashes and Health-Related Characteristics

Both [7] and [8] attempted to understand the factors that increase the risk of older drivers being involved in vehicle crashes and reached very different conclusions. Stewart and his colleagues found that both age and gender are not associated with vehicle crashes while Foley et al. found that gender is a more important risk factor than age in the likelihood of being involved in crashes. Medications used were found not to be significant in increasing the risk of crashing by Stewart et al. while Foley et al. found that the use of non-steroidal anti-inflammatory medication increased the risk of crashing. Memory loss was not correlated with vehicle crashes in [7] but was in [8]. Among symptoms, feeling cold in the feet and legs, and irregular heartbeat, were the two most important symptoms relating to the increased likelihood of older drivers being involved in vehicle crashes [7], while having a history of back pain was the most important symptom in [8]. Bursitis (inflammation of a bursa) was the only chronic disease contributing to the high risk of crashing [7], while Foley et al. concluded that no chronic disease contributed to the risk of crashes. In fact, this direct comparison between [7] and [8] is unjustified in that the results from [7] are somewhat artificial due to the temporal ambiguity in its data as mentioned earlier.

# CHAPTER 3. PANEL DATA BASE

## 3.1 The Need for a Panel Data Base

The major drawback of all previous research in the areas of driving cessation and vehicle crashes in relation to health-related factors is the lack of temporal detail between events (i.e., onset of medical condition and symptom, crash, driving cessation, change in driving behavior). Having a temporal profile is crucial to this analysis. It allows one to determine whether crashes and changes in driving behavior take place before or after the onset of a medical condition. This type of delineation removes any confounding effects of having individuals involved in crashes or changes in their driving behavior before the onset of their medical condition. For these individuals, whether medical conditions and functional limitations contribute to a higher probability of highway crashes cannot be determined with certainty. Also, it cannot be determined with certainty whether these factors contribute to changes in driving behavior (self-regulated driving due to the disease) [3].

Without this type of time-series data, researchers often link a "snap-shot" of medical conditions and driving patterns to more than one year of crash data, hoping to accumulate enough data on crashes. Examples include [4] through [8], and a Quebec study which adopted 1990 as the reference year for driving patterns (including the amount of driving) and medical conditions, and linked these data to crash data from the 1987-1990 period [9]. Also, Foley et al. [10] used 1989 as the reference year for driving patterns and medical conditions, and linked this 1989 "snap shot" to three years of crash data from 1987 to 1989.

The interpretation of the results of these studies is somewhat difficult. One cannot attribute medical conditions to the increase in highway crash rate or to changes in driving behavior. For example, assume that the group of cases, at reference time *t*, is found to experience a higher (or lower) crash rate than the control group; and that the crash rate is observed during the period from *t-3* to *t* (to accumulate enough crash data). This finding would not, however, allow one to conclude that this difference in crash rate is attributable to a specific medical condition that is observed as of period *t*. There may be cases in which the onset of disease took place between *t-3* and *t*, but after the time of the crash. A similar argument applies when determining the relationship between medical conditions and changes in driving behavior. Recognizing this limitation, Campbell and her associates stated in [6] that since "..the date at which driving was given up was not determined in the questionnaire. Hence, the temporality of conditions and driving cessation cannot be established with certainty..."

To mitigate this limitation, an extensive effort was undertaken by ORNL to develop a data base using the survey data from the Iowa 65+ Rural Health Study[1]. The baseline year of this study began in 1981 and its tenth follow-up ended in 1993. The outcome of ORNL's undertaking is a time profile of each study participant's annual status in terms of his/her general demographic and health conditions, chronic medical conditions and symptoms, changes in driving behavior, attitudes, social support, crashes and other characteristics from 1982 (or 1981 for some participants) to 1993 (or 1992 for some participants). With the nature of this data base being on annual profile of these participants, it is referred to as a panel data base.

This chapter describes the construction of this panel data base. The source of the data that we used to construct this panel data base is characterized in the following section. Section 3.3 outlines the major steps taken during the construction of this data base and Section 3.4 describes the major obstacles in this process. The last section summarizes some characteristics of the study participants in this panel data base.

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1 This study was conducted by the University of Iowa, under the leadership of Dr. R. Wallace, and was funded by the National Institute on Aging.

## 3.2 Source of Data

The Iowa 65+ Rural Health Study began in 1981/82 in two Iowa counties (Iowa and Washington), as part of the Established Population for Epidemiological Studies of Elderly (EPESE) program[2]. Based on the 1980 U.S. Decennial Census, these counties were classified as rural farm and nonfarm areas. All noninstitutionalized individuals 65 years or older residing in these two Iowa counties were included in the baseline survey in 1981/1982. The participation rate was 80% (3,673 persons) in 1982. An in-home interview was conducted every three years (1982, 1985, 1988); and a telephone interview was used in the intervening years.

The baseline survey collected the following information:

- ❐ Demographic attributes, employment status, income, living arrangement, social network and support, life satisfaction, moods, worries, and life events (health or job changed, marriage, death, etc.).
- ❐ Blood pressure, other vital statistics, sleep patterns, chest pain, hearing problems and the use of a hearing aid, oral health, medical service use, smoking and alcohol use.
- ❐ Medical conditions and the onset of the condition such as - myocardial infarction, heart attack and heart diseases, diabetes, high blood sugar, stroke, brain hemorrhage, cancer or tumor, high blood pressure, broken or fractured hip, cataracts, glaucoma, arthritis, Parkinson's disease, and liver and lung diseases.
- ❐ Symptoms and ailments such as pain in legs or joints, arthritis or rheumatism, shortness of breath, cough, and wheezing.
- ❐ Functional status. The ability to perform some physical activities of daily living such as washing windows, walking up and down stairs, shopping for groceries, and preparing meals.
- ❐ Physical functioning such as pushing large objects, writing, standing for a long period, and picking up objects from the floor.
- ❐ Physical activities and hobbies such as doing yardwork, taking a walk, and collecting stamps.

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[2] This study is hereafter referred to as the Iowa EPESE Program.

- ❒ Vision. The ability to recognize friends or read ordinary newspaper print (which was self-reported.)
- ❒ Prescription and over-the-counter drug used in the two-week period prior to the survey. The intake frequency "for yesterday" as well as "during the past two weeks" was recorded for each drug used.
- ❒ Dementia, memory and cognitive function. Memory was self-evaluated.

In its seventh follow-up survey (1989), a set of questions were added on driving practices:

- ❒ Driving behavior and transportation modes (car, taxi, minibus). Information was collected on driver's license status, the reasons for not having a license (no need, never learned to drive, problems with eyesight or health). If the respondent was no longer driving, information was collected on when and why driving was stopped (trouble moving or remembering, slower reaction time, trouble with dizziness, problems with eyesight, cost). If the respondent is still driving, questions were asked about driving frequency (daily, at least twice a week, etc.); any change in the amount of driving compared to 5 years ago; the reasons for driving less; driving frequency after dark, on expressways, on unfamiliar roads, on long trips, and on snowy or rainy roads; and the reasons for driving less under different circumstances (after dark, on expressways, on unfamiliar roads, etc.); vehicle make and model; the estimated annual miles driven during the 12-month period prior to the survey; and the type of restriction on their licenses, if any.
- ❒ Other transportation needs, transportation services, and the use of a restraint device.

This driving-related information was updated in the tenth follow-up (1992).

During the first half of the Iowa EPESE program, the attrition rate was about 5-6% per interview. With an increasing number of the subjects getting older or deceased, the attrition rate toward the second half of the program increased to about 9% per year (Table 3.1). By the 7th follow-up, 2,563 interviews were completed, of which 237 were completed by proxy interview for deceased participants. The ages of the surviving participants in the 10th follow-up range from 76 to 106 years old, with an average age of 84.

Among the surviving participants in the seventh follow-up, 1,340 of them continued to drive. In the tenth follow-up (1992), there were 1,864 surviving participants and 962 of them continued to drive (Table 3.2). In this study, drivers are defined as those who indicated that they drove themselves to places *or* that they still drove. The eighth and the ninth follow-ups did not take place due to budget constraints.

**Table 3.1. Number of Participants in Each Interview, by Gender, Iowa 65+ Rural Health Study**

| Interview (Beg. Yr. - End Yr.) | Gender | | | | Surviving Participants | Deceased Proxy Interview |
|---|---|---|---|---|---|---|
| | Male | | Female | | | |
| | Number | Ave. Age | Number | Ave. Age | | |
| Baseline (1981-1982) | 1,420 (*38.7%*) | 74.74 | 2,253 (*61.3%*) | 75.91 | 3,673 (*100%*) | 0 |
| 1th FU (1982-1986) | 1,327 (*37.9%*) | 75.65 | 2,170 (*62.1%*) | 76.83 | 3,497 (*100%*) | 125 |
| 2nd FU (1983-1986) | 1,215 (*37.5%*) | 76.38 | 2,086 (*62.5%*) | 77.62 | 3,337 (*100%*) | 137 |
| 3rd FU (1984-1986) | 1,137 (*36.4%*) | 77.10 | 1,989 (*59.6%*) | 78.49 | 3,126 *(100%*) | 159 |
| 4th FU (1985-1987) | 1,064 (*35.6%*) | 77.84 | 1,927 (*64.4%*) | 79.35 | 2,991 *(100%*) | 140 |
| 5th FU (1986-1989) | 981 (*35.1%*) | 78.66 | 1,813 (*64.9%*) | 79.98 | 2,794 *(100%*) | 175 |
| 6th FU (1987-1989) | 877 (*34.4%*) | 79.48 | 1,670 (*65.6%*) | 80.82 | 2,547 *(100%*) | 192 |
| 7th FU (1988-1990) | 765 (*32.9%*) | 80.03 | 1,561 (*67.1%*) | 81.52 | 2,326 *(100%*) | 237 |
| 10th FU (1991-1993) | 571 *(30.63%*) | 82.36 | 1,293 *(69.37%)* | 84.08 | 1,864 *(100%*) | 0 |

Note: FU= Follow-Up.

**Table 3.2. Number of Participants Who Still Drive -**
**7th and 10th Follow-ups of the Iowa 65+ Rural Health Study**

| Age | **Baseline** Sample Size | **7th Follow-up** | | **10th Follow-up** | |
|---|---|---|---|---|---|
| | | Sample Size[2] | Drivers[1] | Sample Size[2] | Drivers[1] |
| 65-71 | 1,399 | 0 | 0 | 0 | 0 |
| 72-79 | 1,390 | 1,095 | 846 | 535 | 405 |
| 80+ | 884 | 1,231 | 494 | 1,329 | 557 |
| TOTAL | 3,673 | 2,326 | 1,340 | 1,864 | 962 |

[1] Included those who indicated that they drove themselves to places **or** those who drove during the year when the interview took place.

[2] Excluded dead-proxy interviews.

## 3.3 Construction of A Panel Data Base

The panel data base that we developed consists of an observation (or record) for each participant for each year between 1981 (the first year when the baseline survey began) and 1993 (the last year when the 10th follow-up interview ended). In other words, this panel data base records the status of every Iowa EPESE participant over a period of 13 years, regardless of how many interviews he/she responded to. Consequently, each observation (or record) for each participant in this data base is identified by calendar **year** (i.e., 1984, 1985). This file structure allows all of the data from the different interviews and data from other sources (e.g., crash data from the Iowa DMV) to be combined.

The main reason for building a panel data base in this fashion is that by employing a number of assumptions, the available information can be used as completely as reasonably possible. For example, the question was asked for a small number of chronic conditions in every interview about

**when** the first episode of a chronic condition took place and when the second one, if any. Stroke, heart disease, and fractured hip were examples of these types of chronic conditions. If we know the year when an episode took place, then we can determine the status of these conditions for every year over the thirteen year period, even though the episode might have taken place in a year when no interview was conducted. Driving cessation is another example of this type of variable where we can determine the approximate year when driving ceased. An advantage of a data base of annual observations is that information can be imputed and used for the years when no interviews were conducted.

This panel data base allows the analysis of the data to be performed on a number of subsets, ranging in sample size. Moreover, data construction assumptions used to construct this panel data base can be validated by examining whether results from different subsets of the data differ significantly.

### 3.3.1 Obstacles in Constructing the Panel Data Base

Before discussing how the panel data base was constructed, we discuss the major obstacles to developing this data base. These obstacles originated from three sources:

(a) The ways in which survey questions were asked differed from one interview to the next. First, the same questions were not asked about every medical condition [11]. For example, participants were asked in the baseline interview whether they ever had a history of stroke, but they were asked whether they have had arthritis since the last survey. Second, some medical condition questions were asked in every interview but some were asked in only in-person interviews (1982, 1985, 1988). Third, for some medical conditions, the questions asked in later follow-up interviews were different than those asked in earlier interviews. For example, participants were asked in the baseline interview whether they ever had a history of stroke, but they were asked in later interviews whether they had a stroke since the last survey. Fourth, questions were asked about the onset of some medical conditions , but not for others. Table 3.3 is a summary of the ways in which questions were asked in different interviews.

(b) Item non-response, the absence of the 8th and the 9th follow-ups and the straddling of one interview over more than one year created considerable data gaps. We used various methods to impute estimates for these gaps. Our methods varied depending on whether a date was recorded for the event (e.g., chronic condition, and changes in driving behavior).

(c) Response inconsistency between data collected from different interviews was observed and might be attributable partly to recall bias. This inconsistency problem is particularly severe between data collected in the 10th follow-up and those collected from the previous surveys. It appears that no data quality control measures were employed to insure data inconsistency.

The next section discusses the methods used to overcome these obstacles. There, we describe the steps that we took to construct the panel data base.

**Table 3.3 What Questions were Asked in Different Interviews From Baseline Interview to the 10th Follow-up Interview**

| EPESE Variables | Baseline 1982 | Followup 1 1983 | Followup 2 1984 | Followup 3 1985 | Followup 4 1986 | Followup 5 1987 | Followup 6 1988 | Followup 7 1989 | Followup 10 1992-93 |
|---|---|---|---|---|---|---|---|---|---|
| **GENERAL** | | | | | | | | | |
| Age | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Gender | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | |
| Marital status | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Working at a paying job | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | |
| Full-time or part-time | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | |
| Retirement status | ✓ | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | |
| Education | ✓ | | | | | | | | |
| Living alone | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Income | ✓ | | | | | | | | |
| Support in crises | ✓ | | | ✓ | | | ✓ | | |
| Club membership | ✓ | | | ✓ | | | ✓ | | ✓ |
| Number of groups | ✓ | | | | | | | | ✓ |
| Alcohol | ✓ | | | ✓ | | | ✓ | | ✓ |
| Exercise | ✓ | | | | | | | | |
| **CHRONIC CONDITIONS /DISEASES** | | | | | | | | | |
| Heart attack -- | | | | | | | | | |
| ever had | ✓ | | | | | | | | ✓ |
| had since last interview | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| when had | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Stroke -- | | | | | | | | | |
| ever had | ✓ | | | | | | | | ✓ |
| had since last interview | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |

| **EPESE Variables** | **Baseline 1982** | **Followup 1 1983** | **Followup 2 1984** | **Followup 3 1985** | **Followup 4 1986** | **Followup 5 1987** | **Followup 6 1988** | **Followup 7 1989** | **Followup 10 1992-93** |
|---|---|---|---|---|---|---|---|---|---|
| when had | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Broken hip -- | | | | | | | | | |
| ever had | ✓ | | | | | | | | ✓ |
| had since last interview | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | |
| when had | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Broken bone -- | | | | | | | | | |
| ever had | ✓ | | | | | | | | ✓ |
| had since last interview | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | |
| when had | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | |
| High blood pressure -- | | | | | | | | | |
| ever had | ✓ | | | ✓ | | | ✓ | ✓ | ✓ |
| when had | ✓ | | | ✓ | | | ✓ | ✓ | ✓ |
| Glaucoma -- | | | | | | | | | |
| ever had | ✓ | | | ✓ | | | ✓ | | ✓ |
| Cataracts -- | | | | | | | | | |
| ever had | ✓ | | | ✓ | | | | | ✓ |
| Arthritis -- | | | | | | | | | |
| ever had | ✓ | | | ✓ | | | ✓ | ✓ | ✓ |
| Diabetes mellitus -- | | | | | | | | | |
| ever had | ✓ | | | | | | | | ✓ |
| had since last interview | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | |
| when had | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Parkinsonism -- | | | | | | | | | |

| EPESE Variables | Baseline 1982 | Followup 1 1983 | Followup 2 1984 | Followup 3 1985 | Followup 4 1986 | Followup 5 1987 | Followup 6 1988 | Followup 7 1989 | Followup 10 1992-93 |
|---|---|---|---|---|---|---|---|---|---|
| ever had | ✓ | | | ✓ | | | ✓ | ✓ | ✓ |

| EPESE Variables | Baseline 1982 | Followup 1 1983 | Followup 2 1984 | Followup 3 1985 | Followup 4 1986 | Followup 5 1987 | Followup 6 1988 | Followup 7 1989 | Followup 10 1992-93 |
|---|---|---|---|---|---|---|---|---|---|
| Cancer -- | | | | | | | | | |
| ever had | ✓ | | | | | | | | ✓ |
| had since last interview | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | |
| when had | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Osteoporosis | | | | | | | | | |
| ever had | | | | ✓ | | | ✓ | ✓ | ✓ |
| **OTHER CHRONIC CONDITIONS** | | | | | | | | | |
| Anemia -- | | | | | | | | | |
| ever had | ✓ | | | ✓ | | | ✓ | | |
| Phlebitis -- | | | | | | | | | |
| ever had | ✓ | | | ✓ | | | ✓ | | ✓ |
| Asthma -- | | | | | | | | | |
| ever had | ✓ | | | ✓ | | | ✓ | | ✓ |
| Lung disease -- | | | | | | | | | |
| ever had | ✓ | | | ✓ | | | ✓ | | ✓ |
| Ulcers -- | | | | | | | | | |
| ever had | ✓ | | | ✓ | | | ✓ | | ✓ |
| Liver disease -- | | | | | | | | | |
| ever had | ✓ | | | ✓ | | | ✓ | | ✓ |
| Pain or cramps in leg - | | | | | | | | | |
| had in the past year | ✓ | | | | | | | | |
| Upset stomach -- | | | | | | | | | |
| had in the past year | ✓ | | | | | | | | |

| EPESE Variables | Baseline 1982 | Followup 1 1983 | Followup 2 1984 | Followup 3 1985 | Followup 4 1986 | Followup 5 1987 | Followup 6 1988 | Followup 7 1989 | Followup 10 1992-93 |
|---|---|---|---|---|---|---|---|---|---|
| Dry skin -- | | | | | | | | | |
| had in the past year | ✓ | | | | | | | | |
| Flat feet -- | | | | | | | | | |
| had in the past year | ✓ | | | | | | | | |
| Bunions -- | | | | | | | | | |
| had in the past year | ✓ | | | | | | | | |
| Other feet problems -- | | | | | | | | | |
| had in the past year | ✓ | | | | | | | | |
| Kidney -- | | | | | | | | | |
| had in the past year | ✓ | | | | | | | | |
| ever had | | | | ✓ | | | ✓ | | ✓ |
| Prostate glands -- | | | | | | | | | |
| had in past year | ✓ | | | | | | | | |
| ever had | | | | ✓ | | | ✓ | | ✓ |
| **SYMPTOMS** | | | | | | | | | |
| Vision Problems-- | | | | | | | | | |
| seeing friend across street | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| reading newspaper | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Shortness of breath | ✓ | | | ✓ | | | | | |
| Pain -- | | | | | | | | | |
| back | ✓ | | | ✓ | | | | | |
| joints | ✓ | | | | | | ✓ | | |
| stiffness | ✓ | | | | | | ✓ | | |
| Mental status test | ✓ | | | ✓ | | | ✓ | | ✓ |
| Word recall test | ✓ | | | ✓ | | | ✓ | | ✓ |
| Lost consciousness | | | | ✓ | | | | ✓ | |

| EPESE Variables | Baseline 1982 | Followup 1 1983 | Followup 2 1984 | Followup 3 1985 | Followup 4 1986 | Followup 5 1987 | Followup 6 1988 | Followup 7 1989 | Followup 10 1992-93 |
|---|---|---|---|---|---|---|---|---|---|
| **ATTITUDES AND MOODS** | | | | | | | | | |
| Self perceived health | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Growing older better than I thought | ✓ | | | ✓ | | | | | |
| As happy as when younger | ✓ | | | ✓ | | | | | |
| Best years | ✓ | | | ✓ | | | | | |
| Things are boring | ✓ | | | ✓ | | | | | ✓ |
| **DEPRESSION** | | | | | | | | | |
| Felt depressed | ✓ | | | ✓ | | | ✓ | | ✓ |
| **DRIVING STATUS** | | | | ✓ | | ✓ | | ✓ | ✓ |
| **ACTIVE STATUS** | | | | | | | | | |
| Death | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Hospitalization | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Nursing home | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Institutionalized | | | | | | ✓ | ✓ | ✓ | |
| Moving out of state | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | |
| **SELF REPORTED CRASHES** | | | ✓ | | ✓ | ✓ | | | |

### 3.3.2 Steps in Constructing the Panel Data Base

We constructed the panel data base in major three steps. Figure 3.1 depicts these major steps.

Step 1

The first step was to process and convert twelve data files to SAS[3] files. The twelve files are the nine survey files (baseline survey plus eight follow-ups), two crash files from the Iowa Department of Motor Vehicles (one covers the period from 1985 to 1989, and the other from 1990 to 1993), and a file with information about the nature of the interview and about the participants' status (i. e., information on whether the interview was an in-person interview, a proxy-interview, or a deceased proxy-interview, and when a participant was deceased[4]). The output of Step 1 is a master survey file consisting of 3,673 records, one for each participant in the baseline interview. Each record contains more than 1,200 variables, comprising nine sets of variables -- one set for information collected in each of the nine interviews. If a subject did not participate in all of the nine interviews, then information for the interviews in which the subject did not participate was set to be "missing." For example, if a subject responded to a total of five interviews, then there are five sets of non-missing variables in his record (assuming every question in the interview was answered), one set for each of the interviews to which he responded. The remaining four sets of information that were pertinent to the interviews, to which he did not respond, were set to be missing. Note that certain questions in the interview were always skipped in proxy interviews.

Since the objectives of this project are focused on driving cessation and highway crashes, only those who were drivers (regardless of when driving cessation took place) are of interest. Of the 3,673 subjects who responded to the baseline interview, 2,207 indicated that they drove or that they held a driver's license sometime during their lifetime. Also included in this group of 2,207 subjects

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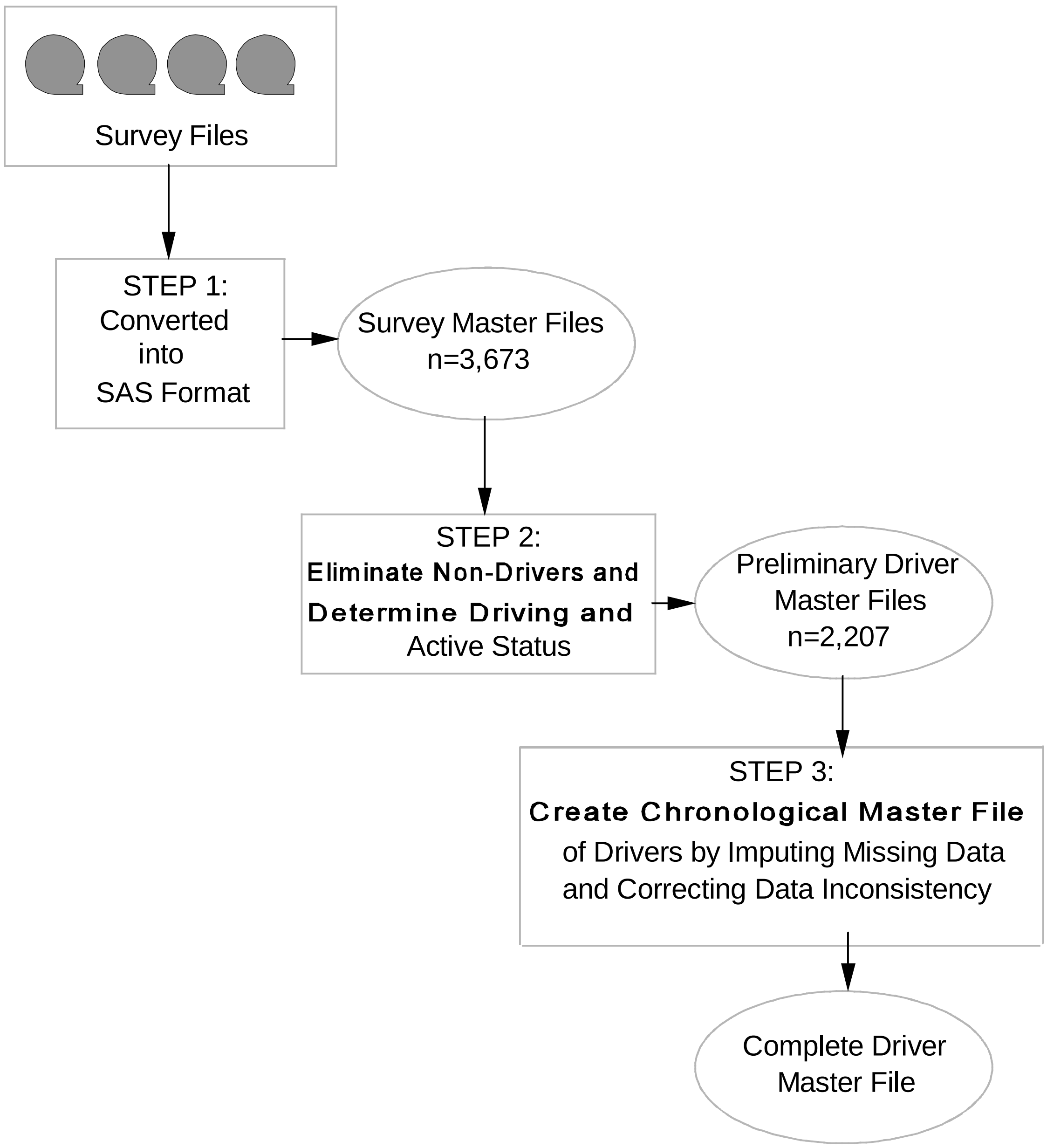
3 SAS is a trademark of SAS Institute Inc., Cary, North Carolina.

4 Incorporating information from the death registry.

**Figure 3.1 Diagram of Panel Data Base Construction**



were Iowa EPESE participants who died between 1981/1982 and 1992/1993 but who had indicated in one of their interviews that they drove or have held a driver's license. Note that individuals who died prior to the first driving question was asked in 1985 were clearly excluded from the analysis. In essence, this group encompasses every Iowa EPESE participant who was a driver or held a driver's license sometime during his/her lifetime regardless of how many interviews he/she participated in, and regardless of when he/she had ceased driving. The figure of 2,207 defines all of the eligible participants for the analysis. All of our subsequent analyses were performed based on different subsets of these 2,207 subjects, depending on the nature of the analysis. Of these 2,207 subjects, only 1,500 participated in the 10th follow-up. Therefore, the sample size is reduced to 1,500 after 1990. The discussion in Section 3.3 focuses mainly on these two groups of subjects -- the 2,207 or the 1,500.

There are pros and cons in using either of these groups for model development. While the sample of 2,207 participants provides a larger sample, it covers a shorter time period from 1981 to 1989. On the other hand, the sample of 1,500 participants is a smaller sample but covers a longer period from 1981 to 1993. The trade-offs between these two samples will be examined in the modeling exercise and will be discussed in Chapters 4 and 5.

## Step 2

The second major step in constructing the panel data base was to determine the **driving** and "**active**" status of these 2,207 participants (Figure 3.1). Given the objectives of this project, information on driving status is crucial, and the driving status can be either "ceased driving," "still driving," or "unknown and/or not reported." A simple driving-related question of "*Did you drive this year?*" was asked in the 3rd and the 5th follow-ups. Not until the 7th follow-up were more detailed driving-related questions administered. Included in the 7th follow-up was a question on "*When did you stop driving?*" Based on the answers to these questions, the year when driving ceased was roughly established. The annual driving status beyond the year when driving reportedly ceased was set to be "ceased driving."

It is important to distinguish clearly those who have stopped driving completely from those who did not have the need to drive in earlier years but who have resumed driving in later years (such as widowed females). The way we distinguished these two groups of individuals was based on the survey response to the question of "*When did you stop driving?*." Those who responded positively to the question were considered to have actually "ceased" driving. Those who did not respond to the question were characterized as those who might not have had the need to drive in particular years, but who have resumed driving later.

Sometimes the response to the question of "*When did you stop driving?*" was inconsistent with the responses in the 3rd and the 5th follow-ups on "*Did you drive this year?*." In this case, the responses in the earlier follow-ups took precedent. The reason for this is that recall bias in earlier follow-ups was considered less severe than that in later follow-ups. For example, a participant may have reported in the 3rd and the 5th follow-ups (mainly in 1985 and 1987, respectively) that he drove during those years, but he reported in the 7th follow-up (1989) that he had stopped driving 3 years ago, that is, sometime in 1986. Under this circumstance, it is assumed that this participant was driving during the year when he was interviewed for the 5th follow-up and has not driven thereafter. Figure 3.2 illustrates this example.

Since the first driving-related question was not asked until the 3rd follow-up (in 1985), we estimated the driving status for the years prior to 1985 in the following way. Our procedure considers the driving status in the first year for which driving-status data exist. Driving status can be determined either by the direct response to "*Did you drive this year?*," or be **derived** based on the response to "*When did you stop driving?*" If driving status was determined from a direct response, then the driving status from 1981 to that year, data on which were missing, was set to be identical to the survey response. For example, if data on driving status were first available in 1985, and if the data were based on the question "*Did you drive this year?*," then it is assumed that this participant drove from 1981 to 1985. On the other hand, if the information on driving status was derived from the response to "*When did you stop driving?*," then the driving status for all years prior to that year were assumed to be "still driving." The basic idea behind these data-imputation rules

**Figure 3.2 An Example of How Driving Status was Determined If Inconsistent Data were Recorded in the Interviews**

| | 1985 | 1986 | 1987 | 1988 | 1989 |
|---|---|---|---|---|---|
| | FU 3 | | FU 5 | | FU 7 |
| "*Did you drive this year?*" | Yes | | Yes | | |
| "*When did you stop driving?*" | | | | | 3 years ago |
| Imputed Driving Status | Yes | Yes | Yes | No | No |

Note: FU=Follow-up

is that people who drive, begin to drive before they are elderly, and continue to drive each year until they stop driving.

The status of the 2,207 participants -- deceased, in nursing home, institutionalized, or active -- was determined from information on "housing" (i.e., "*Have you moved to an institution?*"), "nursing home stay" and "institutionalization," and information from the death registry. If a participant is not deceased, not in a nursing home, and not institutionalized, then he/she was considered to be "active." In analyzing crash data, information on whether the individual was still a resident of Iowa was considered in determining the "active" status of this individual. Note that this active status, similar to driving status, is an annual "observation" in our data base and varies from one year to the next. In some cases, a subject was in nursing home(s) for several years, but then became "active" for a number of years. The resulting data file at the end of Step 2 includes nine sets of information, one for each of the nine interviews, and the subjects' annual driving and "active" status.

Step 3

The main objective of Step 3 was to create a chronological profile of the participants, one record per participant for each of the 13 calendar years from 1981 (when the baseline survey began) to 1993 (when the 10th follow-up ended.) Since there were at most nine interviews (baseline plus eight follow-ups) administered to any participant, information will be missing for at least 4 of the 13 years, if date information was not asked for particular questions. Thus, one of the main tasks of Step 3 was to impute estimates to fill the *annual gaps* for the years where either no interviews were conducted or the participants did not respond to the interviews. The second task of Step 3 was to impute missing data due to *item non-response* (i.e., an individual responded to the interview but did not provide an answer to a specific question.) Estimates to address both the *annual gaps* and *item non-response* were imputed with the same guidelines used to address missing data. The last, but not the least, task of Step 3 was to rectify *data inconsistency*.

Missing data were imputed based on various rules, primarily depending on whether information was available on *when* a given event (e.g., onset of medical conditions, crashes) took place. Since the availability of this type of "date" information varies for different survey variables, they were grouped into categories so that reasonable imputation rules can be applied. The categories were: (1) those with "date" information available such as "*When did you stop driving?*," and "*Since we talked to you last, has a doctor told you that you had stroke(s)? If so, when?*," and (2) those without "date" information such as the date of onset of arthritis and Parkinson's disease.

If data were available on *when* an event took place, then the imputation process was considerably simpler than if no "date" information was given. Basically, missing data were imputed and inconsistency corrected based on the year when the event occurred (e.g., when a participant was told that he had a given medical condition.)

For survey variables (or events) where **<u>no</u>** date information was available, rules for imputing missing data are primarily based on the responses recorded in the interviews both <u>prior</u> and <u>subsequent</u> to the intermittent year(s) with missing information. The rules that we used are as follows:

**Table 3.4. Rules for Imputing Missing Data**

| If response in the "**prior**" interview was: | **Imputed** responses for intermittent year(s) with missing data | If response in the "**subsequent**" interview was: |
|---|---|---|
| No | *No* | No |
| No | *Yes* | Yes |
| No | *Suspected* | Suspected |
| Suspected | *No* | No |
| Suspected | *Yes* | Yes |
| Suspected | *Suspected* | Suspected |
| Yes | ***??*** | No |
| Yes | *Yes* | Yes |
| Yes | *Yes* | Suspected |

These rules state, for example, that if the response in the prior interview was "suspected" and the response in the subsequent interview was "yes," then the status for intermittent year(s) was assumed to be "yes." The challenge in imputing missing data arises when there is response inconsistency, such as the case when the response in the prior interview indicated "yes" but the response in the subsequent interviews "no."

Considerable response inconsistency was observed between the data collected in the later follow-ups and the data collected in the earlier interviews. These inconsistencies were especially evident for conditions such as arthritis, but considerably less so for conditions such as Parkinson's disease. These inconsistencies are partly attributed to recall bias and were categorized into two types: *Type I error* and *Type II error*. Response inconsistency was particularly evident in data collected in the 10th follow-up.

*Type I error* occurred when the participant reported in the earlier interviews that he/she has had a given condition but reported in the later follow-ups that he/she has **never** had the condition.

*Type II error* occurred when the participant reported in the earlier interviews that he/she has never had a given condition but reported in the later follow-ups that he/she has had the condition and that the onset date of that condition was when he/she reportedly did not have that condition. For example, there is a *Type II error* if a participant reported from the baseline interview (1982) through the 7th follow-up (1989) that he did not have any stroke, but reported in the 10th follow-up that he had had a stroke in 1986, during the period when he had earlier reported no stroke history.

The prevalence of reporting inconsistency is demonstrated by using the stroke history as an example. Twenty (= 16+4) participants reported in the 10th follow-up that they have never had a stroke, when the data from the previous interviews indicated that they have had a stroke(s) (Table 3.5). These 20 participants had *Type I errors*. Seventy-seven participants reported no stroke history between 1982 and 1989, but indicated in the 1992 interview that they have had a stroke. Because of this descrepancy, we further checked the consistency of these data. Based on the date when a stroke was reportedly diagnosed, we confirmed that 58 of these 77 participants had a stroke between the 7th follow-up (1989) and the 10th follow-up (1992). This leaves 19 participants who reported that their stroke(s) were diagnosed during a period when they previously reported no stroke history. Thus, Type II error in reporting the history of stroke occurred in 19 (= 77-58) participants.

To correct these response inconsistencies, two general sets of rules were developed, depending on whether the date of the event was reported. These rules are similar to those used in imputing the missing data. If the onset date of a medical condition was inquired in the interview, *Type I* and *Type II errors* were corrected based on that date. Note that without the information on when an event takes place, only *Type I error* will be observed.

**Table 3.5. Reporting of *Stroke* History**
[Based on data from the Iowa 65+ Rural Health Study]

| No. of *strokes* from 1982 to 1989 | Answer to "*Ever had a stroke*?" in the 10th Follow-up (1992-1993) | | | | |
|---|---|---|---|---|---|
| | No | Yes | Suspect | Missing | Total |
| None | 1,006 | **77**[1] | 10 | 195 | 1,288 |
| 1 | **16** | 63 | **4** | 21 | 104 |
| 2 | 4 | 9 | 0 | 3 | 16 |
| 3 | 0 | 2 | 0 | 0 | 2 |
| 4 | 0 | 1 | 0 | 1 | 2 |

[1] Fifty-eight participants who had a stroke between the 7th follow-up (1989) and the 10th follow-up (1992) disqualify them from the Type II error category.

If information was not available on the date of an event, then the following rules were used to rectify response inconsistencies. In the cases of *Type I error* (i.e., "had" in the past but "never had" in the later follow-ups), the negative response in the later follow-up was ignored and the participant was assumed to have a history of that medical condition ever since the year when he/she was told by a doctor that he/she had that medical condition. In the case of *Type II errors* (i.e., "never had" in the past but "had" in the later follow-up), we assume that the participant was told by a physician that he had the medical condition beginning in the survey year when he was told to have that condition. In general, *Type I errors* are more prevalent than *Type II errors* (Table 3.6). Seventy percent of the participants in the 10th follow-up were free from recall bias.

**Table 3.6. Number of Participants Reporting *Type I* and *Type II Errors***
[ **Participants in the 10th Follow-up of Iowa EPESE**]

| Number of Errors | Participants Reporting Type I Error | Participants Reporting Type II Error | Total Number of Participants |
|---|---|---|---|
| 0 | 1,077 *(76.3%)* | 1,305 *(92.4%)* | 993 *(70.3%)* |
| 1 | 296 *(21.0%)* | 105 *(7.4%)* | 355 *(25.1%)* |
| 2 | 35 *(2.5%)* | 2 *(0.1%)* | 60 *(4.2%)* |
| 3 | 4 *(0.3%)* | 0 *(0.0%)* | 4 *(0.3%)* |
| Total | 1,412 *(100.0%)* | 1,412 (*100.0%)* | 1,412 *(100.0%)* |

To illustrate the aforementioned rules in imputing estimates of missing data and in correcting response inconsistency, we use an individual with Parkinson's disease as an example. Questions related to Parkinson's disease were asked in the baseline, 3rd, 6th, 7th and 10th follow-ups, and the questions were phrased as: "*Has a doctor ever told you that you had Parkinson's disease?*" The problem now becomes: what was the status on Parkinson's disease in those years when no interviews were conducted? Estimates of the status on Parkinson's disease were imputed based on the rules in Table 3.4. The imputed values are given in Column (4) of Table 3.7. However, a serious inconsistency was observed in this participant's reporting of his history of Parkinson's disease. In 1985, this participant reported that he was told by a doctor that he had Parkinson's disease. Nevertheless, his responses in the 6th, 7th and 10th follow-ups indicated that he was **never** told by a doctor that he had Parkinson's disease. To correct for this inconsistency, it was assumed that this participant had Parkinson's disease ever since 1985 and, in our data base, we corrected his annual status on Parkinson's disease (Column (5) of Table 3.7.)

**Table 3.7. An Example of How Annual History of Medical Conditions was Established**
A case of Parkinson's disease

| Year (1) | Interview type (2) | Survey response *(ever had?)* (3) | Imputed response (4) | Corrected status on Parkinson's Disease (5) |
|---|---|---|---|---|
| 1981 | • | • | suspected | suspected |
| 1982 (Baseline) | in-person | suspected | | suspected |
| 1983 (Follow-up 1) | in-person | • | yes | yes |
| 1984 (Follow-up 2) | in-person | • | yes | yes |
| 1985 (Follow-up 3) | telephone | yes | | yes |
| 1986 (Follow-up 4) | in-person | • | ?? | yes |
| 1987 (Follow-up 5) | telephone | • | ?? | yes |
| 1988 (Follow-up 6) | telephone | no | | yes |
| 1989 (Follow-up 7) | in-person | no | | yes |
| 1990 | • | • | no | yes |
| 1991 | • | • | no | yes |
| 1992 (Follow-up 10) | telephone proxy | no | | yes |
| 1993 | • | • | no | yes |

## 3.4 Chronological Profile of Participants

A total of 3,673 subjects participated in the 1981/1982 baseline interview: 38.7% were male and 61.3% female. The proportion of females in this cohort was slightly greater than that in the general older population (61.3% vs. 59.7%). By 1992/93, almost 70% of the cohort were females. Female participants, as a whole, are older than their male counterparts (Table 3.1).

Active Status

Of the 2,207 individuals, 11 were institutionalized within one year of the baseline interview (Table 3.8). Three years into the study (1985), 46 participants died, 18 moved out of the State and 8 were institutionalized. Only slightly more than three quarters of the original 2,207 were active by 1989, and the number dropped to 1,195 by 1993. Note that this variable was not directly recorded in the interviews but was deduced based on many pieces of information collected in the interviews (See Section 3.3.)

**Table 3.8 Active Status of Iowa EPESE Participants[1], from 1981 to 1993**

| Year | Status | | | | | |
|---|---|---|---|---|---|---|
| | Active | Dead | Moved outside State | Institutionalized /Nursing Home | Unknown | TOTAL |
| 1981 | 2,207 | 0 | 0 | 0 | 0 | 2,207 |
| 1982 | 2,207 | 0 | 0 | 0 | 0 | 2,207 |
| 1983 | 2,196 | 0 | 0 | 11 | 0 | 2,207 |
| 1984 | 2,191 | 0 | 10 | 6 | 0 | 2,207 |
| 1985 | 2,135 | 46 | 18 | 8 | 0 | 2,207 |
| 1986 | 2,049 | 107 | 25 | 23 | 3 | 2,207 |
| 1987 | 1,941 | 185 | 29 | 43 | 9 | 2,207 |
| 1988 | 1,847 | 264 | 31 | 47 | 18 | 2,207 |
| 1989 | 1,708 | 347 | 42 | 86 | 24 | 2,207 |
| 1990 | 1,404 | 0 | 35 | 52 | 9 | 1,500 |
| 1991 | 1,368 | 1 | 35 | 87 | 9 | 1,500 |
| 1992 | 1,302 | 8 | 35 | 148 | 7 | 1,500 |
| 1993 | 1,195 | 115 | 32 | 158 | 0 | 1,500 |

[1] Those who drove or held a driver's license sometime during their entire life.

Demographics, Living Arrangement and Social Support

As expected, the proportion of participants who were married continued to decrease over time and the proportion who were widowed increased (Table 3.9). Almost two-thirds of the participants had retired. However, a small but not negligible proportion of the participants, about 10%, continued to hold a paid-job.

**Table 3.9. Marital Status of Iowa EPESE Participants[1] From 1981 to 1993**

| | Married | Widowed | Divorced/ Separated[2] | TOTAL |
|---|---|---|---|---|
| 1981 | 1,442(65.34%) | 628 (28.45%) | 137 (6.21%) | 2,207 (100%) |
| 1982 | 1,439 (65.20%) | 631 (28.59%) | 137 (6.21%) | 2,207 (100%) |
| 1983 | 1,408 (63.80%) | 663 (30.04%) | 136 (6.16%) | 2,207(100%) |
| 1984 | 1,374 (62.26%) | 697 (31.58%) | 136 (6.16%) | 2,207 (100%) |
| 1985 | 1,324 (59.99%) | 747 (33.85%) | 136 (6.16%) | 2,207 (100%) |
| 1986 | 1,287 (58.31%) | 781 (35.39%) | 139 (6.3%) | 2,207 (100%) |
| 1987 | 1,252 (56.72%) | 816 (36.97%) | 139 (6.3%) | 2,207 (100%) |
| 1988 | 1,205 (54.60%) | 861 (39.01%) | 141 (6.39%) | 2,207 (100%) |
| 1989 | 1,151 (52.15%) | 913 (41.37%) | 143 (6.48%) | 2,207 (100%) |
| 1990 | 646 (43.07%) | 763 (50.87%) | 91 (6.07%) | 1,500 (100%) |
| 1991 | 646 (43.07%) | 763 (50.87%) | 91 (6.07%) | 1,500 (100%) |
| 1992 | 646 (43.07%) | 763 (50.87%) | 91 (6.07%) | 1,500 (100%) |
| 1993 | 646 (43.07%) | 763 (50.87%) | 91 (6.07%) | 1,500 (100%) |

[1] Those who drove or held a driver's license sometime during their entire life.
[2] Including unknown.

Also, more and more of the participants lived alone, from 31% in 1982 to 50% in 1993. During the early part of the Iowa EPESE, 15-18% of the participants reported that they had been in a hospital overnight at least once during the 12-month period prior to the interview. This percentage increased to 27% in 1989 and 33% in 1993. Between 1981 and 1993, almost 70% of the 2,207 participants had at least one overnight stay in a hospital.

When asked whether they believed that they could count on their close relatives for help in a crisis, 80 to 90 percent of the participants responded positively. Also, 60 to 65 percent of them were members of various social and/or religious groups. Throughout the years, there were basically no changes among the elderly in receiving this type of social support.

Health Perception and Health-Related Behavior

The participants were asked the question of "*Compared to other people your own age, would you say that your general health is excellent, good, fair, poor, or very poor*?". The majority of them perceived their health to be poor. Over time, the percentage of those who considered themselves in poor health increased (Table 3.10). Overall, this Iowa cohort perceived themselves in better health condition than their counterparts from a national survey [12]. While 78% of the Iowa participants perceived themselves in good to excellent health, 69% of the general older population considered themselves in good to excellent health.

From the baseline survey to the 10th follow-up, the status did not change much on whether the participants exercised on a regular basis. During the baseline interview, 71% of the 2,207 participants reported that they exercised on a regular basis. About the same percentage of the participants in the 10th follow-up continued to exercise on a regular basis. Consistent with the literature, the proportion of participants who consumed alcohol decreased over time, from 52% in 1982 to 31% in 1993.

**Table 3.10. Self-Perceived Health Status of Iowa EPESE Participants[1] From 1981 to 1993**

| Year | Self-perceived Health | | |
|---|---|---|---|
| | Excellence and Good | Fair to Very Poor | TOTAL |
| 1981 | 1,733 *(78.5)* | 474 (*21.5*) | 2,207 *(100.0)* |
| 1982 | 1,733 *(78.5)* | 474 (*21.5*) | 2,207 *(100.0)* |
| 1983 | 1,725 (*78.2)* | 482 (*21.8*) | 2,207 *(100.0)* |
| 1984 | 1,726 (*78.2)* | 481 (*21.8)* | 2,207 *(100.0)* |
| 1985 | 1,738 (*78.8*) | 469 (*21.3*) | 2,207 *(100.0)* |
| 1986 | 1,648 (*74.7*) | 559 (*25.3*) | 2,207 *(100.0)* |
| 1987 | 1,593 (*72.2*) | 614 *(27.8*) | 2,207 *(100.0)* |
| 1988 | 1,602 (*72.6*) | 605 *(27.4)* | 2,207 *(100.0)* |
| 1989 | 1,535 (*69.6*) | 672 (*30.4*) | 2,207 *(100.0)* |
| 1990 | 1,059 *(70.6)* | 441 (*29.4)* | 1,500 *(100.0)* |
| 1991 | 1,059 *(70.6)* | 441 (*29.4)* | 1,500 *(100.0)* |
| 1992 | 1,059 *(70.6)* | 441 (*29.4)* | 1,500 *(100.0)* |
| 1993 | 1,059 *(70.6)* | 441 (*29.4)* | 1,500 *(100.0)* |

[1] Those who drove or held a driver's license sometime during their entire life.

Chronic Conditions

Questions were asked about the chronic conditions in the Iowa EPESE. Nine of the conditions were recognized in the literature that are likely to affect older drivers' decisions to stop driving or their likelihood of being involved in vehicle crashes. They are: arthritis, cardiovascular disease, cancer, cataracts, diabetes, glaucoma, hip fracture, Parkinson's disease, and stroke. Consequently, only the impacts of these 9 conditions on the decision to stop driving or the likelihood of being involved in a crash are investigated in this study. The ways by which these 9 conditions were asked not only differ between the baseline interview and the follow-up interviews, but they also differ from one condition to the next (Table 3.11). This inconsistency in phrasing condition-related questions caused difficulties in constructing the panel data base (as discussed in Section 3.3).

From information in the panel data base, the accumulative history of medical conditions is summarized in Tables 3.12A and 3.12B. The characteristic of this history is that once a participant was "told" by a doctor that he/she had a condition, he/she will always be enumerated as part of the group having that condition in all subsequent years. It is recognized that some medical conditions might not persist over time and that using cumulative history to develop analytical models might be inappropriate. This issue will be addressed in greater detail in Chapters 4 and 5.

Among the medical conditions studied, arthritis was the most common condition among the Iowa EPESE cohort. The rate was 71 cases of arthritis per 100 persons in 1981, and 88 per 100 persons in 1993 (Table 3.12B). Cataract increased the most, from 19 cases per 100 persons in 1981 to 69 cases per 100 in 1993 (Figure 3.2). This Iowa cohort was similar to the general older population at the national scale, in that its prevalence rates of cataract, heart disease and diabetes closely corresponded to those observed in the general older population [12]. In the national population in 1981, there were 15.6 cases of cataract per 100 persons who were 65 years and over, compared to a rate of 19 in the Iowa EPESE cohort. The prevalence rates for heart disease were 11.6 cases per 100 persons 65 years and older in the national population compared to 11.6 in the Iowa EPESE cohort; and 9 cases of diabetes per 100 in the national sample compared to 10.8 per 100 in the Iowa EPESE.

**Table 3.11. How Questions Pertinent to Nine Medical Conditions Were Phrased From Baseline to Follow-up 10**

| Condition | Baseline | 2nd to 7th Follow-up | 10th Follow-up |
|---|---|---|---|
| Cardiovascular disease | **Ever** told by a doctor? If so, how many, where (if applied) and when? | Since **last interview**, told by a doctor? If so, how many, where (if applied) and when? | **Ever** told by a doctor? If so, how many, where (if applied) and when? |
| Cancer | " | " | " |
| Diabetes | " | " | " |
| Hip Fracture | " | " | " |
| Stroke | " | " | " |
| Arthritis | In the past year, have you had? | Ever told by a doctor?* | Ever told by a doctor? |
| Parkinson's disease | Ever told by a doctor? | " | " |
| Cataracts | " | Ever told by a doctor?** | " |
| Glaucoma | " | " | " |

* At 7th follow-up only.
** At 3rd follow-up only.

**Table 3.12A. Cumulative History and Prevalence Rate[1] of Medical Conditions Observed in Iowa EPESE Participants[2] From 1981 to 1993**

| Year | *Has a doctor ever told you that you had...?* | | | | | *n* |
|---|---|---|---|---|---|---|
| | Cardiovascular Dis. | Cancer | Diabetes | Hip Fracture | Stroke | |
| 1981 | 235 *(10.7)* | 307 (*13.9*) | 238 (*10.8*) | 57 *(2.6)* | 93 *(4.2)* | 2,207 |
| 1982 | 255 *(11.6)* | 357 (*16.2*) | 253 (*11.5*) | 64 *(2.9)* | 119 *(5.4)* | 2,207 |
| 1983 | 270 *(12.2)* | 388 (*17.6*) | 273 (*12.4*) | 68 (*3.1*) | 133 (*6.0*) | 2,207 |
| 1984 | 291 (*13.2*) | 415 (*18.8*) | 299 (*13.6*) | 77 (*3.5*) | 165 (*7.5*) | 2,207 |
| 1985 | 305 (*13.8*) | 462 (*20.9*) | 320 (*14.5*) | 84 *(3.8)* | 188 (*8.5*) | 2,207 |
| 1986 | 316 *(14.3)* | 504 (*22.8*) | 337 *(15.3)* | 87 (*3.9*) | 218 (*9.9*) | 2,207 |
| 1987 | 343 (*15.5*) | 556 (*25.2*) | 357 *(16.2)* | 100 *(4.5)* | 249 *(11.3)* | 2,207 |
| 1988 | 356 (*16.1*) | 590 (*26.7*) | 381 (*17.3*) | 114 *(5.2)* | 266 (*12.1*) | 2,207 |
| 1989 | 382 (*17.3*) | 625 (*28.3*) | 395 (*17.9*) | 130 (*5.9*) | 295 (*13.4*) | 2,207 |
| 1990 | 223 *(14.9)* | 428 (*28.5*) | 263 *(17.5)* | 95 (*6.3*) | 216 (*14.4*) | 1,500 |
| 1991 | 226 *(15.1)* | 447 (*29.8*) | 274 (*18.3*) | 102 (*6.8*) | 237 (*15.8*) | 1,500 |
| 1992 | 235 (*15.7*) | 492 (*32.8*) | 286 *(19.1)* | 119 (*7.9*) | 266 *(17.7)* | 1,500 |
| 1993 | 235 (*15.7*) | 493 (*32.9*) | 286 (*19.1*) | 119 (*7.9*) | 266 (*17.7*) | 1,500 |

[1] Numbers in the parentheses are the prevalence rates in hundredth.

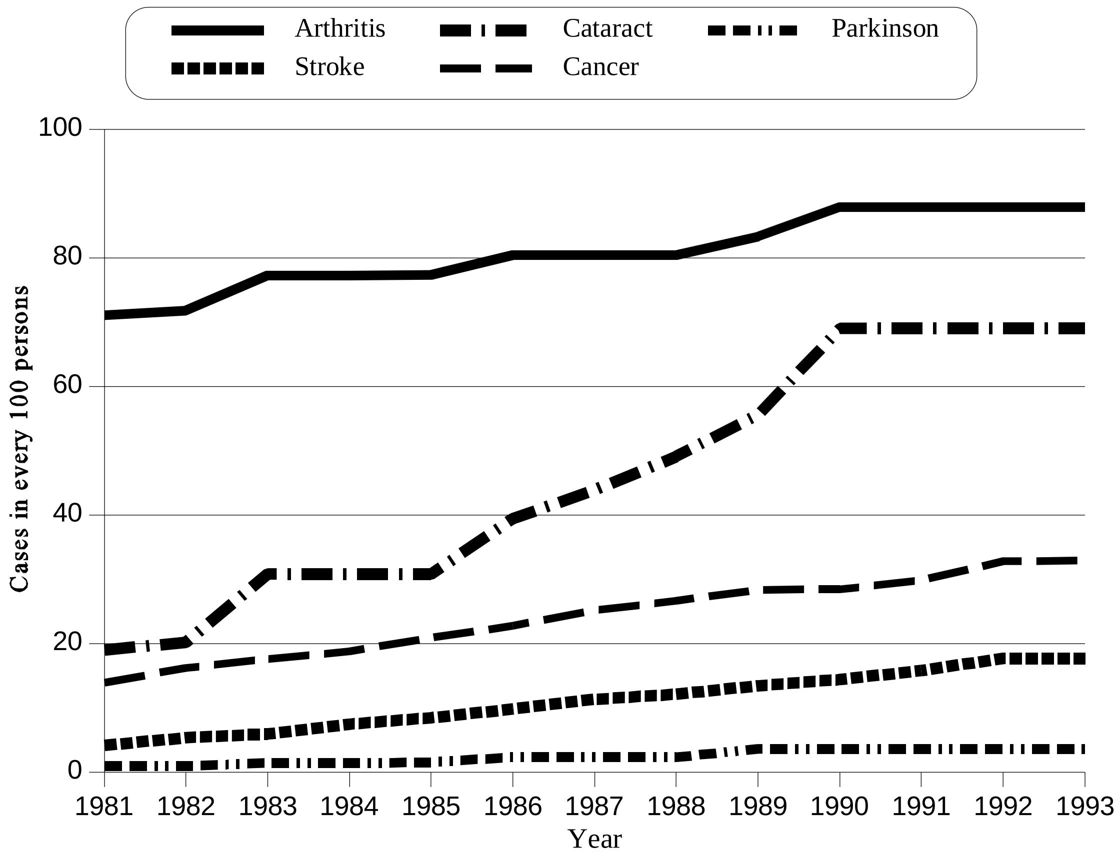
[2] Those who drove or held a driver's license sometime during their entire life.

**Table 3.12B. Cumulative History and Prevalence Rate[1] of Medical Conditions Observed in Iowa EPESE Participants[2] From 1981 to 1993**

| Year | *Has a doctor ever told you that you had...?* | | | | | | | | *n* |
|---|---|---|---|---|---|---|---|---|---|
| | Arthritis | | Cataract | | Glaucoma | | Parkinson's Disease | | |
| | Yes | Suspected | Yes | Suspected | Yes | Suspected | Yes | Suspected | |
| 1981 | 1,568 *(71.1)* | 474 *(21.5)* | 419 (*19.0*) | 122 *(5.5)* | 63 *(2.9)* | 36 (*1.6*) | 21 *(1.0)* | 11 (*0.5*) | 2,207 |
| 1982 | 1,584 *(71.8*) | 147 *(6.7)* | 445 (*20.2*) | 80 *(3.6)* | 64 *(2.9)* | 19 *(0.9)* | 21 *(1.0)* | 4 *(0.2*) | 2,207 |
| 1983 | 1,705 *(77.3)* | 26 (*1.2)* | 679 (*30.8*) | 74 *(3.4)* | 102 *(4.6)* | 32 (*1.5)* | 33 *(1.5)* | 8 (*0.4*) | 2,207 |
| 1984 | 1,705 *(77.3)* | 26 (*1.2)* | 679 (*30.8*) | 73 *(3.3)* | 102 *(4.6)* | 30 *(1.4)* | 33 *(1.5)* | 7 *(0.3*) | 2,207 |
| 1985 | 1,708 *(77.4)* | 13 *(0.6)* | 679 (*30.8*) | 56 (*2.5)* | 106 *(4.8)* | 16 *(0.7*) | 35 *(1.6)* | 4 *(0.2*) | 2,207 |
| 1986 | 1,777 (*80.5)* | 14 (*0.6)* | 871 (39.5) | 28 (*1.3)* | 151 *(6.8)* | 23 (*1.0*) | 53 *(2.4)* | 9 *(0.4)* | 2,207 |
| 1987 | 1,777 (*80.5)* | 14 (*0.6)* | 972 (*44.0)* | 32 (*1.5)* | 151 (*6.8*) | 23 (*1.0*) | 53 (*2.4*) | 9 (*0.4*) | 2,207 |
| 1988 | 1,777 (*80.5)* | 11 *(0.5)* | 1,084 (*49.1*) | 39 (*1.8)* | 151 *(6.8)* | 7 (*0.3*) | 53 (*2.4*) | 3 *(0.1)* | 2,207 |
| 1989 | 1,840 *(83.4*) | 7 (*0.3*) | 1,227 (*55.6)* | 32 (*1.5)* | 176 (*8.0*) | 12 (*0.5*) | 62 (*3.7*) | 4 (*0.2*) | 2,207 |
| 1990 | 1,318 *(87.9)* | 2 (*0.1)* | 1,035 *(69.0)* | 27 (*1.8)* | 185 *(12.3)* | 12 *(0.8)* | 56 (*3.7*) | 7 *(0.5)* | 1,500 |
| 1991 | 1,318 *(87.9)* | 2 (*0.1)* | 1,035 *(69.0)* | 27 (*1.8)* | 185 *(12.3)* | 12 *(0.8)* | 56 (*3.7*) | 7 *(0.5)* | 1,500 |
| 1992 | 1,318 *(87.9*) | 2 (*0.1*) | 1,035 *(69.0)* | 27 (*1.8)* | 185 *(12.3)* | 12 *(0.8)* | 56 (*3.7*) | 7 *(0.5)* | 1,500 |
| 1993 | 1,318 *(87.9*) | 2 (*0.1)* | 1,035 *(69.0)* | 27 (*1.8)* | 185 *(12.3)* | 12 *(0.8)* | 56 (*3.7*) | 7 *(0.5)* | 1,500 |

[1] Numbers in the parentheses are the prevalence rates in hundredth.
[2] Those who drove or held a driver's license sometime during their entire life.

**Figure 3.3. Increased Prevalence of Selected Medical Conditions Over Time
Iowa EPESE Program, from 1981 to 1993**



Symptoms, Mental Status and Attitudes

To assess their visual acuity, participants were asked to report whether they could see well enough to recognize their friends across the street when wearing their glasses/contact lenses. This question was asked consistently from the baseline survey through the 10th follow-up. Individuals' self-assessments of their visual acuity did not change greatly during the 13 year period. In 1982, 96 percent of the 2,207 participants reported that they could see well enough to recognize their friends across the street and this percentage dropped by merely 6 points to 90% in 1993. Similarly, 97% of the participants reported in 1982 that they could see well enough to read ordinary newspaper print when wearing their lenses/glasses. The corresponding 1993 percentage was 91%.

In a 1982 word-recall test, almost none of the 2,207 participants could recall more than 75% of the words accurately, while 58% could recall only less than 25% of the words accurately (Table 3.13). Memory recall became an obvious problem ten years later. Three-quarters of the 1,500 participants in 1992 had a recall error of more than 75%, compared to the 1982 proportion of 58%.

In addition to word-recall tests, participants were asked to rate subjectively their own memory capability. Almost 70% of the participants to the baseline interview perceived themselves as having either "excellent" or "good" memory. Individuals were apparently more optimistic about their memory recall than what the word-recall tests suggested. Of those individuals who perceived themselves as having "excellent" or "good" memory, half of them recalled 25% or fewer of the words correctly while none of them could recall 75% or more of the words correctly (Table 3.14).

Although the proportion of the participants who felt depressed increased slightly from 1982 to 1993, it remained small at about 3-4%. Note that this "depression" question was asked only in the baseline, 3rd, 6th and the 10th interviews. A larger percentage of the participants felt bored. Eight to ten percent of the participants expressed boredom and the percentage did not change noticeably between 1982 and 1993.

**Table 3.13. Number and Percentage of Participants by Recall Errors in Word-Recall Tests Iowa EPESE Participants[1], from 1981 to 1993**

| Year | Recall Error (Percent of Words Recalled Incorrectly) | | | |
|---|---|---|---|---|
| | 0 - 25% | 26 - 74% | 75 - 100% | TOTAL |
| 1981 | 1 *(00.5)* | 924 (*41.9*) | 1,282 (*58.09*) | 2,207 |
| 1982 | 1 *(00.5)* | 906 (*41.1)* | 1,300 (*58.9*) | 2,207 |
| 1983 | 0 (*0.00)* | 676 (*30.6*) | 1,531 *(69.37)* | 2,207 |
| 1984 | 0 (*0.00)* | 676 (*30.6*) | 1,531 *(69.37)* | 2,207 |
| 1985 | 0 (*0.00)* | 668 (*29.9*) | 1,547 (*70.10*) | 2,207 |
| 1986 | 1 *(00.5)* | 575 (*26.1*) | 1,631 (*73.90*) | 2,207 |
| 1987 | 1 *(00.5)* | 575 (*26.1*) | 1,631 (*73.90*) | 2,207 |
| 1988 | 1 *(00.5)* | 575 (*26.1*) | 1,631 (*73.90*) | 2,207 |
| 1989 | 0 (*0.00)* | 505 (*22.8)* | 1,703 (*77.16*) | 2,207 |
| 1990 | 0 (*0.00)* | 367 (*24.4)* | 1,133 (*75.53)* | 1,500 |
| 1991 | 0 (*0.00)* | 367 (*24.4)* | 1,133 (*75.53)* | 1,500 |
| 1992 | 0 (*0.00)* | 367 (*24.4)* | 1,133 (*75.53)* | 1,500 |
| 1993 | 0 (*0.00)* | 367 (*24.4)* | 1,133 (*75.53)* | 1,500 |

[1] Those who drove or held a driver's license sometime during their entire life.

**Table 3.14. Correlation between Self-Perceived Memory Recall in 1982 and Scores from a Twenty-Word Recall Test in 1982**

| Number and Percentage of Participants | | | | |
|---|---|---|---|---|
| Self-Perceived Memory | % Words Recalled Correctly | | | |
| | < 25% | 25 - 50% | > 50% | TOTAL |
| Excellent | 92 (*50.3%*) | 86 (*47.0%*) | 5 (*2.7%*) | 183 (*100%*) |
| Good | 531 (*50.5%*) | 497 (*47.2%*) | 24 (2.3%) | 1,052 (*100%*) |
| Fair | 318 (*63.1%*) | 183 (*36.3%*) | 3 (*0.6%*) | 504 (*100%*) |
| Poor | 42 (*73.7%*) | 13 (*22.8%*) | 2 (*3.5%*) | 57 (*100%*) |
| Very poor | 2 (*40.0%*) | 3 (*60.0%*) | 0 (*0.0%*) | 5 (*100%*) |

Functional Status

The participants were asked whether they needed help in performing seven physical activities that are important in day-to-day living. These activities are called activities of daily living (ADLs). Walking across a small room and bathing are the two most common ADLs for which the elderly needed assistance. Except for eating (i.e., holding a fork, cutting food, drinking from a glass), the percentage of elderly needing help in performing these ADLs increased considerably over time (Table 3.15). Compared to a national sample of elderly people, this Iowa cohort was notably more capable in performing ADLs. While 4.6% of the persons 65 years and over from a national survey needed help to walk across a small room [12], the corresponding percentage in the Iowa cohort was 3.6% (Table 3.16). The greatest difference between the national sample and the Iowa cohort was the percentage of individuals who received help in bathing, 6% vs. 1.5%, respectively.

**Table 3.15. Percentage of Iowa EPESE Participants[1] Who Received Help in Activities of Daily Living**

| Year | Activities in which help received | | | | | | |
|---|---|---|---|---|---|---|---|
| | Walking | Bathing | Grooming | Dressing | Eating | Transferring[2] | Toileting |
| 1981 | *3.6* | *1.5* | *0.5* | *1.4* | *0.3* | *1.9* | *1.5* |
| 1982 | *3.5* | *1.5* | *0.5* | *1.3* | *0.3* | *1.8* | *1.4* |
| 1983 | *2.5* | *1.3* | *0.7* | *1.8* | *0.2* | *1.2* | *1.1* |
| 1984 | *2.6* | *2.2* | *0.5* | *2.7* | *0.3* | *2.0* | *1.7* |
| 1985 | *3.6* | *5.4* | *1.1* | *2.9* | *0.9* | *2.8* | *2.8* |
| 1986 | *5.4* | *4.9* | *1.5* | *3.8* | *0.6* | *3.4* | *3.2* |
| 1987 | *6.6* | *6.4* | *2.1* | *4.5* | *1.2* | *3.6* | *3.9* |
| 1988 | *6.8* | *8.2* | *3.0* | *5.7* | *2.0* | *4.3* | *3.9* |
| 1989 | *10.7* | *11.6* | *3.8* | *8.2* | *2.3* | *7.4* | *7.3* |
| 1990 | *17.3* | *21.9* | *8.3* | *12.7* | *3.7* | *10.9* | *11.7* |
| 1991 | *17.3* | *21.9* | *8.3* | *12.7* | *3.7* | *10.9* | *11.7* |
| 1992 | *17.3* | *21.9* | *8.3* | *12.7* | *3.7* | *10.9* | *11.7* |
| 1993 | *17.3* | *21.9* | *8.3* | *12.7* | *3.7* | *10.9* | *11.7* |

1 Between 1981 and 1989, the total number of participants who drove or held a driver's license sometime during their entire life was 2,207. From 1990 to 1993, the corresponding number was 1,500.

2 Getting in and out of a bed or chair

**Table 3.16. Comparison in Percent of Elderly[1] Receiving Help in ADLs Between the National Health Interview Survey and the Iowa EPESE**

| ADL receiving help from others | Percentage | |
|---|---|---|
| | National Health Interview Survey[2] | Iowa EPESE[3] |
| Walking | *4.6* | *3.6* |
| Bathing | *6.0* | *1.5* |
| Dressing | *4.4* | *1.4* |
| Eating | *1.1* | *0.3* |
| Transferring[4] | *3.2* | *1.9* |
| Toileting | *2.4* | *1.5* |

[1] 65 years of age and over.
[2] Data from the National Health Interview Survey 1986 Functional Limitations Supplement.
[3] Reported in the baseline interview.
[4] Getting in and out of a bed or chair.

In addition, the participants were asked to report on whether they received help from others in performing higher level physical activities such as walking half a mile, climbing stairs, and washing windows and floors. The majority of the participants were able to perform heavy work around the house, walk half a mile, or climb stairs without help from others. However, these capabilities degenerated rapidly with aging. By 1993, almost half of the participants needed help in performing most of these activities (Table 3.17).

## Driving Behavior

Questions related to driving status were asked in the 3rd, 5th, 7th and 10th follow-ups. In the first two interviews, a single question of "*Did you drive this year?*" was asked. However, significantly more extensive questions on driving were administered in the later two interviews (for detailed driving questions see Section 3.2). We used the answer to the question of "*If you stopped driving, how long ago did you stop driving*?" to establish the year when driving ceased.

**Table 3.17. Percentage of Iowa EPESE Participants[1]**
**Who Received No Help in Performing Higher Level Activities**

| Year | Activities in which **NO** help received | | |
|---|---|---|---|
| | Heavy house work | Walking half a mile | Climbing stairs |
| 1981 | *77.8* | *88.6* | *96.7* |
| 1982 | *78.2* | *88.4* | *96.8* |
| 1983 | *85.0* | *86.9* | *97.7* |
| 1984 | *86.2* | *85.9* | *97.3* |
| 1985 | *76.4* | *81.7* | *96.7* |
| 1986 | *74.8* | *76.7* | *95.4* |
| 1987 | *72.0* | *72.7* | *93.6* |
| 1988 | *67.9* | *70.8* | *92.5* |
| 1989 | *65.1* | *65.7* | *88.8* |
| 1990 | *52.9* | *58.5* | *79.5* |
| 1991 | *52.9* | *58.5* | *79.5* |
| 1992 | *52.9* | *58.5* | *79.5* |
| 1993 | *52.9* | *58.5* | *79.5* |

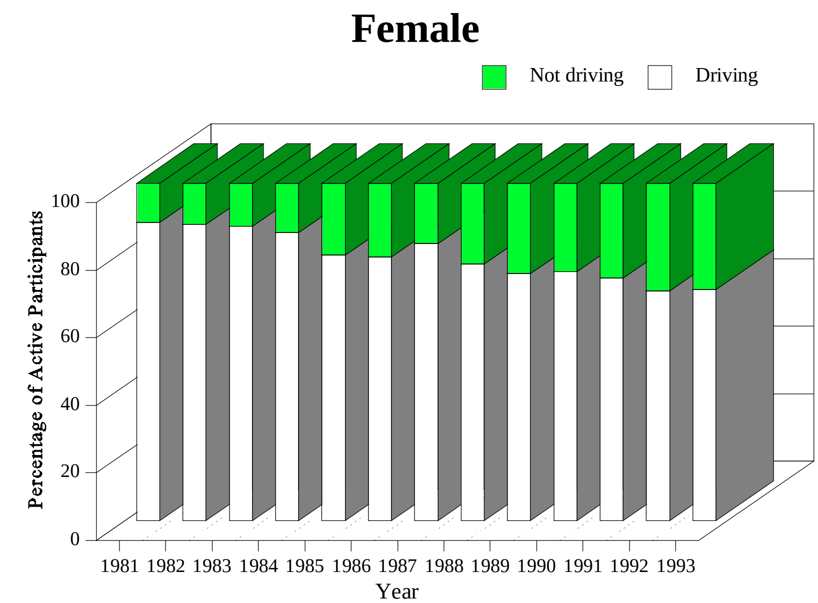
[1] Between 1981 and 1989, the total number of participants who drove or held a driver's license sometime during their entire life was 2,207. From 1990 to 1993, the corresponding number was 1,500.

Of the 2,207 participants who responded to the baseline interview and who had driven or held a driver's license some time during their entire lifetime, four did not report whether they can see well enough to recognize friends across the street or read ordinary newspaper print. Thus, data for 2,203 participants were used for our study. Of these participants who were active (i.e., alive, not hospitalized or institutionalized) in 1981, 2,034 continued to drive. One decade later, only half of them continued to drive. As expected, the percentage of those who were active, and who continued to drive, decreased with aging. A gender difference is remarkably prominent in the percentage of those who continued to drive (Figure 3.3). In 1981, only less than 3% of the male participants did not drive compared to 12% for the females. By 1993, 14% of the males did not drive compared to 32% for the females.

There is a group of participants whose driving behavior was observed to fluctuate, from driving to not driving, during the study period from 1981 to 1993. The Iowa 65+ Rural Health Study first began in 1981/1982. Fifty-one participants who reported in 1981/1982 that they drove, stopped driving for one or more years, and then resumed driving for one or more years. Fourty-seven participants who did not drive when the study began resumed driving during the course of the study.

In the 7th follow-up, 40% of the participants reported that they drove much less or somewhat less compared to their driving five years ago, half of them drove about the same, and 7% reported that they drove more. Three years later in the 10th follow-up, a higher percentage of the participants reported that they drove less than five years ago. In general, those who reported in 1989 that their driving was less than that of 5 years ago continued to curtail their driving with time. On the other hand, only 37% of those who reported in 1989 that they have not changed their driving behavior reduced their driving (Figure 3.4).

**Figure 3.4. Driving Status of Those Who Were Active by Gender**



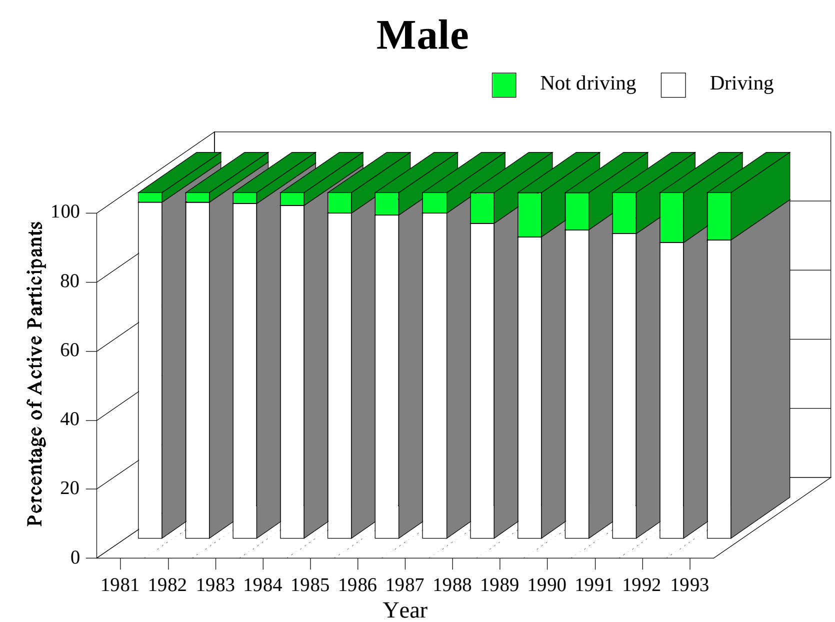
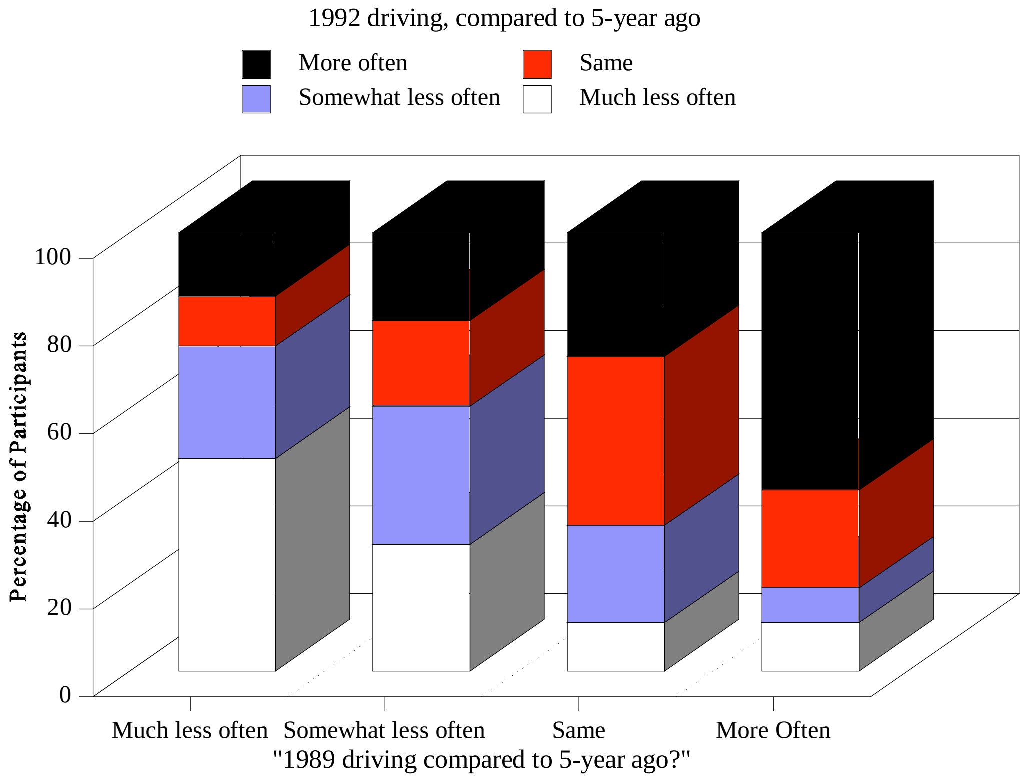
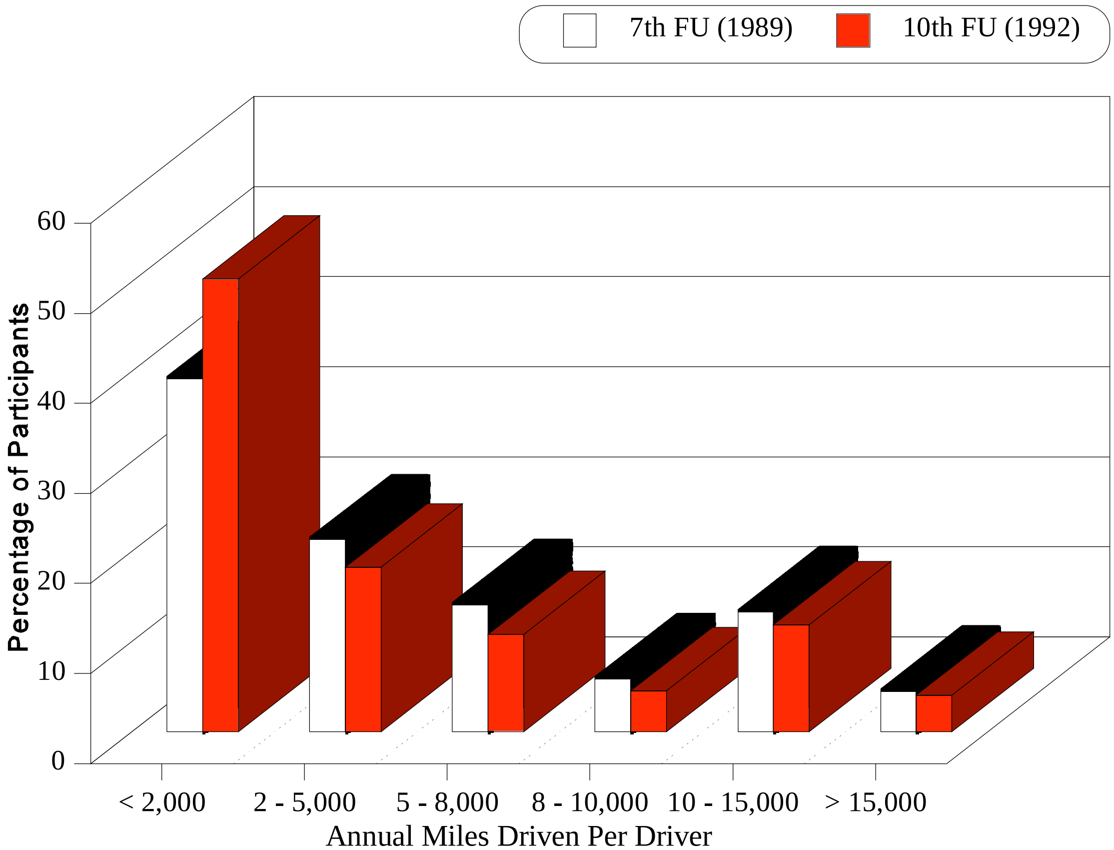



**Figure 3.5. Changes in the Amount of Driving with Time**




In 1989 (the 7th follow-up), about 40% of the participants drove less than 2,000 miles per year. Less than 3 years later, the percentage of drivers who drove less than 2,000 miles a year had increased to 50.3%. (With this cohort aging, the distribution of their annual miles driven per driver shifted toward the left in Figure 3.5). One-quarter of the drivers reported in 1992 that they drove less than 500 miles per years. Since such detailed breakdown of the annual miles driven (i.e., less than 500-mile category) was not available in the 7th follow-up, we cannot assess how the trends in this low-driving category have changed from 1989 to 1992.

**Figure 3.6. Distribution of Annual Miles Driven per Driver**
**Iowa EPESE Participants, 7th and 10th Follow-Up Interviews**



# CHAPTER 4. ANNUAL DRIVING STATUS

## 4.1 Descriptive Statistics of the Panel Data

Attrition in participation is common in longitudinal studies and typically increases with time, particularly in studies of elderly subjects. Almost all of the analysis techniques for panel data require the data set to be balanced in that the number of annual observations for each participant must be the same. This means that any analyses that require a balanced panel data set fail to take full advantage of the information collected from all of the participants by excluding participants who have dropped out of the study.

However, we obtained the latest version of LIMDEP[1] which has the capability of analyzing an **unbalanced** panel data set. The greatest advantage of analyzing an **unbalanced** panel data set as opposed to a **balance** data set is the increase in the sample size. For example, with this version of the software, we were able to include all but four of the 2,207 participants in our analysis. These four participants did not report whether they can see well enough to recognize a friend across the street or to read newspaper print. They were eliminated from our analysis. Taking advantage of all of the data observed from these 2,203 participants between 1981 and 1993, our analysis was based on a sample of 23,994 annual observations. If our analysis had been limited to a **balanced** panel data set, we would have been faced with two options. The first option would have been to use data from 1,614 participants for whom annual data are complete for a period of nine years, from 1981 to 1989. This option would have produced 14,526 (=1,614×9) annual observations. By the time of the latest follow-up of the Iowa EPESE study (in 1993), only 1,161 participants remained. Thus, the second option would have been to use data from these 1,161 participants for whom annual data are complete for a period of thirteen years, from 1981 to 1993. This would have yielded a sample of 15,093 (=1,161×13) annual observations.

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[1] LIMDEP is a trademark of William H. Greene for his computer program.

By using an analysis technique that takes into account **unbalance**d data, we increased the sample size for our analysis by almost 60%. Note that these 23,944 annual observations are not independent observations and, therefore, are not as powerful as 23,944 independent observations. Our analyses recognized and took into account this autocorrelation. Compared to previous studies that were based on a "snap-shot" of the same data, our sample of 23,944 dependent observations is considerably more powerful.

The participants included in our analysis were "active" in that they were not deceased, not in a nursing home, and not in an institution. Approximately 45% of the 2,203 participants were male, with an average annual income of $13,000 (in 1981-1982 dollars). Twenty-two percent of the 2,203 participants had at least 12 years of education. Sixty-five percent of them had retired but 17% of them still held some type of paid job. About one-third of the participants lived alone. In 1993, they ranged in age from 77 to 99 years of old. On average, less than 10% of the participants reported difficulties in performing ADLs or higher level activities (e.g., walking half-a mile, climbing stairs).

Two aspects of the annual driving behavior of older drivers were addressed in this project. The first aspect is the prediction of the **annual driving status** of the participants between 1981 and 1993. The second aspect deals with the determinants of an older driver's annual driving. The remaining of this chapter is divided into two parts -- one on the annual driving status and the other on the amount of annual driving.

## 4.2 Annual Driving Status

### 4.2.1 Model Framework

The annual driving status is defined as "driving during the year" ($Y=0$) or "not driving during the year" ($Y=1$). This dependent variable is different than that in studies that focus on driving cessation. In those studies, individuals are grouped into two categories: those who still drive and those who cease driving permanently. In our analysis, an individual can cease driving for some years but, for some reason, drive in later years. Thus, an objective of our analysis is to ascertain whether a set of factors, *x*, contributes to an older driver's decision to drive or not to drive in a given year. This model can be described generally as

$$\text{Prob}\ (Y=1) = F(\boldsymbol{\beta}'\boldsymbol{x}) \tag{4.1}$$
$$\text{Prob}\ (Y=0) = 1 - F(\boldsymbol{\beta}'\boldsymbol{x})$$

The set of parameters $\boldsymbol{\beta}$ reflect the impacts of the factors *x* on the probability of not driving. The question then becomes: what will be a suitable model for the right-hand side of the above equation?

When the dependent variable is a discrete outcome, such as "continued to drive" or "stopped driving", conventional regression models are inappropriate. The most serious shortcoming of these models in these instances is that $\boldsymbol{\beta}'\boldsymbol{x}$ cannot be constrained to be a value between zero and one, since this constraint will produce nonsensical probabilities and negative variances [13]. Nevertheless, models can be constructed that link the outcome (in our case, driving cessation) to a set of factors, at least in the spirit of regression analysis.

The specific nature of a panel data set is that a group of units (or participants) are observed for a number of years. Consequently, a panel data set allows researchers to use time-series cross-sectional data to examine issues that could not be studied in either time-series or cross-sectional settings alone. The general structure of a binomial model for panel data is:

$$y_{it}^{*} = \beta' x_{it} + \varepsilon_{it} \ , \tag{4.2}$$

where $y_{it}=1$ if $y^{*}_{it} > 0$, and $y_{it}=0$ otherwise. If the error terms $\varepsilon_{it}$'s are uncorrelated for an individual, $cov(\varepsilon_{it}, \varepsilon_{is}) = 0$ where $t \neq s$, then the procedures for analyzing panel data are not necessary, and ordinary binomial models may be used. However, if the error terms $\varepsilon_{it}$'s are correlated for an individual, $cov(\varepsilon_{it}, \varepsilon_{is}) \neq 0$, then a procedure for analyzing panel data is required. Two types of panel data procedures are available -- the *random effects* model and the *fixed effects* model. While the *fixed effects* procedure can only be used to examine the effect of **time varying** factors, the *random effects* procedure is used when there are any **time invariant** variables in the model. Thus, a *random effects* model was used in our analysis since many of the factors in our analysis are time invariant, such as gender and factors that were asked in only one interview (such as income). The *random effects* procedure for the binomial model requires a probit model, as described below.

The *random effects* model can be described as

$$y_{it}^{*} = \beta' x_{it} + \mu_i + \nu_{it} \,, \tag{4.3}$$

where $\mu_i$ is the random disturbance characterizing the *i*th observation and is constance through time,
$v_{it}$ is the disturbance for the *i*th observation in time *t*,
$i = 1,..., N;\quad t= 1,...T$;
$y_{it} = 1$ if $y_{it}^{*} > 0$ and 0, otherwise;
$var[\mu_i + v_{it}] = var[\varepsilon_{it}] = \sigma_\mu^2 + \sigma_v^2$, and
$Corr^2[\varepsilon_{it}, \varepsilon_{is}] = \rho^2 = \sigma_\mu^2 / (\sigma_v^2 + \sigma_\mu^2)$.

To test whether $\rho = corr(\varepsilon_{it}, \varepsilon_{is}) = 0$ (i.e., the observation for the *i*th participant in time *t* is uncorrelated to his observation in time *s*), we estimated gender-specific *random effects* binomial probit models. That is, we assumed that annual observations for a specific participant were correlated (Table 4.1). In these models, the hypothesis of $\rho = corr(\varepsilon_{it}, \varepsilon_{is}) = 0$ was rejected, suggesting that the annual observations for a specific participant should be treated as **dependent** observations. That is, a model that allows the observation for participant *i* at period *t* to be freely correlated with the observation for participant *i* at period *s* would be more appropriate. The *random effects* binomial probit models were estimated using LIMDEP software.

**Table 4.1** ***Random Effects* Probit Models of Annual Driving Status by Gender**
From 1981 to 1993
[0=Driving; 1=Not driving]

| Factor | Female | | Male | |
|---|---|---|---|---|
| | Estimated Coefficient | % with characteristic | Estimated Coefficient | % with characteristic |
| Constant | -15.22** | | -14.44** | |
| ***Demographic Attributes*** | | | | |
| Age (increasing) | 0.17** | 77.43 | 0.13** | 76.80 |
| Income (increasing) | -0.03** | 12,270 | | 13,840 |
| Education (> 12 years) | -0.32** | 27% | 0.66** | 16% |
| Job (yes) | -0.44** | 11% | -0.34* | 21% |
| ***Functional Limitations*** | | | | |
| Need help in walking across a room (yes) | 0.38** | 6% | 0.71** | 6% |
| Need help in personal grooming (yes) | 0.33* | 2% | 1.42** | 2% |
| Need help in bathing (yes) | | 7% | 0.44** | 6% |
| Need help in dressing (yes) | 0.46** | 3% | | 5% |
| Need help in eating (yes) | 0.96** | 1% | | 1% |
| Need help with heavy housework (yes) | 0.37** | 30% | 0.54** | 22% |
| Pushing/pulling large objects (unable) | | 10% | 0.87** | 4% |

| Factor | Female | | Male | |
| --- | --- | --- | --- | --- |
| | Estimated Coefficient | % with characteristic | Estimated Coefficient | % with characteristic |
| Need help with climbing stairs (yes) | 0.35** | 8% | | 5% |
| Stooping, crouching, or kneeling (unable) | 0.24** | 12% | | 6% |
| ***Chronic Conditions*** | | | | |
| Diagnosed with arthritis (yes) | | 82% | 0.76** | 78% |
| Parkinson's disease (yes) | 1.82** | 2% | | 2% |
| First episode of stroke (yes) | 0.40** | 9% | | 11% |
| Second episode of stroke (yes) | 1.05** | 3% | 1.19** | 3% |
| First episode of heart attack (yes) | 0.90** | 9% | | 20% |
| Cataract Surgery (yes) | 0.54** | 16% | | 13% |
| ***Psychosocial characteristics*** | | | | |
| Living alone (yes) | -0.49** | 55% | 0.21* | 17% |
| Club member (yes) | -0.17** | 72% | -0.64** | 56% |
| Exercise regularly | -1.14** | 15% | | 19% |
| Severely depressed[1] | -0.50** | 3% | | 2% |

| Factor | Female | | Male | |
|---|---|---|---|---|
| | Estimated Coefficient | % with characteristic | Estimated Coefficient | % with characteristic |
| ***Physical features*** | | | | |
| Difficulty in seeing friend across street (yes) | 0.49** | 7% | 0.82** | 4% |
| Difficulty in see newspaper prints (yes) | 0.80** | 4% | 1.30** | 5% |
| ***Symptoms*** | | | | |
| Joint pain | | 62% | -0.32** | 58% |
| ***Other health-related factors*** | | | | |
| Consume alcohol (yes) | | 36% | -0.97** | 55% |
| Rho ($\rho$) | 0.80** | | 0.82** | |
| Number of annual observations | 13,932 | | 10,062 | |
| Log-Likelihood | -2871.33 | | -989.80 | |
| Restricted (Slopes=0) Log-L. | -5956.30 | | -2507.03 | |
| Sample size of unbalanced panel data (number of drivers) | 1,218 | | 985 | |

[1] Scored in the top 2% of the overall depression scale.

### 4.2.2 Results

Of the 2,203 participants for whom the annual observations are complete for all, or some, of the thirteen years between 1981 and 1993, 169 (*7.7%)* did not drive and 2,034 (*92.3%)* did in 1981 (Table 4.2 and Figure 3.3). By 1993, only 1,224 remained in the study of whom a quarter did not drive. Gender-specific *random effects* binomial probit models were developed to identify potential risk factors for driving cessation among elderly drivers (Table 4.1). Potential factors contributing to older drivers' decisions to stop driving included demographic attributes, limitations in performing physical activities, chronic conditions, physical features, psychosocial characteristics, symptoms, and other health-related factors.

The demographic variables included in the gender-specific model were age, marital status, income, number of years of education, whether holding a paid job, and retirement status. The limitations in performing ADLs and/or higher level activities included: walking across a small room; bathing; personal grooming; dressing; eating; transferring (e.g., from a bed to a chair); toileting; performing heavy house chores; walking half a mile; climbing stairs; pulling or pushing large objects; lifting or carrying heavy objects; stooping, crouching or kneeling; reaching or extending; and writing and handling small objects.

The presence or absence of the following chronic conditions was examined: arthritis, cataracts, diabetes, glaucoma, hip fracture, heart disease, stroke, Parkinson's disease, cancer and osteoporosis. Whether surgery was performed for a cataract was also evaluated in the model. Other physical features included whether an individual could see a friend across the street or read newspaper print, and whether he/she had high blood pressure. Symptoms included episodes of unconsciousness, persistent back pain and joint pain, and stiffness in the morning.

Psychosocial characteristics included mental status (based on the word-recall tests, mental status test, and self-perceived memory capability), self-perceived health status, depression, boredom,

**Table 4.2 Annual Driving Status of 2,203 Participants from 1981 to 1993**

| Year | Female | | | | | Male | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Drove | | Didn't drive | | TOTAL | Drove | | Didn't drive | | TOTAL |
| | Number | Ave. Age | Number | Ave. Age | | Number | Ave. Age | Number | Ave. Age | |
| 1981 | 1,076 (*88.3%*) | 71.88 | 142 (*11.7%*) | 74.47 | 1,218 (*100%*) | 958 (*97.3%*) | 72.21 | 27 (*2.7%*) | 74.93 | 985 *(100%)* |
| 1982 | 1,068 (*87.7%*) | 72.84 | 150 (*12.3%*) | 75.61 | 1,218 (*100%*) | 957 (*97.2%*) | 73.21 | 28 (*2.8%*) | 75.89 | 985 *(100%)* |
| 1983 | 1,055 *(87.2%)* | 73.77 | 155 (*12.8%*) | 76.66 | 1,210 (*100%*) | 952 *(96.9%)* | 74.19 | 30 (*3.1%*) | 77.10 | 982 *(100%)* |
| 1984 | 1,036 (*85.3%*) | 74.69 | 178 (*14.7%*) | 77.96 | 1,214 (*100%*) | 947 *(96.3%)* | 75.16 | 36 (*3.7%*) | 78.53 | 983 *(100%)* |
| 1985 | 944 (*78.6%*) | 75.47 | 257 (*21.4%*) | 78.58 | 1,201 (*100%*) | 893 *(94.2%)* | 76.02 | 55 (*5.8%*) | 79.25 | 948 *(100%)* |
| 1986 | 916 *(78.1%)* | 76.35 | 257 (*21.9%*) | 79.66 | 1,173 (*100%*) | 839 (*93.5%*) | 76.78 | 58 (*6.5%*) | 80.55 | 897 *(100%)* |
| 1987 | 931 *(82.0%)* | 77.28 | 205 (*18.0%*) | 81.57 | 1,136 (*100%*) | 782 (*94.2%*) | 77.60 | 48 (*5.8%*) | 81.33 | 830 *(100%)* |
| 1988 | 841 (*76.1%*) | 77.94 | 264 *(23.9%)* | 82.45 | 1,105 (*100%*) | 701 (*91.2%*) | 78.19 | 68 (*8.8%*) | 82.81 | 769 *(100%)* |
| 1989 | 774 *(73.1%)* | 78.64 | 285 (*26.9%*) | 83.44 | 1,059 (*100%*) | 600 (*87.3%*) | 78.68 | 87 (*12.7%*) | 83.61 | 687 *(100%)* |

| Year | Female | | | | | Male | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Drove | | Didn't drive | | TOTAL | Drove | | Didn't drive | | TOTAL |
| | Number | Ave. Age | Number | Ave. Age | | Number | Ave. Age | Number | Ave. Age | |
| 1990 | 669 *(73.8%)* | 79.45 | 237 *(26.2%)* | 84.02 | 906 (*100%*) | 474 (*89.4%*) | 79.32 | 56 (*10.6%*) | 82.95 | 530 *(100%)* |
| 1991 | 633 *(71.8%)* | 80.23 | 249 *(28.2%)* | 85.06 | 882 (*100%*) | 457 *(88.2%*) | 80.18 | 61 (*11.8%*) | 83.39 | 518 *(100%)* |
| 1992 | 570 *(68.1%)* | 80.90 | 267 *(31.9%)* | 85.47 | 837 (*100%*) | 426 (*85.7%*) | 80.94 | 71 (*14.3%*) | 84.59 | 497 *(100%)* |
| 1993 | 529 *(68.4%)* | 81.78 | 244 *(31.6%)* | 86.06 | 773 (*100%*) | 389 *(86.2%*) | 81.89 | 62 *(13.7%)* | 84.10 | 451 *(100%)* |

living arrangement, and the extent to which social support was received (such as club membership, whether the person could count on close relatives in a crisis). Hospitalization or nursing home admission were assessed as part of the "other health-related factors." Also included in this category of independent variables were alcohol consumption, and exercise regimen.

**Results for Older Female Drivers**

The significant factors that affect the likelihood that an older *female* driver ceases to drive were: aging, impaired vision, and limitations in physical functioning (as represented by limited capabilities in performing ADLs and higher level physical activities (Table 4.1)). Chronic conditions that significantly contributed to older *female* drivers' decisions to cease driving were primarily neurological diseases -- Parkinson's disease, both the first and second strokes, and the first episode of a heart attack. Simply being diagnosed as having cataracts did not stop afflicted female drivers from driving. However, having cataract surgery significantly increased the probability of driving cessation in these drivers.

When arthritis and limited functioning (e.g., difficulty in performing ADLs) are included in the model, the impact of arthritis on older female drivers' decisions to stop driving became insignificant. Apparently, functional limitations dictated older female drivers' decisions to stop driving and the mere presence of arthritis was not a factor. In other words, simply being diagnosed with arthritis did not stop the afflicted older female drivers from driving. Only when their ability to function became obviously impaired did older female drivers cease to drive. Functional impairment can be due to arthritis or to other conditions. But, in some respect, the cause of the functional impairment is probably unimportant in decisions of whether to drive. Consistent with previous findings in the literature ([4]-[7]), glaucoma, diabetes and osteoporosis were not associated with the probability of driving cessation in older drivers.

The factors that significantly influenced older female drivers' decisions to drive were: living alone, holding a paid job, being better educated and wealthier, being a member of social/religious organizations, and exercising regularly. These factors imply a better quality of life and a greater need to drive. Moreover, living alone in a rural area, typically without alternative transportation, increased the need to continue to drive. This finding was consistent with the finding in [5] in that Kington et al. found that older individuals living in households with multiple adults were more likely to cease driving. Kington et al.'s explanation was that with multiple adults in the household, the need to drive themselves to places was drastically reduced.

The estimated coefficients for the depression factor exhibits an unexpected sign. It indicates that being severely depressed <u>increased</u> the likelihood of driving -- contrary to what is generally believed. More than 85% of the female drivers who lived alone were widowed, while about 15% of the female drivers who did not live alone were widowed. Among those who were widowed and living alone, about 2% of them were severely depressed (as represented by being on the top two percentiles of the overall depression scale), while 0.3% of those who were widowed but were not living alone were severely depressed. We speculate that female drivers who live alone typically have little option but to live alone, and that, because of this situation, are more likely to be severely depressed. As a result of these female drivers living alone, their needs to drive increased. The underlying reason for this unexpected finding needs further investigation.

## <u>Results for Older Male Drivers</u>

The significant predictors for older *male* drivers' decisions to stop driving are in Table 4.1. Being older and better educated, having limited gross mobility capabilities, and impaired vision (reflected by being unable to recognize friends across the street and to read newspaper print) significantly affect the likelihood that an older male driver stops driving. Contrary to findings in the model for female drivers, older male drivers who are better educated and who live alone are more likely to *stop* driving than those who are less educated and who do not live alone.

Chronic conditions that significantly contributed to older *male* drivers' decisions to cease driving were arthritis and a second episode of stroke. Unlike older *female* drivers, it appears that the impact of arthritis on older *male* drivers' decisions to stop driving is so great that it remains significant even if the limited functioning factor (e.g., difficulties in performing ADLs) is included in the model. Interestingly, the first episode of stroke did not prevent the afflicted older *male* drivers from driving. However, the second episode of stroke was a significant factor in older *male* drivers' decisions to stop driving.

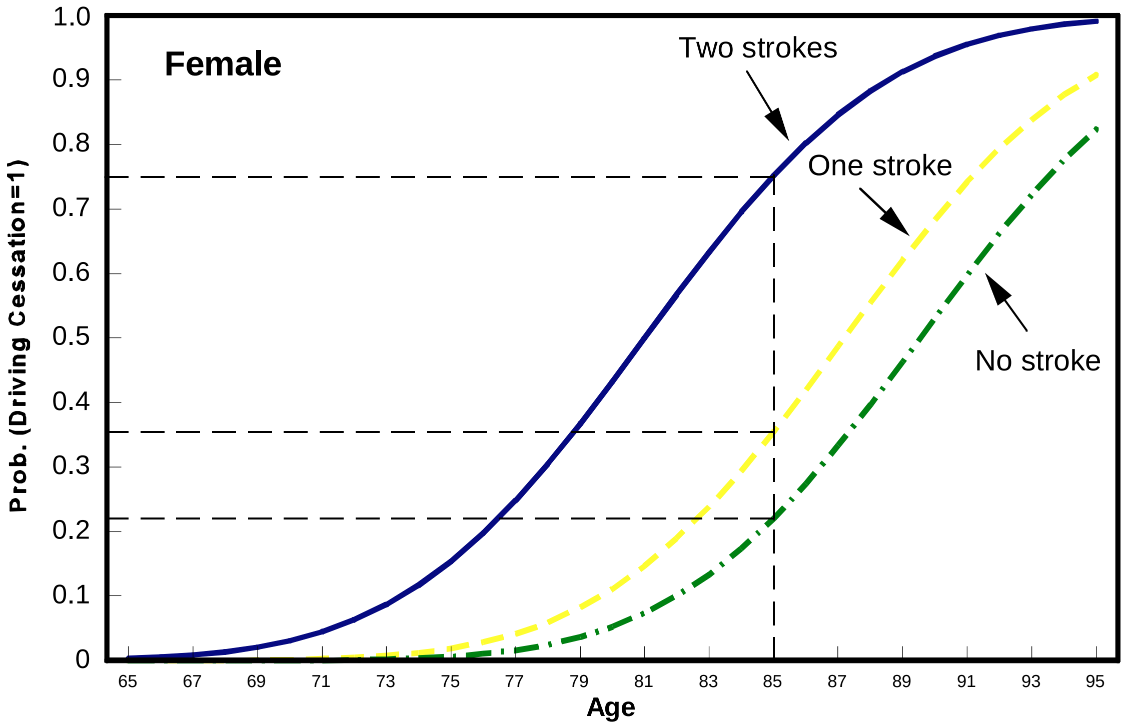
Older male drivers who consumed alcohol were more likely to continue to drive. This might be attributable to the association between alcohol consumption and social activities -- alcohol is commonly consumed at social occasions, and participating in more social events means that the individual is less likely to cease driving. Being a member of social/religious organizations and being employed suggest stronger mobility needs and, therefore, increase the likelihood of continuing to drive.

The impact of having persistent pain in a joint on older male drivers' decisions to stop driving was unclear. The unexpected sign of the estimated coefficient for this factor suggests that pain in the joints <u>increased</u> the likelihood of driving. Also unclear were the impacts of educational level and living arrangement (i.e., living alone) on older *male* drivers' decisions to stop driving. The underlying reasons for these unexpected findings need further investigation.

### 4.2.3 <u>Interpretation of Coefficients</u>

The magnitude of the estimated coefficients provides a sense of the relative significance of the respective factors in contributing to the overall driving-cessation decision. However, it should be noted that the parameters of the model, like those of any nonlinear regression model, are not necessarily the marginal effects that we are used to analyzing in linear regression models. Since a nonlinear model is used, the marginal increase in the probability of driving cessation is nonlinear as well. Thus, the fact that the estimated coefficient of the variable that denotes a second episode of stroke ($\beta_{2nd\ stroke}$= 1.05) in the model for female drivers is two and a half times that of the first episode of stroke ($\beta_{1st\ stroke}$= 0.40) does not mean that the marginal effect of the second stroke on the probability of driving cessation in older female drivers is two and a half times that of the first stroke. In fact, an 85 year old female driver who experiences a second stroke was twice as likely to stop driving as another 85 year old driver who experiences only one stroke, given that everything else is equal. The marginal increase of the second stroke on the probability of driving cessation in older *female* drivers is illustrated in Figure 4.1.

**Figure 4.1 Effect of Strokes on the Probability of Driving Cessation in Older *Female* Drivers [of an average female driver without any other risk factors present]**



Since the marginal effects are nonlinear, one cannot simply add the estimated coefficients to measure the joint impact. The marginal effect of factor *x* on the probability of driving cessation is computed by taking the derivative of the density function:

$$\frac{\partial\ E(y)}{\partial\ x} = f\ (\beta' x)\ \beta\ =\ \varphi\ (\beta' x)\ \beta \qquad (4.4)$$

where φ(t) is the standard normal density. Based on this approach, the marginal effect of any chronic condition on driving, and of any other risk factor, can easily be computed. Figure 4.2 illustrates the marginal increase in the probability of driving cessation in older *female* drivers due to two factors: limited capabilities in gross mobility (reflected by difficulties in performing ADLs and higher level activities), and impaired vision. By also experiencing impaired vision, an older female driver with functional limitations, but without any other risk factors, has her probability of stopping to drive more than double (0.41 vs. 0.95) (Figure 4.2). The joint impact of visual impairment and arthritis in older male drivers is demonstrated in Figure 4.3.

## 4.3 Annual Miles Driven

To model the annual miles driven, only participants who responded to the 7th and the 10th follow-ups were included in our analysis. Specific driving-related questions were asked in these follow-ups. Imputed values for the intermittent years were excluded from the analysis. As a result, there were a total of 2,506 annual observations for which information was available on the annual miles driven.

Based on these 2,506 observations, an ordinary least squares regression model was developed to identify significant factors that explain the variation in the annual miles driven among older drivers. Table 4.3 lists the estimated coefficients of these factors and the corresponding significance level. The factors that increase driving are: being a male and employed, living alone, being in high income categories, being well educated, being a member of a social/religious organizations, being cognitively capable (as represented by scores on word-recall tests and memory tests, and as self-perceived), perceiving oneself to be in good health, exercising regularly, and being one who consumes alcohol. Among them, being a male has the greatest impact on the annual amount of driving, holding everything else constant. All of those factors suggest that having a positive attitude and lifestyle increase driving. On the other hand, aging, having a history of glaucoma, experiencing

**Figure 4.2 Effect of Functional Limitations and Impaired Vision on the Probability of Driving Cessation in Older *Female* Drivers**
**[of an average female driver without any other risk factors present]**

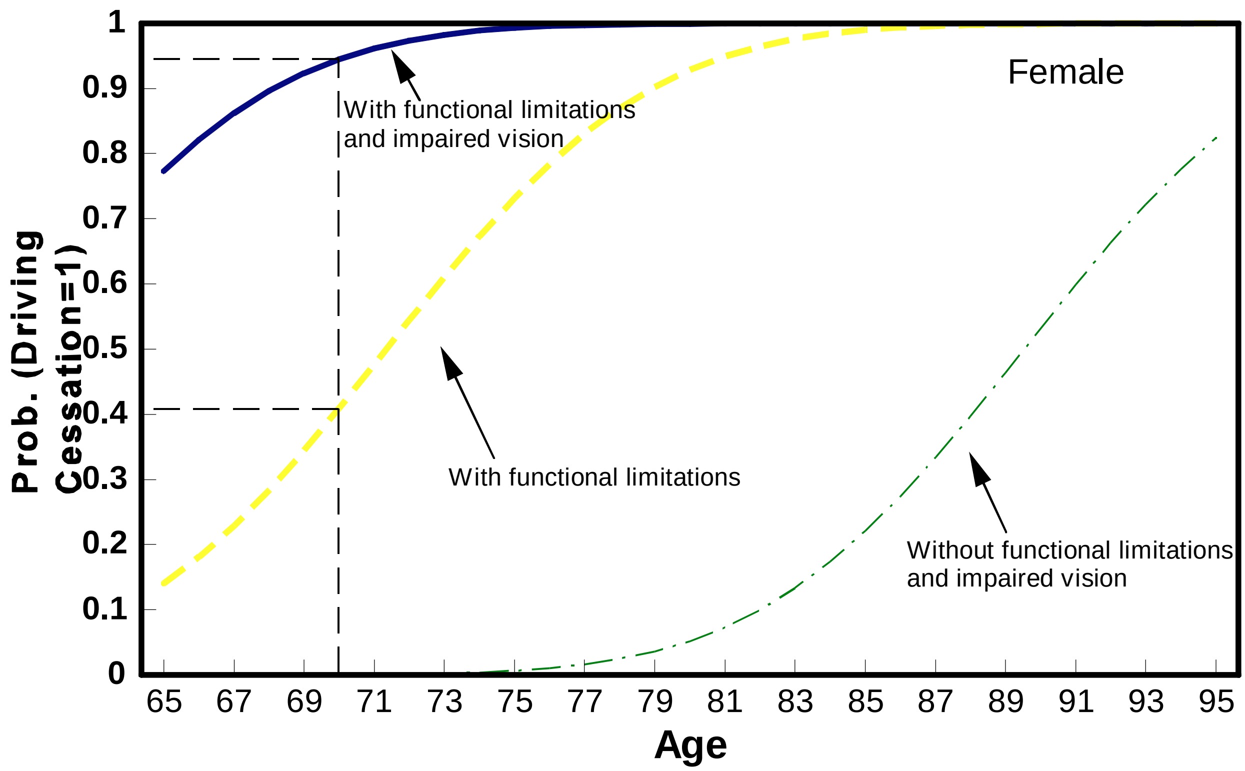


**Figure 4.3 Joint Effect of Visual Impairment and Arthritis on the Probability of Driving Cessation in Older *Male* Drivers [of an average male driver without any other risk factors present]**

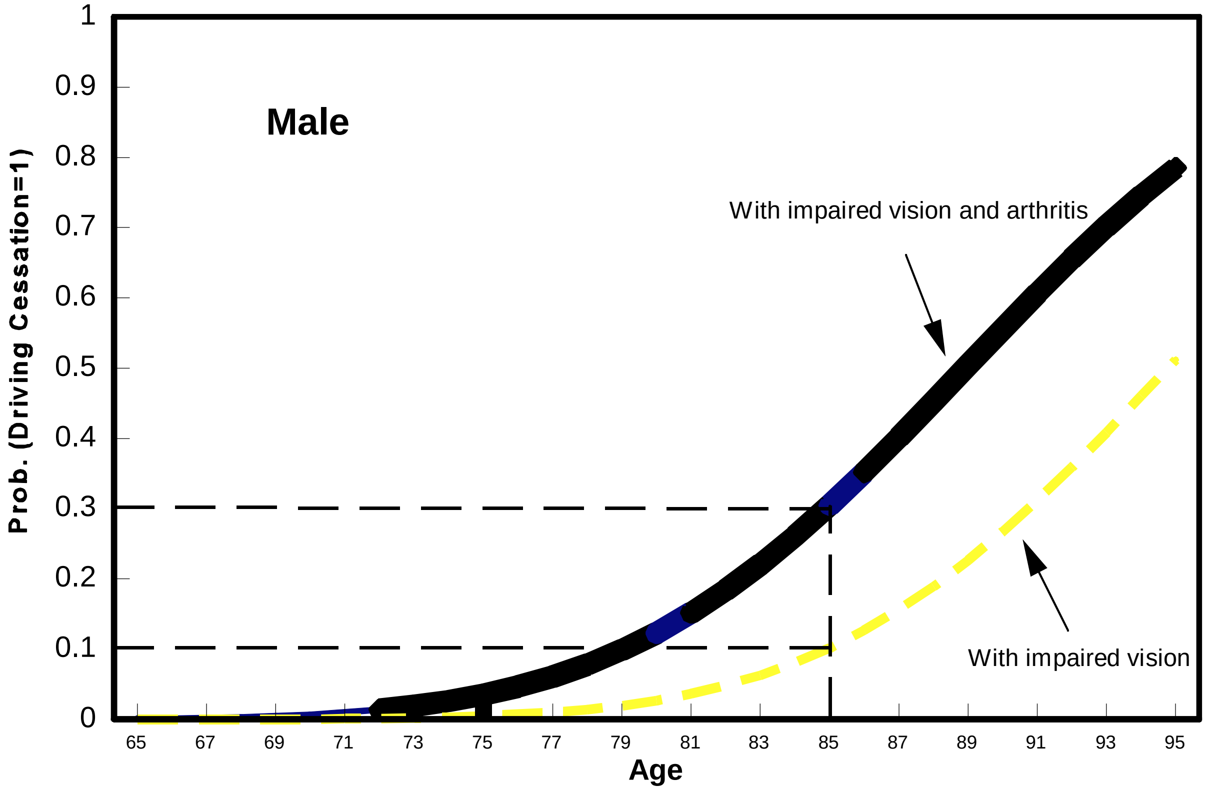


**Table 4.3 Significant Predictors of Annual Miles Driven by Older Drivers**

| Predictor | Estimated Coefficient | *z*-ratio | Prob $\|z^0\| > z$ |
|---|---|---|---|
| Constant | 14.54 | 9.47 | 0.000 |
| ***Demographic Attributes*** | | | |
| Male | 5.03 | 27.86 | 0.000 |
| Age | -0.17 | -9.20 | 0.000 |
| Employed (yes) | 0.77 | 3.35 | 0.001 |
| Education (> 12 years) | 0.91 | 4.81 | 0.000 |
| Income | 0.04 | 2.46 | 0.014 |
| ***Chronic Conditions*** | | | |
| Glaucoma | -0.67 | -2.63 | 0.009 |
| 3rd episode of stroke | -1.88 | -2.61 | 0.009 |
| ***Functional Limitations*** | | | |
| Need help with walking ½ mile | -0.65 | -3.40 | 0.001 |
| ***Psychosocial Characteristics*** | | | |
| Living alone | 0.46 | 2.64 | 0.008 |
| Club member (yes) | 0.87 | 50.63 | 0.000 |
| Self-perceived health condition (good) | 0.42 | 2.16 | 0.031 |
| Bad self-perceived memory | -1.03 | -2.57 | 0.010 |
| Good self-perceived memory | 0.58 | 2.04 | 0.042 |
| Scores low in word-recall test | -0.62 | -3.01 | 0.003 |
| Scores high in memory test | 0.47 | 2.35 | 0.019 |
| Exercise regularly | 0.40 | 2.07 | 0.038 |
| ***Other health-related factors*** | | | |
| Consume alcohol (yes) | 0.43 | 2.60 | 0.009 |

a third episode of stroke, being unable to walk half a mile without help, and having a self-perceived cognitive inability reduce the amount of driving. Among all of the ADLs and higher level physical acitivities, only having difficulty in walking half a mile is a significant factor.

## 4.4 Discussion

By analyzing an **unbalanced** panel data set, we increased the sample size by 60% compared to if our analysis was restricted to a **balanced** data set. The test result of $H_o$: $\rho = corr\ (\varepsilon_{it}, \varepsilon_{is})$ indicated that the annual observation for participant *i* at time *t* is statistically correlated with his observation at time *s*, suggesting that a model that allows the annual observations for participants to freely correlated is more appropriate. As a result, *random effects* binomial probit models of driving cessation were developed.

Our *random effects* binomial probit models revealed that the female and male populations have different sets of factors that influence their decisions to cease driving (Table 4.1). Age is one of the factors common to both genders. However, it has a greater influence on an older *female* driver's decision to stop driving than that on an older *male* driver, holding other factors constant. Results from a combined-gender model (not reported in this report) also identified gender as a significant factor in driving cessation in that older women are more likely to stop driving than older men.

We did not find income to be a significant determinant in older *male* drivers' decisions to stop driving. However, like other studies in the literature, income was found to be an important factor in the driving status of older *female* drivers. Employment status is typically used to gauge the need to drive. A comparison of the estimated coefficients for employment status and income suggest that being employed is a more important factor in driving status than income (Table 4.1). However, the impact of employment status on older *male* drivers was only marginal.

Disabilities in gross mobility (e.g., difficulties in performing ADLs and higher level physical activities) had different influence on the driving decisions of men and women. For example, being unable to stoop, crouch or kneel increased the probability of driving cessation in an older woman, but was not a significant factor in older men. On the other hand, difficulties in performing other ADLs and physical activities, that significantly affect the decision to stop driving in *both* men and women, had considerably greater impacts on the probability of driving cessation in male drivers than on female drivers. For example, needing help in personal grooming, such as brushing hair, brushing teeth and washing face, significantly increased the probability of driving cessation. It was true for both male and female drivers (Table 4.1). However, the influence of this specific functional limitation on male drivers' likelihood to cease driving was four times that of female drivers. This seems to suggest that once older male drivers experienced limitations in performing their ADLs and other physical activities, they were more likely to quit driving than their female counterparts, everything else being constant. This observation is also true of the influence of visual impairments. The influence of visual impairments (as represented by difficulty in recognizing friends across the street and in reading newspaper print) on the decision to cease driving was notably greater in male drivers than in female drivers. These differences in how men and women react differently in their decisions to stop driving with respect to physical activity limitations and visual impairment coincide with the findings by Campbell et al. [6]. It is not clear whether this gender difference is attributable to gender differences in their levels of tolerance. In other words, is it true that when men recognize their physical limitations, they are frequently more severe than those in women?

Scores from the word-recall tests and memory tests were used as a proxy to gauge one's cognitive status. Similar to the finding in [4], cognitive ability was found not to be associated with the decision to stop driving. We agree with the explanation offered by Marottoli et al. [4] regarding this lack of association. In their paper, Marottoli et al. suggested that "...it may be due to lack of awareness of their deficits by cognitively impaired individuals who therefore see no reason to stop driving." When comparing scores from the word-recall tests and memory tests to their self-assessed memory capability, we found that individuals in this Iowa cohort were overly optimistic about their cognitive ability. This observation confirms the claim made by Marottoli and his colleagues of individuals' lack of awareness of their cognitive ability.

Five chronic conditions were explicitly associated with driving cessation -- arthritis, Parkinson's disease, cataracts, stroke(s) and heart attack. In general, these findings conform to the literature, except heart attack. Our analysis also showed that these conditions influenced male drivers differently than female drivers. In our analysis, we distinguished between individuals who had multiple strokes from 1981 to 1993 from those who had one stroke. Similarly, those who had more than one heart attack were identified separately from those who had only one. The rationale for making these distinctions was our hypothesis that multiple episodes of stroke or heart attack may have a compounding impact on older drivers' decisions to stop driving.

Parkinson's disease was the most influential medical condition affecting driving cessation in *female* drivers ($\beta_{\text{Parkinson's}} = 1.82$), but was not even a significant factor in *male* drivers. This finding agrees with that reported by Campbell et al. in [6]. The influence of the second stroke in women is almost three times that of the first stroke, and the influence of the third stroke was insignificant relative to the second. However, this is not the case for men. While the first stroke hardly had any impact on male drivers' decisions to stop driving, the impact of the second stroke was more influential in men than the presence of any other medical condition. These findings confirm our hypothesis that multiple episodes of stroke have a more profound impact on the decision to stop driving than a single episode.

Cataracts were linked to driving cessation in [4] but not in [6] and [7]. Our results suggest that being diagnosed with cataracts did not prevent elderly drivers from driving, in either men or women. However, *female* drivers who had had cataract surgery were more likely to stop driving than those who were diagnosed with cataracts but who had not had any surgery. This might suggest that visual impairment as a result of the cataract was considerably more severe for those who required surgery than those who did not.

Only one other study ([5]) found arthritis to be a significant factor in driving cessation, and its conclusion, however, was contrary to ours. Kington et al. in [5] concluded that those with arthritis are more likely to drive than those without. The authors attributed this finding to the possible difficulty that arthritic elderly have in using poorly-suited alternative transportation modes (e.g., buses), and that continuing to drive is the least difficult mode of transportation. Our analysis, on the other hand, found that arthritis is one of the two medical conditions among men that increases the odds of stopping to drive, but that it is insignificant in women's decisions. Even after taking into account the impact of functional limitations on driving cessation, arthritis remains significant in driving cessation among male drivers.

The mere existence of chronic conditions generally did not affect the decision to stop driving. Instead, they manifested their influence on driving cessation through functional limitations. Arthritis in women is one such condition. When arthritis became severe enough to impair functional capabilities, then afflicted older *female* drivers began to think about stopping to drive. Our model clearly suggests that when both arthritis and difficulties in performing ADLs and/or higher level activities are included in the model of female drivers, the influence of functional limitations outweighs the mere existence of arthritis. Although this example with arthritis is only true for women, we believe that in general it is true. This is because when only chronic conditions were included in the model, without taking into account the impacts of functional limitations, a greater number of chronic conditions become significant than when the impacts of functional limitations are considered in the model. Disability in gross mobility and visual impairment clearly contribute to driving cessation.

As expected, having a positive attitude and life style, in terms of exercise and social support, increase the probability of continuing to drive. Consuming alcohol also increases the probability of continuing to drive in men, potentially due to the connection between alcohol consumption and social activities.

More than half of the female drivers lived alone compared to only 17% of the male drivers. In theory, one expects that living alone increases the probability of continuing to drive. Results from our analysis indicated that this is true for women but not for men. Instead, men who lived alone were more likely not to drive than those who did not, holding other factors constant. We speculate that when women lived alone, they did so involuntarily by becoming widowed. On the other hand, we speculate that men are more likely to live alone willingly than women. This hypothesis is supported, but not tested, by the survey data that about 20% of the men who lived alone were not widowed while the corresponding percentage for women was 8%. By being forced into living alone, women have to continue to drivie so as to satisfy their basic transportation needs. Whereas, when men elect to live alone, they are more likely to cease driving. This hypothsis needs further verification.

In general, results from the *random effects* binomial probit models are consistent with the literature, except for three factors. These factors showed unexpected impacts on driving cessation -- depression, persistent pain in joints, and education level. The role of depression in driving cessation was not conclusive in [4]. However, our model suggests that severe depression decreased the probability of driving cessation in older *female* drivers. We speculated that since women who live alone were more likely to be severely depressed than those who did not live alone, the impacts of living alone and severe depression in women cannot be clearly separated. Male drivers who were better educated were more likely to cease driving than those who were not; and men who suffered persistent pain in their joints appeared more likely to continue driving. These unanticipated findings need to be further investigated in future research.

We found that men who are employed, young and socially active are more likely to drive more miles than their counterparts in the cohort. Aging and increasing difficulty in walking significantly contributed to the decision to drive less. These results are consistent with what Marottoli et al. found in [4]. In addition to these predictors, we found that those who have a positive attitude and life style, in terms of exercising regularly, good self-perceived health condition, and social support, drive more. Living alone in rural areas and consuming alcohol also significantly increase driving. Those who were cognitively capable (e.g., perceived themselves proficient in memory and scored high on memory and work-recall tests) drove more than those who were not.

# CHAPTER 5. RISK FACTORS FOR VEHICLE CRASHES

## 5.1 Description of Data

Although annual information on the participants was observed from 1981 to 1993, crash data for these participants were available only from 1985 to 1993. The Iowa DMV typically retains crash data for five years -- the current year plus four years prior. Thus, when crash data were first requested from the Iowa DMV in 1989, crash data were made available from 1985 to 1989. Crash data earlier than 1985 were then no longer available. Crash data after 1989 has been provided recently by the Iowa DMV at the request of the National Highway Traffic Safety Administration. As a result, this analysis on vehicle crashes is based on the crash data from 1985 to 1993.

Individuals eligible for this analysis were those 1) who were part of the 2,207 group; 2) who were active in terms of being alive, not being institutionalized, not in a nursing home, and not moved out of Iowa; 3) who still drove (self-reported); 4) whose records were found in the Iowa DMV files; **and** 5) who had not surrendered their driver's licenses (based on information maintained by Iowa DMV.) Note that all five conditions have to be met for an individual to be included in the analysis.

Note that only police-reported crashes are included in this study. Based on the 1990 Nationwide Personal Transportation Survey, about 20% of the highway incidents and crashes in a year went unreported [14]. Most of these unreported incidents/crashes were property-damage-only (PDO) accidents with an estimated amount of damage lower than the legal reporting threshold. In any given year between 1985 and 1993, at least 96% of the participants were free from crashes (Table 5.1), reflecting the fact that crashes are relatively rare events. The accident reporting criteria in the State of Iowa are property-damage accidents with damage exceeding $500 or accidents resulting in personal injuries. These criteria were unchanged during the study period.

**Table 5.1 Number of Participants**
**by Number of Crashes Involved in Each Year and the Year**

| Year | No. of Crashes Involved in Each Year | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | No Crash | | One Crash | | Two Crashes | | TOTAL | |
| | Female | Male | Female | Male | Female | Male | Female | Male |
| 1985 | 907 (97.9%) | 858 (96.9%) | 19 (2.1%) | 27 (3.1%) | 0 (0.0%) | 0 (0.0%) | 926 (100%) | 885 (100%) |
| 1986 | 871(97.8%) | 794 (96.6%) | 19 (2.1%) | 27 (3.3%) | 1 (0.1%) | 1 (0.1%) | 891 (100%) | 822 (100%) |
| 1987 | 870(97.4%) | 721 (95.2%) | 23 (2.6%) | 34 (4.5%) | 0 (0.0%) | 2 (0.3%) | 893 (100%) | 57 (100%) |
| 1988 | 791 (98.0%) | 646 (95.5%) | 14 (1.7%) | 30 (4.4%) | 2 (0.3%) | 0 (0.0%) | 807(100%) | 676 (100%) |
| 1989 | 721 (97.4%) | 558 (95.2%) | 18 (2.4%) | 27 (4.6%) | 1 (0.1%) | 1 (0.2%) | 740 (100%) | 586 (100%) |
| 1990 | 624 (97.2%) | 437 (94.6%) | 17 (2.6%) | 24 (5.2%) | 1 (0.1%) | 1 (0.2%) | 642 (100%) | 462 (100%) |
| 1991 | 590 (97.7%) | 421 (95.5%) | 13 (2.2%) | 20 (4.5%) | 1 (0.1%) | 0 (0.0%) | 604 (100%) | 441 (100%) |
| 1992 | 531 (97.8%) | 399 (97.3%) | 12 (2.2%) | 11 (2.7%) | 0 (0.0%) | 0 (0.0%) | 543 (100%) | 410 (100%) |
| 1993 | 493 (97.2%) | 365 (97.3%) | 13 (2.6%) | 10 (2.7%) | 1(0.2%) | 0 (0.0%) | 507 (100%) | 375 (100%) |

The participants were asked in the 7th and the 10th follow-ups to report the number of miles they had driven during the 12 months prior to the interview. Since the responses were categorical (i.e., less than 500 miles, between 500 and 2,000 miles, etc.), the exact number of miles driven for each category was estimated as stated in Table 5.2. Information on annual VMT was asked in the 7th (in 1989) the 10th (1992) follow-ups. Data on the average annual miles driven are missing for the years in which this information was not asked. However, in these two follow-ups, the question was asked about "*Compared to five years ago, do you now drive much less, somewhat less, about the same, or more often?*" The missing annual VMT was first established based on the responses to this question. If the answer was "much less", then the amount of driving five years ago was arbitrary assumed to be twice as much as that in the current year. If the answer was "somewhat less", then the amount of driving five years ago was assumed to be 1.3 times that in the current year. On the other hand, if the response was "more often", then the amount of driving five years ago was set to be 70% of that in the current year. For the years where annual VMT was still missing, a linear interpolation was used.

The number of annual observations included in this analysis (with annual VMT) is only 9,343, indicating that about 20% of the annual observations were deleted from the analysis due to missing data on annual VMT.

Questions about the use of medication (both prescribed and over-the-counter drugs) were asked in the baseline interview as well as in every follow-up interview. The participants were asked to present the medication containers during the in-person interviews so that the interviewers could record accurately the relevant drug data. The in-person interviews took place in the baseline interview, and in the 3rd and 6th follow-ups. The drug data collected in these in-person interviews were made available to us by the National Institute on Aging (NIA) and were used in our analysis. Although the 10th follow-up was also an in-person interview, the processing of the drug use data collected in this follow-up was not completed at the time of our study, and they were not included in our analysis. Drug use during the intermittent years were imputed based on the rules outlined in Table 3.4.

**Table 5.2 Annual Miles Driven for Each Mileage Category 7th and 10th Follow-ups**

| 7th Follow-up | | 10th Follow-up | |
|---|---|---|---|
| Response Category | Estimated Annual Miles Driven | Response Category | Estimated Annual Miles Driven |
| - | - | Less than 500 miles | 500 miles |
| < 2,000 miles | 1,500 miles | 500-1,999 miles | 1,250 miles |
| 2,000-4,999 miles | 3,500 miles | 2,000-4,999 miles | 3,500 miles |
| 5,000-7,999 miles | 6,500 miles | 5,000-7,999 miles | 6,500 miles |
| 8,000-9,999 miles | 9,000 miles | 8,000-9,999 miles | 9,000 miles |
| 10,000-15,000 miles | 12,500 miles | 10,000-15,000 miles | 12,500 miles |
| More than 15,000 miles | 18,000 miles | More than 15,000 miles | 18,000 miles |

A elaborate procedure was developed by the NIA and the University of Iowa to aggregate numerous drugs into several major groups, including diuretics, beta-blockers, other antihypertensives, diabetic insulin/oral hypoglycemics, anti-depressants/psychotropics, anti-anxiety agents, gastrointestinal and lung medications, antihistamines, nonsteroidal anti-inflammatory agents, aspirin, and analgesics/antipyretics [8].

Depression severity was represented by a self-reported index of depressive symptoms developed by the Center for Epidemiological Studies of National Institute of Mental Health. The original form of this test consists of 20 statements, each describing a symptom of depression or diminished morale. The Iowa 65+ Rural Health Study used an abbreviated version of the index which consists of 11 items. The 11 questions were:

1. I did not feel like eating. My appetite was poor.
2. I felt depressed.

3. I felt that everything I did was an effort.
4. My sleep was restless.
5. I was happy.
6. I felt lonely.
7. People were unfriendly.
8. I enjoyed life.
9. I felt sad.
10. I felt that people disliked me.
11. I could not "get going."

Instead of using the score from the single question of "I felt depressed" to determine the depression scale of the participants, a single composite score of depressive symptomatology can be developed from the scores on the eleven questions. This depressive symptomatology index ranges from zero (indicating no symptoms) to a maximum score of eighteen [8]. Based on this depressive symptomatology index, Foley et al. [8] found that the 20% most severely depressed participants were not different from the less depressed participants in their crash involvement rates. As a result, we divided the top 20$^{th}$ percentile into finer groups: the top 2%, 2% - 5%, 5% - 10%, and 10% - 20%, based on the total score on the aforementioned eleven questions. In addition, the responses to the two questions regarding being depressed or bored were also examined.

## 5.2 Model Development

### 5.2.1 Model Specifications

In theory, the problem of identifying risk factors is equivalent to finding a model that generates the data that we observe. In our case, the data that we observe are the survey data and the crash data from the Iowa DMV. Since the true model is unknown, the goal of any modeling effort is to develop a model that approximates the true model as closely as possible. The model selection procedure is generally based on an approach that begins by testing the most general specification, and then progresses to test a series of more restricted specifications. This approach follows classical Neyman-Pearson hypothesis testing. In the case where there are a large number of potential risk factors that contain some degree of redundant information, it is highly probable that more than one model will have approximately the same high likelihood of generating the data that we observe. In such cases, theory as well as modeling objectives, such as policy analysis, should guide model selection decisions.

In this regard, the issue of whether to include information on annual miles driven is an important one. The number of miles driven (VMT) has been widely used in highway safety analysis as a proxy to measure the extent to which one exposes oneself to vehicle crashes. The theory is that the more one drives, the more one exposes oneself to crashes and the more likely one is to be involved in a crash. The opponents of this viewpoint argue that from the policy making perspective, how much one drives is irrelevant since licensing guidelines cannot be based on the amount of driving. The validity of this claim is questionable since one of the licensing restrictions in Iowa is to restrict one's driving within a limited number of miles radius from one's residence. Nevertheless, we developed two separate models based on two sets of risk factors -- one included the average annual miles driven by an average older driver and the other did not.

A similar model specification issue is the question of whether less objective variables, such as perceived health, should be included in the model. At this point, we do not limit our analysis to only objective measures because the findings from our analysis will be used not only to assist the development of licensing guidelines but also to help older drivers become more aware of different risk factors that affect the probability of vehicle crashes.

Other model specification issues are less clear cut. For example, the symptoms and treatments of a particular medical condition are usually highly correlated, and may represent the underlying risk factors equally well. In some cases, the choice of variables may have important implications, but the modeling criteria with the available sample cannot clearly discriminate between them. In presenting the modeling results we will discuss these issues in more detail for the particular cases that we encountered.

### 5.2.2 Model Framework

Although we can analyze crash data using multiple linear regression models, Miaou et al. in [15] identified several undesirable statistical properties of these models for the types of analysis in this study:

① Vehicle crashes are discrete events. The use of a continuous distribution, such as a normal distribution, to model vehicle crashes only approximates a discrete process.

② For some model formulations, the models might predict a **negative** number of crashes.

③ Vehicle crashes are rare events in that the probability of observing no crash is highly likely. The underlying probability distribution is thus significantly skewed to the right, and the normal distribution is clearly inappropriate under this situation.

To avoid these properties, the Poisson regression model has been widely used to study count data. The Poisson regression model stipulates that each count $y_i$ is drawn from a Poisson distribution with parameter $\lambda_i$, which is related to the regressors, $\boldsymbol{x}_i$. The primary equation of the model is

$$Prob\ (Y_i = y_i) = \frac{e^{-\lambda_i}\ \lambda_i^{y_i}}{y_i!} \tag{5.1}$$

where $y_i = 0, 1, 2, \ldots$ $\lambda_i$ is commonly formulated as being log-linearly dependent on the regressors, $\boldsymbol{x}_i$,

$$\ln \lambda_i = \beta' x_i \tag{5.2}$$

and

$$E\ [Y_i\ |\ x_i] = Var\ [Y_i\ |\ x_i] = \lambda_i = e^{\beta' x_i} \qquad (5.3)$$

In principal, the Poisson model is a nonlinear regression model with a log-likelihood function of

$$\ln\ L = \sum_i\ [-\lambda_i + y_i \beta' x_i - \ln\ y_i!]. \qquad (5.4)$$

The parameters $\boldsymbol{\beta}$ can be estimated by using maximum likelihood techniques.

The Poisson model has been criticized for its implicit assumption in that the variance of $y_i$ is equal to its mean. In many cases, count data are found to exhibit greater variation (or **overdispersion**) relative to a Poisson model. In other words, the variance of the data is frequently greater than that indicated by the Poisson model. Several factors contribute to the overdispersion in the data, including omitted variables, uncertain in explanatory variables, and correlations of dependent variables among sample units [15]. The overdispersion parameter is therefore tested to see if it is significantly different from zero. If so, the negative binomial regression model is employed as an alternative to the Poisson model.

The negative binomial model is an extension of the Poisson regression model which allows the variance of the process to differ from the mean. The model re-specifies (5.2) to be

$$\ln\ \lambda_i = \beta'\ x_i + \varepsilon, \qquad (5.5)$$

where exp($\varepsilon$) has a gamma distribution with mean 0 and variance $\gamma$. The resulting probability distribution is

$$Prob[Y = y_i \mid \varepsilon] = \frac{e^{-\lambda_i \exp(\varepsilon)} \lambda_i^{y_i}}{y_i !} \qquad (5.6)$$

where $y_i = 0, 1, \ldots$

To address the possibility of correlation among the $y_i$*'s*, the number of accidents in a year for the *ith* participant for all years during the study period (from 1985 to 1993), we tested a *random effects* specification for the Poisson regression model and the negative binomial model.

## 5.3 Results

We developed a Poisson regression model to relate demographic attributes, the use of medication, and health-related factors to the probability of older drivers being involved in vehicle crashes. Two types of model specifications were tested - a *random effects* error structure, and a negative binomial distribution. Tests of the hypothesis that the overdispersion parameters are zero were not rejected at any reasonable significance level. Therefore, we concluded that the Poisson specification with independent observations is appropriate.

Similar to the analysis of driving status, the potential factors contributing to older drivers' probability of being involved in a vehicle crash include: demographic attributes, limitations in performing physical activities, chronic conditions, physical features, psychosocial characteristics, symptoms, and other health-related factors (as described in Chapter 4.) The only variables that were excluded in the driving status model, but that were included in the crash model, were the annual miles driven by individual drivers and the use of medication.

The first stage of our analysis is to develop separate gender-specific models. The results from these models were then used to formulate a single combined-gender model to explain the variation in the crash rates between genders. Results from the first stage of this analysis suggest that there are significant gender differences in a number of the risk factors that determine the probability of an older driver being involved in vehicle crashes. The most notable gender difference is the impact of employment status on crash involvement rate. For example, the crash rate of older male drivers who had jobs was significantly higher than those without jobs. Whereas, older *female* drivers who had a job had a significantly lower crash rate than those without a job, although the impact of employment status on older female drivers' involvement in crashes was marginal (Table 5.3).

<u>Considering annual VMT as a crash risk factor</u>

Gender-specific crash models were developed by including the annual miles driven (VMT) as a risk factor in vehicle crashes. The results for older female drivers are shown in Table 5.3. After testing a series of restricted models derived from the most general model that was considered in this study, we developed the final model. Since a significance level of $\alpha$=0.05 is typically used, Model 1 in Table 5.3 is the final model. However, if one chooses to use the selection criterion of significance at the $\alpha$=0.10 level, then Model 6 in Table 5.3 is the final model. Models 2 through 5 test Model 1 for omitted variables. The test results for each hypothetical omitted variable are presented in Table 5.3. For example, the difference between Models 1 and 5 is the consideration of having difficulty seeing a friend across the street. The likelihood ratio test of this omitted variable is significant at 0.05 level but the Wald test is significant at 0.10 level.

The final crash model for older *female* drivers, Model 1 of Table 5.3, was then subjected to a number of diagnostic tests for omitted variables. The complete results of these diagnostic tests are summarized in Appendix 1. From these diagnostic tests, four factors were identified as being borderline in significance. They were: hospital stay, being employed, having experienced one stroke, and having difficulty in seeing a friend across the street. For example, a test of whether having difficulty seeing a friend across the street should be included in the final model yields a Wald test statistic which is significant at the $\alpha = 0.10$ level and a log-likelihood ratio test statistic which is significant at the $\alpha = .05$ level (Model 5 in Table 5.3). All of these borderline factors have a negative coefficient, suggesting that they are augmenting the impacts of the annual miles driven on crash involvement, by adjusting the relative exposure. An important result demonstrated by Table 5.3 is that the final model coefficients are reasonably robust with respect to the inclusion of any one of these borderline variables. Thus, even if the difficulty of seeing a friend across the street really should be included in the model, the conclusions regarding the factors -- annual miles driven, and having difficulty in extending arms over shoulder level -- would not noticeably change.

Having difficulty in extending arms above shoulder level increases the probability of an older female driver being involved in vehicle crashes. This functional limitation is one of the surrogate indicators of older drivers' gross mobility. The probability of being involved in vehicle crashes and the odds ratio for the final model are presented in Table 5.4. There are two parts to this table. The first part are the probabilities of an older *female* driver being involved in vehicle crashes as a function of two risk factors -- annual miles driven, and a limitation in gross mobility (as represented by having difficulty in extending her arms over her shoulders.) The second part of the table are the odd ratios. The first row of the odd ratios contains the odds ratio for an older *female* driver who has no difficulty in extending her arms above her shoulders, and drives 12,000, 18,000 and 24,000 miles in a year, relative to a similar driver driving only 6,000 miles a year. For example, an older female driver who drives an average of 12,000 miles a years is 1.5 times more likely to be involved in vehicle crashes than another female driver who drives 6,000 miles a year, given that both women have no difficulty in extending their arms above their shoulders. Similarly, the second row of this table contains the odds ratio for an older female driver who has difficulty in extending her arms above her shoulders relative to one without this disability, given that both women drive the same number of miles a year. For example, an older female who has difficulty in extending her arms above her shoulders is more than twice likely to be involved in vehicle crashes than another female driver without this functional limitation, given both women drive 6,000 miles a year.

**Table 5.3 Selection of Crash Models for Older *Female* Drivers**

**[Poisson Regression Model, *with* the Annual VMT]**

| Variable | Model 1 | Model 2 | Model 3 | Model 4 | Model 5 | Model 6 | % with characteristic |
|---|---|---|---|---|---|---|---|
| Constant | -3.97** | -3.94** | -3.91** | -3.93** | -3.93** | -3.79** | |
| Annual miles driven | 0.07** | 0.07** | 0.07** | 0.07** | 0.07** | 0.07** | 3,230 |
| Having difficulty in extending arms | 0.85** | 0.84** | 0.97** | 0.88** | 0.98** | 1.09** | 2% |
| | | | | | | | |
| Employed | | -0.57* | | | | -0.60* | 12% |
| Hospital stay (yes) | | | -0.48* | | | -0.44* | 17% |
| 1st episode of stroke | | | | -0.93* | | -0.90* | 7% |
| Difficulty in seeing a friend across street (yes) | | | | | -1.88* | -1.85* | 4% |
| Log Likelihood (LL) | -616.4 | -614.7 | -614.7 | -614.2 | -612.9 | -607.4 | |
| LL Ratio | | 3.47* | 3.38* | 4.50** | 7.00** | 17.94** | |
| Number of Observations = 5288<br>Restricted Likelihood value = -622.6 | | | | | | | |

**Significant at $\alpha$ =0.05.

* Significant at $\alpha$ =0.10.

**Table 5.4 Probabilities and Odd Ratios of Crash Risk Factors**
**Older *Female* Drivers**

| | Annual Miles Driven | | | |
|---|---|---|---|---|
| | 6,000 | 12,000 | 18,000 | 24,000 |
| ***Probability*** | | | | |
| Annual miles driven | 0.028 | 0.042 | 0.064 | 0.095 |
| Having difficulty in extending arms | 0.065 | 0.096 | 0.142 | 0.208 |
| ***Odds Ratio*** | | | | |
| Annual miles driven | 1.00 | 1.51 | 2.26 | 3.37 |
| Having difficulty in extending arms | 2.29 | 2.27 | 2.24 | 2.19 |

Estimation results for older *male* drivers are summarized in Table 5.5. The final model estimates are contained in the column labeled "Model 1." The significant risk factors in this model are the annual miles driven, living alone, being employed, having a history of glaucoma, having impaired cognitive ability, and using anti-depression drugs. Glaucoma is likely to result in substantial deterioration of peripheral vision which is essential for safe driving. One of the side effects of anti-depressants, particularly cyclic anti-depressants, is sedation, and susceptibility to these side effects increases with age [17]. Moreover, two of the frequently prescribed anti-depressants (amitriptyline and trazodone) are found to have a detrimental effect on cognitive, psychomotor and car-driving tasks [17].

The estimated mileage coefficient for older *male* drivers is almost half that estimated for older *female* drivers, indicating that the influence of mileage on the likelihood of being involved in vehicle crashes is significantly smaller in men than in women. In addition, the employment status for older *male* drivers increases the probability of being involved in a vehicle crash. The probabilities of being involved in vehicle crashes and the odds ratios for this model are presented in Table 5.6. The interpretation of the odd ratios in this table is the same as that in Table 5.4. These odd ratios suggest that the use of an anti-depression drug, which doubles the probability of being involved in a vehicle crash, is the single most influential risk factor other than the amount of driving.

**Table 5.5 Selection of Crash Models for Older *Male* Drivers**
**[Poisson Regression Model, *with* the Annual VMT]**

| | Model 1 | Model 2 | Model 3 | Model 4 | | % with characteristic |
|---|---|---|---|---|---|---|
| Average miles driven | 0.04** | 0.04** | 0.04** | 0.04** | | 8,320 |
| Living alone | 0.42** | 0.40** | 0.38** | 0.36** | | 17% |
| Employed (yes) | 0.47** | 0.49** | 0.47** | 0.49** | | 21% |
| History of Glaucoma (yes) | 0.54** | 0.49** | 0.51** | 0.46** | | 7% |
| Low scores on word-recall tests | 0.40** | 0.40** | 0.38* | 0.38* | | 78% |
| Anti-depressant (yes) | 0.72** | 0.63* | 0.68** | 0.59* | | 3% |
| | | | | | | |
| Feel bored | | 0.47** | | 0.50 | | 3% |
| Depressed[1] | | | 0.58* | 0.43** | | 10% |
| Log Likelihood (LL) | -712.4 | -710.4 | -711.1 | -709.4 | | |
| LL Ratio | | 4.12** | 2.55 | 6.05** | | |
| Number of observations = 4,110<br>Restricted log likelihood = -726.98 | | | | | | |

[1] Scored in the top 2nd to 5th percentile of the overall depression scale.
**Significant at $\alpha$ =0.05.
* Significant at $\alpha$ =0.10.

**Table 5.6 Probabilities and Odd Ratios of Crash Risk Factors**
**Older *Male* Drivers**
**[Poisson Regression Model, *with* the Annual VMT]**

| | Annual Miles Driven | | | |
|---|---|---|---|---|
| | 6,000 | 12,000 | 18,000 | 24,000 |
| ***Probability*** | | | | |
| Annual miles driven | 0.020 | 0.026 | 0.034 | 0.044 |
| Living alone | 0.031 | 0.040 | 0.051 | 0.066 |
| Employed (yes) | 0.032 | 0.042 | 0.054 | 0.069 |
| History of glaucoma (yes) | 0.035 | 0.045 | 0.057 | 0.074 |
| Scored low on word-recall tests | 0.030 | 0.039 | 0.050 | 0.065 |
| Anti-depressant (yes) | 0.042 | 0.054 | 0.069 | 0.088 |
| All above variables | 0.233 | 0.290 | 0.358 | 0.437 |
| ***Odds Ratio*** | | | | |
| Annual miles driven | 1.00 | 1.29 | 1.66 | 2.14 |
| Living alone | 1.51 | 1.51 | 1.51 | 1.50 |
| Employed (yes) | 1.58 | 1.58 | 1.58 | 1.57 |
| History of glaucoma (yes) | 1.70 | 1.69 | 1.69 | 1.68 |
| Scored low on word-recall tests | 1.49 | 1.49 | 1.49 | 1.48 |
| Anti-depressant (yes) | 2.04 | 2.03 | 2.03 | 2.02 |
| All above variables | 11.40 | 11.02 | 10.55 | 9.99 |

Complete diagnostic test results for omitted variables in the model for older *male* drivers are contained in Appendix 2. These results identified two borderline risk factors: boredom and scoring in the top 2nd to 5th percentile on the overall depression scale. When the boredom variable is included in the model, it is significant at the 0.05 level. However, including this marginal risk factor reduces the magnitude of the coefficient for anti-depressant drugs to insignificant at the 0.05 level (Model 2 in Table 5.5). Since it may be more desirable to develop a model based on less subjective factors, the use of an anti-depressant drug is included in the model instead of the self assessment of boredom. This is despite the fact that the resulting log-likelihood statistics for this model is somewhat small. A comparison of the estimated coefficients for a particular factor across various models indicates that these estimation results are fairly robust with regard to the inclusion of any one of the borderline factors (Table 5.5).

Surprising, the only common risk factor in the two gender-specific models (Tables 5.3 and 5.5) was the annual miles driven. As a first step in developing a single model for both genders, we combined all of the significant factors identified from the gender-specific models and examined the coefficient estimates for both genders separately as well as combined. The results of this initial stage of the analysis are summarized in Table 5.7. The gender-specific percentages of older drivers who have given medical conditions and symptoms are in Table 5.8. Experiencing back pain was also included in this examination due to the results from the diagnostic tests for omitted variables (Appendix 3). Inspection of the coefficient estimates suggests that both genders may have the same values for the factors -- the annual miles driven, living alone, and experiencing back pain. Tests of these hypotheses were not rejected at the .10 significance level. However, hypothesis tests that both genders share the same coefficient values for the following factors: employed, a history of glaucoma, impaired cognitive ability (as represented by the scores of word-recall tests), use of an anti-depressant, and having difficulty in extending arms over shoulders, were all rejected at the .05 significance level.

A combined model for both genders was then estimated using these pooling test results. The estimated coefficients for the final model of combined genders are presented in Model 1 in Table 5.9. The risk factors that increase older drivers' likelihood of being involved in vehicle crashes are: the amount of annual driving, living alone, and experiencing back pain. These are risks that are common to both women and men. Risk factors that are specific to older *male* drivers are: employment, a history of glaucoma, cognitive disability, and use of anti-depressants. The probabilities of being involved in vehicle crashes and the odds ratios for this final combined-gender model are presented in Table 5.10. These odd ratios show that the most influential risk factor other than the amount of annual driving is the use of an anti-depressant for males.

**Table 5.7 Crash Models by Gender**
**[Maximum Likelihood Poisson Regression Model, *with* the Annual VMT]**

| | Gender | | |
|---|---|---|---|
| | Combined | Female | Male |
| Male | 0.38** | | |
| Annual miles driven | 0.05** | 0.07** | 0.04** |
| Living alone | 0.27** | 0.17 | 0.43** |
| Back pain | 0.20* | 0.21 | 0.21 |
| Employed (yes) | 0.15 | -0.58* | 0.47** |
| History of glaucoma (yes) | 0.32* | 0.09 | 0.53** |
| Scored low on word-recall tests | 0.15 | -0.05 | 0.40** |
| Anti-depressant (yes) | 0.37 | 0.16 | 0.72** |
| Having difficulty in extending arms (yes) | 0.52 | 0.77** | -0.09 |
| | | | |
| Sample size *(n)* | 9,398 | 5,288 | 4,110 |
| Log-Likelihood (*LL)* | -1333.27 | -613.3846 | -711.5348 |
| Restricted *LL* | -1360.186 | -622.5977 | -726.982 |

** - Significant at .05 level
* - Significant at .10 level

## Table 5.8 Percentages of Medical Conditions and Symptoms by Gender

| | Living alone | | Back pain | | Employed (yes) | | Glaucoma | | Impaired cognitive ability | | TOTAL | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Female** | **Male** | **Female** | **Male** | **Female** | **Male** | **Female** | **Male** | **Female** | **Male** | **Female** | **Male** |
| 1985 | 51.5% | 12.8% | 44.2% | 38.8% | 13.7% | 23.9% | 5.2% | 3.6% | 57.5% | 74.6% | 699 | 578 |
| 1986 | 53.1% | 13.3% | 44.3% | 38.9% | 14.4% | 21.9% | 7.5% | 6.2% | 62.5% | 77.9% | 702 | 579 |
| 1987 | 53.9% | 14.9% | 44.8% | 38.7% | 12.2% | 21.6% | 7.8% | 6.1% | 62.7% | 77.9% | 739 | 589 |
| 1988 | 56.8% | 15.4% | 44.9% | 38.5% | 11.4% | 20.2% | 7.2% | 5.3% | 62.6% | 77.7% | 738 | 584 |
| 1989 | 60.4% | 17.8% | 44.6% | 38.7% | 9.8% | 17.4% | 8.9% | 6.9% | 68.8% | 79.4% | 728 | 569 |
| 1990 | 65.8% | 21.8% | 43.6% | 37.4% | 10.1% | 20.0% | 13.4% | 11.2% | 68.0% | 79.3% | 635 | 455 |
| 1991 | 65.4% | 23.4% | 44.9% | 35.7% | 9.9% | 21.1% | 13.9% | 12.3% | 67.8% | 80.1% | 497 | 342 |
| 1992 | 63.8% | 23.9% | 45.8% | 36.0% | 10.0% | 22.0% | 12.1% | 11.8% | 65.4% | 79.3% | 439 | 314 |
| 1993 | 65.8% | 16.0% | 41.4% | 42.0% | 13.5% | 17.0% | 15.3% | 6.0% | 66.7% | 71.0% | 111 | 100 |
| Total sample | | | | | | | | | | | 5,288 | 4,110 |

**Table 5.8 Percentages of Medical Conditions and Symptoms by Gender (continued)**

| | Use of Anti-depressant | | Difficulty in extending arms | | Bored | | Depressed | | Difficulty in seeing a friend across street | | TOTAL | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Female | Male | Female | Male | Female | Male | Female | Male | Female | Male | Female | Male |
| 1985 | 4.1% | 2.8% | 1.7% | 0.9% | 7.7% | 10.2% | 3.4% | 1.7% | 3.3% | 1.9% | 699 | 578 |
| 1986 | 5.3% | 2.6% | 1.3% | 0.9% | 7.6% | 10.2% | 3.0% | 1.7% | 3.0% | 1.2% | 702 | 579 |
| 1987 | 5.1% | 2.9% | 2.2% | 1.4% | 7.4% | 10.5% | 2.8% | 1.7% | 2.8% | 1.9% | 739 | 589 |
| 1988 | 5.1% | 2.7% | 2.6% | 1.2% | 7.5% | 10.4% | 2.8% | 1.5% | 3.7% | 2.7% | 738 | 584 |
| 1989 | 5.1% | 2.8% | 1.1% | 0.4% | 7.6% | 9.7% | 5.5% | 4.4% | 3.7% | 2.5% | 728 | 569 |
| 1990 | 5.2% | 2.6% | 3.6% | 1.8% | 6.8% | 9.0% | 5.2% | 4.4% | 6.9% | 4.4% | 635 | 455 |
| 1991 | 5.0% | 2.3% | 3.6% | 1.2% | 6.4% | 9.1% | 4.6% | 4.7% | 7.2% | 3.8% | 497 | 342 |
| 1992 | 5.7% | 2.5% | 3.2% | 1.0% | 6.4% | 8.0% | 4.3% | 4.5% | 5.7% | 2.6% | 439 | 314 |
| 1993 | 6.3% | 4.0% | 2.7% | 3.0% | 9.0% | 10.0% | 8.1% | 2.0% | 6.3% | 4.0% | 111 | 100 |
| Total sample | | | | | | | | | | | 5,288 | 4,110 |

## Table 5.9 Selection of Combined-Gender Crash Models,
**[Poisson Regression Model, *with* the Annual VMT]**

| | Model 1 | Model 2 | Model 3 | Model 4 | Model 5 | Model 6 | Model 7 |
|---|---|---|---|---|---|---|---|
| Annual miles driven | 0.05** | 0.05** | 0.05** | 0.05** | 0.05** | 0.05** | 0.05** |
| Living alone | 0.31** | 0.31** | 0.29** | 0.33** | 0.30** | 0.32** | 0.29* |
| Back pain | 0.23** | 0.22* | 0.21* | 0.23* | 0.21* | 0.24** | 0.21* |
| Employed (male only) | 0.44** | 0.46** | 0.44** | 0.43** | 0.44** | 0.43** | 0.44** |
| History of glaucoma (male only) | 0.54** | 0.50** | 0.51** | 0.53** | 0.54** | 0.59** | 0.53** |
| Scored low on word-recall tests (male only) | 0.33** | 0.32** | 0.32** | 0.30** | 0.35** | 0.33** | 0.29* |
| Anti-depressant (male only) | 0.69** | 0.63* | 0.66* | 0.68* | 0.70** | 0.68** | 0.58* |
| | | | | | | | |
| Feel Bored | | 0.37** | | | | | 0.31** |
| Depressed[1] | | | 0.55** | | | | 0.5 |
| Employed (female only) | | | | -0.53* | | | -0.51* |
| Having difficulty in extending arms | | | | | 0.77** | | 0.76* |
| Difficulty in seeing friends across the street (yes) | | | | | | -0.81* | -0.88* |
| Log Likelihood (*LL*) | -1329.4 | -1327.3 | -1327.1 | -1327.8 | -1327.8 | -1327.3 | -1320.2 |
| *LL* Ratio | | 4.04** | 4.55** | 3.12* | 3.14* | 4.17** | 18.21** |
| Number of observations = 9,389<br>Restricted log likelihood = -1359.9 | | | | | | | |

[1] Scored in the [illegible]
Significant [illegible]

**Table 5.10 Probabilities and Odd Ratios of Crash Risk Factors, Gender Combined [Poisson Regression Model, *with* the Annual VMT]**

| | Annual Miles Driven | | | |
|---|---|---|---|---|
| | 6,000 | 12,000 | 18,000 | 24,000 |
| ***Probability*** | | | | |
| Annual miles driven | 0.020 | 0.027 | 0.036 | 0.047 |
| Living alone | 0.028 | 0.037 | 0.048 | 0.064 |
| Back pain (yes) | 0.025 | 0.034 | 0.044 | 0.058 |
| Employed (male only) | 0.031 | 0.041 | 0.055 | 0.072 |
| History of glaucoma (male only) | 0.034 | 0.045 | 0.060 | 0.079 |
| Scored low on word-recall tests (male only) | 0.028 | 0.037 | 0.049 | 0.065 |
| Anti--depressant (male only) | 0.040 | 0.053 | 0.070 | 0.092 |
| **All factors for *males*** | **0.229** | **0.293** | **0.368** | **0.457** |
| **All factors for *females*** | **0.035** | **0.046** | **0.060** | **0.079** |
| ***Odds Ratio*** | | | | |
| Annual miles driven | 1.00 | 1.32 | 1.75 | 2.31 |
| Living alone | 1.36 | 1.36 | 1.36 | 1.36 |
| Back pain (yes) | 1.25 | 1.25 | 1.25 | 1.25 |
| Employed (male only) | 1.54 | 1.54 | 1.54 | 1.53 |
| History of glaucoma (male only) | 1.70 | 1.69 | 1.69 | 1.68 |
| Scored low on word-recall tests (male only) | 1.38 | 1.39 | 1.39 | 1.38 |
| Anti--depressant (male only) | 1.98 | 1.97 | 1.97 | 1.95 |
| **All factors for *males*** | **11.30** | **10.88** | **10.37** | **9.74** |
| **All factors for *females*** | **1.71** | **1.70** | **1.70** | **1.69** |

Diagnostic tests for omitted variables in the combined-gender model are presented in Appendix 3 and are summarized in Table 5.9. Boredom, being severely depressed (as represented by being in the top 2% - 5% of the overall depression score), and having difficulty in extending arms over shoulders in female drivers are all significant at the .05 level if included individually in the final combined-gender model. The decision to exclude these variables is, therefore, somewhat arbitrary. To have a final model with all factors significant at the .05 level would require omitting one or more factors in Model 1 in Table 5.9 to accommodate the borderline factors identified in the diagnostic tests, i.e., boredom, being severely depressed, and having difficulty in extending arms over the shoulders in female drivers. The resulting log-likelihood values for the alternative models would therefore be less than those in Table 5.7, and would be approximately similar to that of Model 1 in Table 5.9. A comparison of coefficient estimates across alternative models (Models 1 through 7 in Table 5.9) indicates a plausible range due to mis-specification arising from an omitted variable. It is interesting to note that including the variable, boredom, has the largest effect on the coefficient of the variable, use of an anti-depressant by male drivers. Both variables are indicators of depression. Similarly, including the variable, having difficulty seeing a friend across the street, appears to have the largest effect on the estimated coefficient of a history of glaucoma in male drivers. The other two borderline factors, scoring in the top 2%-5% on the overall depression scale and having difficulty in extending their arms over their shoulder in female drivers, appear to have a more diverse effect, yielding a small change in several of the final coefficients.

Without considering VMT as a crash risk

Tables 5.11, 5.12 and 5.14 present results from the Poisson regression models, identifying factors that significantly increase the probability of older drivers' being involved in vehicle crashes, **without** considering the impact of the annual VMT. The hypothesis $H_0$: $\gamma$ (overdispersion) = 0 was accepted, suggesting that the Poisson regression is an appropriate specification, instead of the negative binomial regression model. Similar to the model development in the case where the impact of the amount of annual driving was included, gender-specific crash models were developed by excluding the annual miles driven. After testing a series of restricted models derived from the most general model , we developed two final models. The final models were then subjected to a number of diagnostic tests for omitted variables. Variables identified in the diagnostic tests as being borderline in significance were tested by individually including them in the final model. After gender-specific models were finalized, a single model for both genders was developed by combining all of the significant factors identified from the gender-specific models. We estimated the coefficient estimates for both genders separately as well as combined. Next, we tested whether a risk factor that is common to both genders has a similar impact on both genders. The final model included significant risk factors that were common to both genders and those that are specific to a gender. Finally, the final combined-gender model was subjected to a series of diagnostic tests for omitted variables. The final crash model for older female drivers, without the annual driving factor, is Model 1 in Table 5.11; the male model is Model 1 in Table 5.12; and the combined-gender model is Model 1 in Table 5.14.

As indicated in Table 5.11, living alone and having persistent back pain increase the probability of an older *female* driver being involved in vehicle crashes. If the annual-driving variable is excluded from the model, then two factors have negative signs: having difficulty in recognizing friends across the street and being diagnosed with osteoporosis. This result suggests that these factors augment the effect of annual driving on crash involvement, by adjusting the relative exposure. Three variables were identified by the diagnostic tests as being marginal in significance. They were: being severely depressed, having difficulty in climbing stairs, and having difficulty in extending arms above shoulder level. If the model includes severe depression, then the coefficient for the living-alone variable became insignificant at the 0.05 level. This result restates our earlier hypothesis that women who live alone might be more likely to be severely depressed than those who do not live alone. The probabilities of being involved in vehicle crashes and the odds ratios for this final model are in Table 5.11.

Men who lived alone, had been diagnosed with glaucoma, suffered from persistent back pain, were bored, and were employed had a significantly higher crash involvement rate than those who did not (Table 5.12). Recall that when we considered annual driving factor in the model, our decision of whether to use the anti-depression drugs variable or the boredom variable in the model was based on the criterion that it is preferable to use fewer subjective factors (Model 2 in Table 5.5). Thus, a model with the anti-depressant variable was considered to be the final model. Interestingly, when the impacts of annual driving were ignored in the model, the use of anti-depressant drugs by male drivers became insignificant in crash involvement, and feeling bored became significant at the 0.05 level. This is due to the noise in the crash data that was not explained by the amount of annual driving. The annual-driving variable is a significant factor in crash involvement ($p = 0.000001$). Without this variable in the model to explain much of the variation in crash involvement, there is a lot of noise remained in the data. As a result, impact of anti-depression drugs is embedded in this noise and is difficult to detect. We strongly believe that any crash model is highly likely to be mis-specified if the annual-driving factor is excluded.

Glaucoma is the only chronic condition that has a noticeable crash risk in men. The odds ratio of glaucoma (Table 5.12) suggests that the probability of being involved in one crash in a year for an older *male* driver who has a history of glaucoma is 60% greater than that of an older *male* driver without a history of glaucoma, everything else being equal. An employed male is 54% more likely to be involved in vehicle crashes than one who is not.

A single model for both genders was developed by first combining all of the significant factors identified from the gender-specific models (Tables 5.11 and 5.12). We estimated the coefficient estimates for both genders separately as well as combined (Table 5.13). Then, we tested whether a risk factor that is common to both genders has a similar impact on both genders.

The estimated coefficients for the final combined-gender model without VMT are presented in Table 5.14. Without the annual-driving variable in the model, being a male is the single most influential risk factor for crash involvement. Two borderline variables were identified from the diagnostic tests: experiencing unconsciousness, and being cognitively impaired (Appendix 6). Difficulties in recognizing friends across the street and in doing heavy housework, and osteoporosis in female drivers *decreased* the probability of older drivers being involved in vehicle crashes. This

**Table 5.11 Significant Risk Factors for Older *Female* Drivers Being Involved in Crashes [Poisson Regression Model, *without* the Annual VMT]**

| Variable | Model 1 | | Model 2 | Model 3 | Model 4 | Model 5 | % with characteristic |
|---|---|---|---|---|---|---|---|
| | | Odds Ratio | | | | | |
| Constant | -4.01** | | -4.02** | -4.00** | -4.02** | -4.01** | |
| Living alone | 0.32** | 1.37 | 0.30* | 0.32** | 0.31* | 0.29* | 59% |
| Back pain | 0.48** | 1.60 | 0.45** | 0.48** | 0.47** | 0.45** | 44% |
| Difficulty in seeing a friend across street (yes) | -1.40** | 0.25 | -1.44** | -1.37** | -1.45** | -1.43** | 5% |
| Diagnosed with osteoporosis | -0.51** | 0.60 | -0.53** | -0.50** | -0.53** | -0.54** | 18% |
| | | | | | | | |
| Depressed[1] | | | 0.63* | | | 0.64** | 4% |
| Need help in climbing stairs (yes) | | | | -1.18* | | -1.28* | 4% |
| Difficulty in extending arms over shoulder | | | | | 0.64* | 0.66* | 3% |
| Log Likelihood (LL) | -755.4 | | -753.6 | -753.3 | -754.3 | -750.1 | |
| LL Ratio | | | 3.63* | 4.16** | 2.23 | 10.61** | |
| Number of Observations = 6550<br>Restricted Likelihood value = -766.2 | | | | | | | |

[1] Scored in the top 2nd to 5th percentile of the overall depression scale. **Significant at $\alpha$ =0.05. * Significant at $\alpha$ =0.10.

**Table 5.12 Significant Risk Factors for Older *Male* Drivers Being Involved in Crashes [Poisson Regression Model, *without* the Annual VMT]**

| Variable | Model 1 | | Model 2 | Model 3 | Model 4 | Mode |
|---|---|---|---|---|---|---|
| | | Odds ratio | | | | |
| Constant | -3.61 | | -3.63** | -3.58** | -3.59** | -3.5 |
| Living alone | 0.36** | 1.43 | 0.34** | 0.36** | 0.37** | 0.35 |
| Diagnosed with glaucoma | 0.50** | 1.63 | 0.46** | 0.51** | 0.53** | 0.50 |
| Back pain | 0.29** | 1.33 | 0.27** | 0.29** | 0.30** | 0.29 |
| Bored | 0.48** | 1.60 | 0.43** | 0.49** | 0.49** | 0.45 |
| Employed (yes) | 0.44** | 1.54 | 0.45** | 0.42** | 0.43** | 0.41 |
| | | | | | | |
| Depressed[1] | | | 0.35* | | | 0.37 |
| Need help in waling across a small room (yes) | | | | -0.69* | | -0.7 |
| Episode of unconsciousness | | | | | -0.80* | -0.7 |
| Log Likelihood (LL) | -915.7 | | -914.2 | -914.0 | -913.7 | -910 |
| LL Ratio | | | 2.98* | 3.48* | 4.00** | 10.5 |
| Number of Observations = 5414<br>Restricted Likelihood value = -928.2 | | | | | | |

[1] Scored in the top 5th to 10th percentile of the overall depression scale.
**Significant at $\alpha$ =0.05.
* Significant at $\alpha$ =0.10.

**Table 5.13 Test of Pooling Capability of Risk Factors in Gender-Specific Crash Models [Estimated Coefficient of Poisson Regression Model, *without* the Annual VMT]**

| | Gender | | |
|---|---|---|---|
| | Combined | Female | Male |
| Male | 0.55** | | |
| Living alone | 0.32** | 0.32** | 0.33** |
| Back pain | 0.36** | 0.47** | 0.30** |
| Employed (yes) | 0.19 | -0.33 | 0.41** |
| History of glaucoma (yes) | 0.41** | 0.30 | 0.51** |
| Bored | 0.40** | 0.35 | 0.44** |
| Depressed[1] | 0.36** | 0.26 | 0.43** |
| Difficulty seeing friends across street | -0.84** | -1.35** | -0.40 |
| Osteoporosis | -0.42** | -0.47* | -0.29 |
| Difficulty doing heavy housework | -0.29** | -0.33* | -0.26 |
| | | | |
| Sample size *(n)* | 11,955 | 6,553 | 5,414 |
| Log-Likelihood (*LL)* | -1667.304 | -751.266 | -912.189 |
| Restricted *LL* | -1705.729 | -766.265 | -928.151 |

[1] Scored on the top 10th percentile of the overall depression scale.
** - Significant at .05 level
* - Significant at .10 level

**Table 5.14 Significant Risk Factors for Older Drivers Being Involved in Crashes**
**[Poisson Regression Model, *without* the Annual VMT]**

| Variable | Model 1 | | Model 2 | Model 3 | Model 4 | % with characteristic |
|---|---|---|---|---|---|---|
| | | Odds Ratio | | | | |
| Constant | -4.05** | 1.00 | -4.04** | -3.98** | -3.98** | |
| Male | 0.47** | 2.45 | 0.49** | 0.47** | 0.48** | 45% |
| Living alone | 0.34** | 2.16 | 0.34** | 0.33** | 0.34** | 40% |
| Back pain | 0.36** | 2.20 | 0.37** | 0.36** | 0.37** | 41% |
| Employed (male only) | 0.40** | 2.29 | 0.38** | 0.40** | 0.39** | 9% |
| Diagnosed with glaucoma | 0.42** | 2.34 | 0.43** | 0.41** | 0.42** | 9% |
| Bored | 0.42** | 2.34 | 0.42** | 0.42** | 0.42** | 9% |
| Depressed[1] | 0.35** | 2.18 | 0.35** | 0.35** | 0.35** | 10% |
| Difficulty in seeing a friend across street (yes) | -0.83** | 0.68 | -0.85** | -0.83** | -0.85** | 4% |
| Diagnosed with osteoporosis (female only) | -0.47** | 0.97 | -0.47** | -0.48** | -0.48** | 10% |
| Need help in heavy housework | -0.28** | 1.17 | -0.27** | -0.29** | -0.28** | 23% |
| | | | | | | |
| Episode of unconsciousness | | | -0.55* | | -0.55* | 4% |
| % of words incorrectly recalled | | | | -0.27* | -0.27* | 24% |
| Log Likelihood (LL) | -1665.5 | | -1663.8 | -1663.8 | -1662.1 | |
| LL Ratio | | | 3.52* | 3.44*. | 6.97** | |
| Number of Observations = 11955<br>Restricted Likelihood value = -1705.73 | | | | | | |

**Significant at α =0.05. * Significant at α =0.10. [1] Scored in the top 20th percentile of the overall depression scale.

result suggests that when older drivers have visual and gross mobility difficulties, they are more inclined to self regulate (i.e., reduce their driving), and, thus, their exposure to crashes.

## 5.4 Discussion

The inclusion of the amount of driving as a measure of accident exposure in crash models is still controversial. Due to the debate, we developed two separate models -- one included the amount of annual driving and the other did not. Regardless of how many and which variables were included in the model, the estimated coefficient for the annual driving remained robust and its significance level high ($p$ = 0.00001). This result suggests that the annual-driving variable is the single most important risk factor in crash involvement and any models without this variable are highly likely to be mis-specified. This assertion was tested statistically.

To confirm the hypothesis that any models without the annual driving factor are mis-specified, we conduct some tests. Recall that the sample size decreased from 11,955 to 9,389 when the annual-driving factor was included in the model because of the missing data on this factor. To eliminate the effect of different sample sizes on the analysis results, we first re-estimated the crash model without the annual-driving factor using the smaller sample size (n=9389) (the crash model as reported in Table 5.14). We then re-estimated the model with the annual-driving factor. When included in the model, the annual-driving factor became significant at $p$= 0.00008. Furthermore, the three factors (difficulty seeing friends across the street, osteoporosis in women, and difficulty doing heavy housework) that decreased the probability of crash involvement in Table 5.14 became insignificant. Another significant change in the estimated coefficient is the male factor. Being a male used to be a risk factor if the annual-driving factor is excluded from the model (Table 5.14). However, it became insignificant at $p$=0.114 when taking into account the effect of the annual-driving factor on crash involvement. These results suggest that the annual-driving factor, being the single most important factor in crash involvement, explains much of the variation in crash data. Without it, a considerable level of noise remained in the data and the impact of the annual-driving factor on crash involvement is then being mimicked by (a combination of) other factors. These test results confirm our believe that any models ***without*** the annual-driving factor are mis-specified.

Poisson regression models and negative binomial models were used to identify risk factors that contribute to the probability of older drivers being involved in vehicle crashes. The hypothesis that overdispersion is statistically different from 0 was not accepted, indicating that a Poisson regression specification is appropriate. In fact, both Poisson and negative binomial models yield very similar results. As in the models for driving status (Chapter 4), we did not limit our analyses to a balanced data set. Instead, Poisson regression models of crash involvement were developed based on an **unbalanced** data set. This unbalanced data set enables us to use a much larger sample size for our analysis.

Test results of whether men and women share the same set of risk factors in crash involvement, and whether these factors have the same influence on crashes clearly indicated that they do not. As a result, our model development process had to expand to reflect these differences. First, gender-specific models were developed. The final gender-specific models were then subjected to a series of diagnostic tests for omitted variables. To develop a single combined-gender model, we first combined all significant factors that were identified in gender-specific models and examined the coefficient estimates for both genders as well as for them combined. The final combined-gender model includes risk factors that are common to both genders and risk factors that are specific to each gender. Finally, this model was subjected to diagnostic tests for omitted variables.

When included in the model, the variable that denotes annual driving is the single most influential risk in crash involvement. Interestingly, when annual driving is included in the model, gender became insignificant even at the 0.10 level. This result is primarily due to the strength of annual driving in explaining the crash variation between genders. Use of anti-depression drugs by male drivers is the second most important risk factor in crash involvement. For male drivers, being employed and cognitively disabled, having a history of glaucoma, and using anti-depression drugs amplify the likelihood of being involved in vehicle crashes. The chance of older *male* drivers who use anti-depressant being involved in crashes is double that of identical drivers who do not use anti-depression drugs. After controlling for the amount of driving, we found that men who are cognitively impaired (as represented by the low score on a word-recall test) are 40% more likely to be involved in vehicle crashes than men who are not, holding other risk factors constant. In contrast, cognitive ability is irrelevant in older *female* drivers being involved in crashes. It is clear that the more older drivers drive the more likely they will be involved in crashes. After controlling for the impacts of annual driving on crash involvement, living alone and experiencing back pain also increase the likelihood of crash involvement. Recall that the sample size is reduced by more than 20% when we include the annual-driving factor in the model.

When the amount of driving is excluded from the model, the results from the Poisson model suggest that gender (male), depression and boredom, living alone, back pain, difficulty in recognizing friends across the street, difficulty in doing heavy housework, and a history of glaucoma contribute to the likelihood of older drivers being involved in vehicle crashes. Cognitive ability (as represented by scores on word-recall tests and memory tests) is no longer significant as a risk factor when VMT is excluded from the model. We strongly believe that the exclusion of annual driving from the crash model leads to a considerable level of data noise not being explained, and that any crash models without VMT are highly likely to be mis-specified.

Foley et al. in [8] noted that individuals with high scores for depression symptoms were about 50% more likely to be involved in crashes than those with lower scores. However, they found that depression was no longer significant in a multivariate model. Although glaucoma was not found in [8] to be a significant risk in crash involvement, Foley and his colleagues observed an elevated crash rate among those who had a history of glaucoma and hypothesized that "glaucoma...may result in substantial deterioration of peripheral vision, an essential function for safe driving. Also, medications for glaucoma may have psychotropic and cognitive effects." Like depression, glaucoma was eliminated as a significant crash risk when other risk factors were simultaneously taken into account in [8]. Note that Foley et al.'s speculations in [8] were based on a crash model <u>without</u> taking into account the impacts of annual driving. Unlike Foley et al.'s findings in [8] that depression and glaucoma became insignificant in a multi-variate model, results from our models *without* the annual driving factor prove conclusively that depression and glaucoma are significant risks in older drivers' being involved in vehicle crashes, even in a multi-variate framework.

# CHAPTER 6. SUMMARY AND FUTURE WORK

The objectives of this study were to determine: a) whether a statistical relationship(s) exists between age-related medical conditions, functional impairments, and increased number of highway crashes; and b) how demographic attributes and health-related factors influence older drivers' decisions to continue or to stop driving.

Much of the research on the relationships between chronic conditions in elderly drivers (e.g., arthritis, cataracts, diabetes, stroke, Parkinson's disease), changes in driving behavior, and the occurrence of vehicle crashes has used simple descriptive or bivariate analysis [1]. These analysis techniques examine the impact of a specific risk factor independent of other risk factors. They ignore the **joint** impacts of different risk factors. In contrast to a bivariate analysis, a multivariate analysis examines the impact of a specific risk factor on the outcome of interest (either crashes or driving cessation) by statistically holding the remaining risk factors constant. Only in the past few years have multivariate analysis techniques been used to quantify the **joint** impacts of various risk factors on driving cessation and on vehicle crash patterns among elderly drivers [4-8]. Previous studies that use simple descriptive or bivariate analysis techniques are considered inferior to studies that use multivariate analysis techniques, and therefore are not discussed in our literature review.

Among the four papers that are related to driving cessation and that are reviewed in Chapter 2 ([4]-[7]), only the models reported by Marottoli et al. [4] have any real predictive content. By that, we mean that Marottoli et al. correlated the occurrence of driving cessation/changes that took place between 1983 and 1989 to a set of risk factors observed in the baseline interview in 1982. In that sense, Marottoli et al.'s model truly describes how demographic attributes, chronic conditions, and physical function limitations affect older drivers' decisions to stop driving. In contrast, although some of the drivers in Kington et al. [5] may have stopped driving in 1989 (when the risk factors were observed), it is unclear how many of them stopped driving *before* 1989. If driving cessation occurred many years before 1989, then the driving cessation models estimated by Kington et al. [5] "predict" the probability of stopping to drive based on a set of risk factors observed later than the date when driving cessation occurred. This problem is more evident in Campbell et al. [6] and Stewart et al. [7]. Since the year of driving cessation is unknown for former drivers in the Florida Geriatric Research Program, Campbell [6] and Stewart [7] related risk factors observed in 1987 to the probability of driving cessation, which may have occurred a decade ago. This limitation also applies to Stewart et al.'s work on vehicle crashes [7].

Another limitation in all of the previous work is that only a "snap-shot" of the longitudinal data is used. That is, instead of taking full advantage of the longitudinal data by using cross-sectional time-series analysis techniques, previous work aggregates the observations made over several years into a single observation. This is done by arbitrarily "matching" a period of vehicle crashes (or driving cessation) to a set of explanatory variables. By so doing, not only are the associated degrees of freedom for the analysis tremendously reduced, but the causality in the model is also lost. Furthermore, by only analyzing a "snap-shot" of the data, one totally overlooks the **contemporaneous** correlation between crashes (or driving status) and contributing factors, and disregards much of the benefits of having the longitudinal data. This contemporaneous correlation is analogous to the "..temporality of conditions and driving cessation.." referred by Campbell et al. in [6]. No study to date, until our study, has addressed this contemporaneous correlation (or temporality) issue in older drivers' involvement in vehicle crashes.

The bias that results from aggregating observations over time is minimized by maximizing the contemporaneous correlation between the outcome of interest (either crashes or driving status) and the contributing factors. We constructed a **panel** data set to capture this contemporaneous correlation. This data set was based on data from the Iowa 65+ Rural Health Study. The reasons for using data from this study are that: 1) it covers the longest possible time period (1981-1993) and 2) it contains a wealth of information relative to other data sources. Three major obstacles were encountered in constructing the panel data base:

1. Survey questions were not asked consistently from one interview to the next;

2. Considerable data gaps existed due to non-response and item non-response, the absence of the 8th and the 9th follow-ups (they were not administered due to funding shortage), and the straddling of one interview over more than one year; and
3. Response inconsistency between data collected from different interviews, particularly between data collected in the 10th follow-up and those collected from the previous surveys. This problem might be attributable partly to recall bias.

Due to these obstacles, the construction of the panel data base was a major undertaking. Various sets of "rules" were developed to impute estimates of the missing data and to rectify data inconsistencies. The panel data set that we developed consists of **an** observation (or record) for each participant for each year between 1981 (the first year when the baseline survey began) and 1993 (the last year when the 10th follow-up interview ended). This panel data set was used to study older drivers' decisions to stop driving and their involvement in vehicle crashes.

As mentioned in Chapter 4, attrition in participation is common in longitudinal studies and typically increases with time, particularly in studies of elderly subjects. Almost all of the analysis techniques for panel data require the data set to be balanced, in that the number of annual observations for each participant must be the same. This means that any analyses that require a balanced panel data set fail to take full advantage of the information collected from **all** of the participants by excluding participants who have dropped out of the study. By contrast, our analysis was based on an **unbalanced** panel data set.

The latest version of LIMDEP permits us to analyze an **unbalanced** panel data set. There is significant advantage to analyzing an **unbalanced** panel data set. As a result, our analysis on driving status was based on a sample of 23,994 annual observations from 2,203 participants. If our analysis had been limited to a **balanced** panel data set, we would have had two options: 14,526 (=1,614×9) annual observations from 1,614 participants for a period of nine years; or 15,093 (=1,161×13) annual observations from 1,161 participants for a period of thirteen years. By using an analysis technique that takes into account **unbalance**d data, we increased the sample size for our analysis by almost 60%. Note that our analysis on vehicle crashes was based on a sample that was considerably smaller than the one used for driving status, due to the limited availability of crash data (from 1985 to 1993 only). Although these 23,994 annual observations are not independent observations, they are not as powerful as 23,944 independent observations. Nevertheless, a comparison of sample size demonstrates the power of our analysis over others (Table 6.1).

**Table 6.1 Comparison of Sample Sizes in Various Studies**

| | Driving Cessation Model | Vehicle Crashes Model |
|---|---|---|
| Marottoli et al. [4] | 595 | |
| Kington et al. [5] | 2,429 | |
| Campbell et al. [6] | 1,656 | |
| Stewart et al. [7] | 1,470 | 1,431 |
| Foley et al. [8] | 1,854 | |
| Hu and Trumble | 23,944 | 11,955* (9,398**) |

* If VMT is excluded from the model.
** If VMT is included in the model.

## 6.1 Older Drivers and Driving Decisions

In our analysis, we studied which explanatory variables contribute to an older driver's decision to drive or not to drive in <u>a given year</u>. The annual driving status is, thus, defined differently from that in studies that focus on driving cessation. In those studies, individuals are grouped into two categories: those who still drive and those who cease driving permanently. In our analysis, an individual can cease driving for some years but, for some reason, drive in later years (such as widowed females). In previous studies, where observations of many years are aggregated into a single observation (i.e., a "snap-shot" approach), this dynamic behavior is completely omitted in the analysis.

After rejecting the hypothesis that the annual observations for a given participant were uncorrelated, we developed two gender-specific *random effects* binomial probit models to identify factors that significantly contribute to older drivers' decisions to continue to drive or to stop driving. Note that the difference between our analysis and those in the literature is that we estimate the **annual driving status** of the participants, while the others predicted the probability of **permanent** driving cessation.

Our *random effects* binomial probit models found that the female and male populations have different sets of factors that influence their decisions to cease driving. Age is one of the factors that are common to both genders. However, it has a greater influence on an older *female* driver's decision to stop drive than that on an older *male* driver, holding other factors constant. That is, becoming one year older affects an older female driver more in her decision to stop driving than in an older male driver.

Income is not a significant determinant in older *male* drivers' decisions to stop driving. However, like other studies in the literature, income was found to be an important factor in the driving status of older *female* drivers. A comparison of the estimated coefficients for employment status and income suggests that being employed is a more important factor in annual driving status than income. However, the impact of employment status on older *male* drivers was only marginal.

The undertaking of trying to draw a consensus from various studies on driving cessation was complicated for two reasons. First, risk factors are almost always defined and/or grouped differently from one study to the next. Second, the temporal relationship between driving cessation, driving changes and medical conditions is different among these studies. While Marottoli et al. [4] predicts the probability of driving cessation/changes that occurred between 1983 and 1989 based on a set of risk factors observed in 1982, the others ([5] - [7]) used risk factors observed at a later date to "correlate" the occurrence of driving cessation/changes during an earlier time period. Nevertheless, Table 6.2 provides an overall comparison of significant factors in older drivers' decisions to stop driving. However, it should be noted that a direct comparison among these studies is inappropriate.

Disabilities in gross mobility (e.g., difficulties in performing ADLs and higher level physical activities) have different influence on the driving decisions of men and women. For example, being unable to stoop, crouch or kneel increased the probability of driving cessation in an older woman, but was not a significant factor in older men. On the other hand, difficulties in performing other ADLs and physical activities, that significantly affect the decision to stop driving in *both* men and women, had considerably greater impacts on the decision to cease driving in men than in women. For example, needing help in personal grooming, such as brushing hair, brushing teeth and washing face, significantly increased the probability of driving cessation in both men and women. However, the influence of this specific functional limitation on male drivers' likelihood to cease driving was <u>four</u> times that of female drivers. This seems to suggest that once older male drivers experienced limitations in performing their ADLs and other physical activities, they were more likely to quit driving than their female counterparts, everything else being constant. This observation is also true of the influence of visual impairments. The influence of visual impairments (as represented by difficulty in recognizing friends across the street and in reading newspaper print) on the decision to cease driving was notably greater in men than in women. These differences in how men and women react differently in their decisions to stop driving with respect to physical activity limitations and visual impairment were also observed by Campbell et al. [6].

Similar to the finding by Marottoli et al. ([4]), cognitive ability was found not to be associated with the decision to stop driving. The explanation offered by Marottoli et al. in [4] was that "...it (this lack of association ) may be due to lack of awareness of their deficits by cognitively impaired individuals who therefore see no reason to stop driving." When comparing scores from the word-recall tests and memory tests to their self-assessed memory capability, we found that individuals in this Iowa cohort were overly optimistic about their cognitive ability. This confirms the claim made in [4] of individuals' lack of awareness of their cognitive ability.

## Table 6.2. Comparison of Significant Factors Affecting Driving Cessation

| Factor | Studies | | | | | | |
|---|---|---|---|---|---|---|---|
| | Marottoli et al. | Kington et al.[1] | Campbell et al.[2] | | Stewart et al.[3] | Hu and Trumble | |
| | | | Female | Male | | Female | Male |
| Demographics and Household Characteristics | | | | | | | |
| Age (increasing) | ✛ | ✛ | ✛ | ✛ | ✛ | ✛ | ✛ |
| Gender (male) | ✗ | — | na | na | — | na | na |
| Race | ✗ | ✗ | -- | -- | -- | -- | -- |
| Employment (yes) | — | -- | -- | -- | -- | — | — |
| Income (increasing) | — | ✗ | -- | -- | -- | — | ✗ |
| Housing arrangement | ✗ | -- | -- | -- | -- | -- | -- |
| No. of adults in HH | -- | ✛ | -- | -- | -- | -- | -- |
| Living alone | -- | -- | -- | -- | -- | — | ✛ |
| Education (increasing) | ✗ | — | -- | -- | -- | — | ✛ |
| Marital status | ✗ | — | -- | -- | -- | ✗ | ✗ |
| Urban area | -- | ✛ | -- | -- | -- | -- | -- |
| Geographic region (West and N. Central) | -- | — | -- | -- | -- | -- | -- |
| Public transit available | -- | ✗ | -- | -- | -- | -- | -- |
| Chronic conditions and symptoms | | | | | | | |
| Arthritis | ✗ | — | ✗ | ✗ | ✗ | ✗ | ✛ |
| Diabetes | ✗ | ✗ | ✗ | ✗ | ✗ | ✗ | ✗ |
| Parkinson's disease | ✛ | ✛[4] | ✛ | ✗ | ✛ | ✛ | ✗ |

| Factor | Studies | | | | | | |
|---|---|---|---|---|---|---|---|
| | Marottoli et al. | Kington et al.[1] | Campbell et al.[2] | | Stewart et al.[3] | Hu and Trumble | |
| | | | Female | Male | | Female | Male |
| Stroke | ✛ | -- | ✗ | ✗ | ✛ | ✛ | ✗ |
| Stroke sequelae | -- | -- | ✗ | ✛ | ✗ | ✛ | ✛ |
| Heart diseases | ✗ | ✗ | ✗ | ✗ | ✗ | ✛ | ✗ |
| Hypertension | -- | ✗ | ✗ | ✗ | ✗ | ✗ | ✗ |
| Syncope | -- | -- | ✛ | ✛ | ✗ | ✗ | ✗ |
| Cataract | ✛ | -- | ✗ | ✗ | ✗ | ✗ | ✗ |
| Cataract surgery (yes) | -- | -- | -- | -- | -- | ✛ | ✗ |
| Glaucoma | ✗ | -- | ✗ | ✗ | ✗ | ✗ | ✗ |
| Macular degeneration | -- | -- | ✛ | ✛ | ✛ | -- | -- |
| Retinal hemorrhage | -- | -- | ✛ | ✗ | ✗ | -- | -- |
| Joint pain | -- | -- | -- | -- | ✗ | ✗ | ✛ |
| Physical capability | | | | | | | |
| Activity limitation (increasing) | ✛ | ✗ | ✛ | ✛ | -- | ✛ | ✛ |
| High-level function limitation (increasing) | ✛ | ✛ | -- | -- | -- | ✛ | ✛ |
| Visual impairment | ✗ | ✛ | ✗ | ✗ | ✛ | ✛ | ✛ |
| Hearing impairment | ✗ | ✗ | ✗ | ✗ | ✗ | ✗ | ✗ |
| Cognition and Attitudes | | | | | | | |
| Health perception (good) | -- | — | -- | -- | -- | ✗ | ✗ |
| Mental status | ✗ | -- | -- | -- | -- | ✗ | ✗ |

| Factor | Studies | | | | | | |
|---|---|---|---|---|---|---|---|
| | Marottoli et al. | Kington et al.[1] | Campbell et al.[2] | | Stewart et al.[3] | Hu and Trumble | |
| | | | Female | Male | | Female | Male |
| Depression | ✗ | -- | -- | -- | -- | — | ✗ |
| Memory loss | -- | -- | ✗ | ✗ | ✗ | ✗ | ✗ |
| Emotional function | -- | ✗ | -- | -- | -- | ✗ | ✗ |
| Drugs | | | | | | | |
| Drug ingredients | -- | -- | -- | -- | —[5] | -- | -- |
| Therapeutic drug | -- | -- | -- | -- | ✗ | -- | -- |
| Behavioral factors[6] | | | | | | | |
| Drinking alcohol | -- | -- | -- | -- | — | ✗ | — |
| Hospitalization | ✗ | -- | -- | -- | ✛ | ✗ | ✗ |
| Institutionalization | ✗ | -- | -- | -- | -- | ✗ | ✗ |
| Social support | ✗ | -- | -- | -- | -- | — | — |
| Exercise regularly | -- | -- | -- | -- | -- | — | ✗ |

-- = not included in the study.
✛ = increased the likelihood of driving cessation.
— = decreased the likelihood of driving cessation.
✗ = nonsignificant.
na = no applicable.

1 Predictors of driving cessation in older drivers after 50 years of age.
2 For combined model.
3 Due to the large number of individual factors tested in the analysis, not all the factors are listed.
4 Neurological impairment.
5 Included the 50 most frequently used drug ingredients, and only one drug ingredient, magnesium hydroxide, is a significant risk factor.

[6] Other behavior factors examined in [7] included smoking, drinking coffee, and exercising regularly.

Unlike other studies in the literature, we distinguished between individuals who had multiple strokes during the study period (from 1981 to 1993) from those who had one stroke. Similarly, those who had more than one heart attack were identified separately from those who had only one. The rationale for making these distinctions was our hypothesis that multiple episodes of stroke or heart attack may have a compounding impact on older drivers' decisions to stop driving. Arthritis, Parkinson's disease, cataracts, stroke(s) and heart attack were explicitly associated with driving cessation. In general, these findings confirm those in the literature, except heart attack (Table 6.2). Our analysis also found that these conditions influenced men differently than women.

Parkinson's disease was the most influential medical condition affecting driving cessation in *female* drivers ($\beta_{\text{Parkinson's}} = 1.82$), but was not even a significant factor in *male* drivers. This finding agrees with that reported by Campbell et al. in [6]. We found that the influence of the second stroke in women is almost three times that of the first stroke, and the influence of the third stroke was insignificant relative to the second. However, this is not the case for men. While the first stroke hardly had any impact on male drivers' decisions to stop driving, the impact of the second stroke was more influential in men than the presence of any other medical condition. These findings confirm our hypothesis that multiple episodes of stroke have a more profound impact on the decision to stop driving than a single episode.

Our results suggest that being diagnosed with cataracts did not prevent elderly drivers from driving, in either men or women. However, *female* drivers who had had cataract surgery were more likely to stop driving than those who were diagnosed with cataracts but who had not had any surgery. This might suggest that visual impairment as a result of the cataract was considerably more severe for those who required surgery than those who did not. Cataracts were linked to driving cessation by Marottoli et al.([4]), but not by Campbell et al. ([6]) nor by Stewart et al. ([7]).

Only one other study (Kington, et al. [5]) found arthritis to be a significant factor in driving cessation, and its conclusion, however, was contrary to ours. Kington et al. in [5] concluded that those with arthritis are more likely to drive than those without. The authors attributed this finding to the possible difficulty that arthritic elderly have in using poorly-suited alternative transportation modes (e.g., buses), and that continuing to drive is the least difficult mode of transportation. Our analysis, on the other hand, found that arthritis is one of the two medical conditions among **men** that increases the odds of stopping to drive, but that it is insignificant in **women**'s decisions. Even after taking into account the impact of functional limitations on driving cessation, arthritis remains significant in driving cessation among male drivers.

We found that the mere existence of chronic conditions generally did not affect the decision to stop driving. Instead, they manifested their influence on driving cessation through functional limitations. Arthritis in women is one such condition. When arthritis became severe enough to impair functional capabilities, then afflicted older *female* drivers began to think about stopping to drive. Our model clearly suggested that when both arthritis and difficulties in performing ADLs and/or higher level activities were included in the model of female drivers, the influence of functional limitations outweighed the mere existence of arthritis. Although this example with arthritis is only true for women, we believe that in general it is true. That is because when only chronic conditions were included in the model, without taking into account the impacts of functional limitations, a greater number of chronic conditions become significant than when the impacts of functional limitations are considered in the model. Disability in gross mobility and visual impairment clearly contribute to driving cessation.

Having a positive attitude and lifestyle in terms of exercise, good health condition, and social support increase the probability of continuing to drive. If the individual consumes alcohol, then that also increases the probability of continuing to drive, potentially due to the connection between alcohol consumption and social activities.

More than half of the female drivers lived alone compared to only 17% of the male drivers. In theory, one expects that living alone increases the probability of continuing to drive. Results from our analysis indicated that this is true for women but not for men. Instead, men who lived alone were more likely not to drive than those who did not live alone, holding other factors constant. We speculate that when women lived alone, they did so involuntarily by becoming widowed. On the other hand, we speculate that men are more likely to live alone willingly than women. This hypothesis is supported, but not tested, by the survey data that about 20% of the men who lived alone were not widowed while the corresponding percentage for women was 8%. By being forced into living alone, women have to continue to drive so as to satisfy their basic transportation needs. Whereas, when men elect to live alone, they are more likely to cease driving. This hypothesis needs further verification.

Previous research has identified age, gender, Parkinson's disease, stroke, and impairments in vision and motor skill as factors that contribute to older drivers' decisions of permanent driving cessation (Table 6.2). In general, results from the *random effects* binomial probit models are consistent with the literature, except for three factors. These factors showed unexpected impacts on driving cessation -- depression, persistent pain in joints, and education level. The role of depression in driving cessation was not conclusive in [4]. However, our model suggests that severe depression <u>decreased</u> the probability of driving cessation in older *female* drivers. We speculate that since women who live alone were more likely to be severely depressed than those who did not live alone, the impacts of living alone and severe depression in women cannot be clearly separated. Male drivers who were better educated were more likely to cease driving than those who were not; and men who suffered persistent pain in their joints appeared more likely to continue to drive. These unanticipated findings need to be further investigated in future research.

We also developed a model to predict an older driver's annual driving. Results from our combined-gender model of the amount of driving are consistent with what Marottoli et al. found in [4]. We found that men who are employed, young, and socially active are more likely to drive more miles than their counterparts in the cohort . Aging and increasing difficulty in walking significantly contributed to the decision to drive less. In addition to these predictors, we found that those who have a positive attitude and life style, in terms of exercising regularly, good self-perceived health condition, and social support drive more. Living alone in rural areas and consuming alcohol also significantly increase driving. Those who were cognitively capable (e.g., perceived themselves proficient in memory and scored high on memory and work-recall tests) drove more than those who were not.

## 6.2 Older Drivers and Vehicle Crashes

In general, our model selection procedure was based on an approach that began by testing the most general specification, and then progressed to test the specifics. The first stage of our analysis was to develop separate gender-specific models. The final gender-specific models were then subjected to a number of diagnostic tests for omitted variables. Variables identified in the diagnostic tests as being marginal in significance were tested by individually including them in the final model. After gender-specific models were finalized, a single model for both genders was developed by combining all of the significant factors identified from the gender-specific models. We then estimated the coefficient estimates for both genders separately as well as combined. Next, we tested whether a set of risk factors that is common to both genders has a similar impact on both genders. The final model included significant risk factors that were common to both genders and those that were specific to a gender. Finally, the final combined-gender model was subjected to a series of diagnostic tests for omitted variables.

Although annual information on the participants was observed from 1981 to 1993, crash data for these participants were available only from 1985 to 1993. The issue of whether to include the information on annual miles driven is an important one. The number of miles driven (VMT) has been widely used in highway safety analysis as a proxy to measure the extent to which one exposes oneself to vehicle crashes. The theory is that the more one drives, the more one exposes oneself to crashes and the more likely one is to be involved in a crash. However, the opponents of this viewpoint argue that from the policy making perspective, how much one drives is irrelevant since licensing guidelines cannot be based on the amount of driving. We, therefore, developed two separate models based on two sets of risk factors -- one included the average annual miles driven by an average older driver and the other did not.

The Poisson regression model has been widely used to study count data so as to avoid the undesirable properties of a multiple regression model. However, the Poisson model has been criticized for its implicit assumption that the variance of $y_i$ is equal to its mean. In many cases, count data are found to exhibit greater variation (or **overdispersion**) relative to a Poisson model. In other words, the variance of the data is frequently greater than that indicated by the Poisson model. The overdispersion parameter was therefore tested to see if it was significantly different from zero. If so, the negative binomial regression model is employed as an alternative to the Poisson model.

Furthermore, to address the possibility of correlation among the number of accidents in a year for a given participant for all years between 1985 and 1993, we also tested a *random effects* specification for the Poisson regression model and the negative binomial model. The hypothesis that the overdispersion is statistically different from 0 was not accepted, suggesting that a Poisson regression specification is appropriate to model older drivers' crash data.

Similar to the analysis of driving status, the potential factors contributing to older drivers' probability of being involved in a vehicle crash include: demographic attributes, limitations in performing physical activities, chronic conditions, physical features, psychosocial characteristics, symptoms, and other health-related factors (as described in Chapter 4.) The only variables that were excluded in the driving status model, but that were included in the crash model, were the annual miles driven by individual drivers and the use of medication. The number of annual observations included in this analysis where the annual-driving factor was included was only 9,343, indicating that about 20% of the annual observations were deleted from the analysis due to missing data on annual VMT.

The amount of annual driving and limitation in gross mobility were the two significant risks in older women being involved in crashes. When included in the model, the variable that denotes annual driving is the single most influential risk in crash involvement. It is clear that the more older drivers drive the more likely they will be involved in crashes. Interestingly, when annual driving is included in the model, gender became insignificant even at the 0.10 level. This result is primarily due to the strength of annual driving in explaining the crash variation between genders.

For male drivers, being employed and cognitively disabled, having a history of glaucoma, and using anti-depression drugs amplify the likelihood of being involved in vehicle crashes. Use of anti-depression drugs by male drivers is the second most important risk next to the amount of annual driving. The chance of older *male* drivers who use anti-depressant being involved in crashes is double that of identical drivers who do not use anti-depression drugs. After controlling for the amount of annual driving, we found that (Table 6.3):

- Men who are cognitively impaired (as represented by a low score on a word-recall test) are 40% more likely to be involved in vehicle crashes than men who are not, holding other risk factors constant.
- In contrast, cognitive ability is irrelevant in older *female* drivers being involved in crashes.
- Living alone and experiencing back pain also increase the likelihood of crash involvement.

**Table 6.3 Significant Risk Factors of Crashes, Combined-Gender Models**
**[Poisson Regression Model, *with* the Annual VMT]**

| | Estimated coefficient | Odds Ratio |
|---|---|---|
| Annual miles driven | 0.05** | 0.05** |
| Living alone | 0.31** | 0.31** |
| Back pain | 0.23** | 0.22* |
| Employed (male only) | 0.44** | 0.46** |
| History of glaucoma (male only) | 0.54** | 0.50** |
| Scored low on word-recall tests (male only) | 0.33** | 0.32** |
| Anti-depressant (male only) | 0.69** | 0.63* |

** Significant at .05 level.

When the amount of driving was excluded from the model, the results from the Poisson model suggest that gender (male), depression and boredom, living alone, back pain, visual impairment (reflected by the difficulty recognizing friends across the street), limitation in gross mobility (e.g., difficulty doing heavy housework), and a history of glaucoma contribute to the likelihood of older drivers being involved in vehicle crashes. Cognitive ability (as represented by scores on word-recall tests and memory tests) is no longer significant as a risk factor when VMT is excluded from the model.

In their multivariate analysis, Foley et al. in [8] found that depression and glaucoma are no longer associated with crash involvement. This is despite their observation that individuals with high scores for depression symptoms were about 50% more likely to be involved in crashes than those with lower scores, and that those who had a history of glaucoma have a higher crash rate than those who did not. Since Foley et al. did not include the impact of annual driving in their crash model, comparison can only be made between their results and results from our crash model that excluded the annual-driving factor (Table 6.4). Unlike the findings by Foley et al. in [8] that depression and glaucoma were insignificant, results from our models *without* the annual driving factor indicate that depression and glaucoma are statistically significant risks in older drivers' being involved in vehicle crashes, even in a multi-variate framework.

When the amount of annual driving is included in the model, then regardless of how many and which variables were included in the model, the estimated coefficient for the amount of annual driving remained robust and its significance level high ($p$ = 0.00001). This result suggests that the annual-driving variable is the single most important risk factor in crash involvement. We strongly believe that the exclusion of annual driving from the crash model leads to a considerable level of data noise not being explained by the model and that any models without this variable are highly likely to be mis-specified.

**Table 6.4 Comparison of Significant Risks for Vehicle Crashes**
**[*Without* VMT in the model]**

| Risk factor | Hu and Trumble | | Foley et al. [8] | | Stewart et al. [7] |
|---|---|---|---|---|---|
| | Significance indicator | % with characteristic | Significance indicator | % with characteristic | Significance indicator |
| Male | ** | 45% | ** | 49% | ○ |
| Age (increasing) | ○○ | | ○ | | ○ |
| Living alone | ** | 40% | -- | | -- |
| Back pain | ** | 41% | ** | 43% | ○ |
| Employed (male only) | ** | 9% | -- | | -- |
| Diagnosed with glaucoma | ** | 9% | ○ | 5% | ○ |
| Bored | ** | 9% | -- | | -- |
| Depressed[1] | ** | 10% | ○ | 18% | -- |
| Difficulty in seeing a friend across street (yes) | ** | 4% | ○ | 3% | -- |
| Diagnosed with osteoporosis (female only) | ** | 10% | -- | | ○ |
| Need help in heavy housework | ** | 23% | ○ | 20% | -- |
| Episode of unconsciousness | * | 4% | -- | | ○ |
| % of words incorrectly recalled | * | 24% | ○ | 35% | ○ |
| Bursitis | -- | | -- | | ** |
| Cold in feet and legs | -- | | -- | | ** |
| Protein in urine | -- | | -- | | ** |
| Irregular heartbeat | -- | | -- | | ** |

** Significant at $\alpha$ =0.05.
* Significant at $\alpha$ =0.10.
○ Insignificant at $\alpha$ =0.05.
○○ Insignificant at $\alpha$ =0.10.
[1] Scored in the top 20th percentile of the overall depression scale.

To confirm the hypothesis that any models without the annual driving factor are mis-specified, we conduct some tests. Recall that the sample size decreased from 11,955 to 9,389 when the annual-driving factor was included in the model because of the missing data on this factor. To eliminate the effect of different sample sizes on the analysis results, we first re-estimated the crash model without the annual-driving factor using the smaller sample size (n=9389) (the crash model as reported in Table 5.14). We then re-estimated the model with the annual-driving factor. When included in the model, the annual-driving factor became significant at $p$= 0.00008. Furthermore, the three factors (difficulty seeing friends across the street, osteoporosis in women, and difficulty doing heavy housework) that decreased the probability of crash involvement in Table 5.14 became insignificant. Another significant change in the estimated coefficient is the male factor. Being a male used to be a risk factor if the annual-driving factor is excluded from the model (Table 5.14). However, it became insignificant at $p$=0.114 when taking into account the effect of the annual-driving factor on crash involvement. These results suggest that the annual-driving factor, being the single most important factor in crash involvement, explains much of the variation in crash data. Without it, a considerable level of noise remained in the data and the impact of the annual-driving factor on crash involvement is then being mimicked by (a combination of) other factors. These test results confirm our believe that any models ***without*** the annual-driving factor are mis-specified.

In sum, we have found conclusively that the more one drives the more one is likely to be involved in vehicle crashes. This is true for both men and women. Living alone and persistent back pain are also crash risks common to both genders. Older women who have these three risk factors are more likely to be involved in crashes than women who do not. However, more factors, in addition to these three factors, affect older men's crash involvement rates. For older men, if they are employed and cognitively disable (reflected by low scores on the word-recall tests), have a history of glaucoma, and use anti-depression drugs, then they are almost seven times more likely to be involved in vehicle crashes than those who do not have these factors, but live alone and suffer from persistent back pain (the odds ratio = 6.85.)

## 6.3 Future Work

Several factors have nonintuitive results in the probability of older *male* drivers' decisions to cease driving. They are educational level, pain in the joints and living alone. Particularly puzzling are the interaction effects between educational level and functional limitations. Without including any functional limitations in the model, better educated men are, as expected, less likely to stop driving. However, once functional limitations are included in the model, the sign for the education factor changes and the higher educational level increases the probability of driving cessation in older male drivers. Another nonintuitive result is on the pain-in-joints variable -- it decreases the probability of driving cessation in older male drivers. Limited resources prevented more detailed investigation of these nonintuitive results. Alternative models should be estimated by substituting in the model different risk factors that are, or are thought to be, highly correlated. For example, joint pain and arthritis are highly correlated. Will results be the same if arthritis is removed from the model?

In addition to these issues related to model specification, the driving status models (Table 4.1) can be improved by 1) testing whether explanatory variables have a similar influence on older **men's**, as well as, on older women's decisions to stop driving, and 2) developing a single combined-gender model based on the pooling test results.

A substantial amount of data had to be imputed due to non-responses, data gaps, and data inconsistencies. Assumptions were made to impute these missing data and to rectify data inconsistencies. They need to be validated. This should be accomplished by estimating separate models based on different subsets of the data base.

The major limitation of this study is that its results might not be able to generalize readily to other populations in the country. Two factors contribute to this non-generalization of the results. First, the two counties included in the Iowa 65+ Rural Health Study are rural counties. As a result, the impact of **public transportation** on driving decision can not be assessed. Also, since the traffic mix in rural areas is typically different from that in urban areas, what effects **traffic mix** and perhaps even **highway geometric design** and **travel speed** have on crash involvement are also unknown. Second, the residents in these two counties are believed to be relatively affluent. Consequently, the impacts of income and employment status on driving decisions may not been fully addressed.

This latter limitation will be addressed by augmenting the results from this study with results of the Study of Physical Performance & Age Related Changes in Sonomans, which will become available later this year. Residents in this study are primarily blue-collared, culturally diverse and living in rural settings. Although not part of this study, it would be tremendously insightful to conduct an analysis similar to ours and to develop similar models using data from the Yale Health and Aging Project. Since this Yale project and the Iowa 65+ Rural Health Study are both part of the EPESE, protocol and design of these two studies are almost identical. The distinction between the Yale project and the Iowa project is that subjects in the Yale project are lower income and reside in urban settings. Since the study of the Health and Functioning in Marin County was designed in such a way that its results can be readily compared to those from the EPESE studies, it will also be beneficial to conduct similar analysis and to develop similar models by using data from the Marin study. By comparing results across these studies, one can more conclusively establish a consensus on the risks of older drivers being involved in vehicle crashes.

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## Appendix 1.

## Diagnostic Tests of Female Crash Model *with* Annual Miles Driven Included

| Factor | Estimated coefficient | *Z* ratio | Prob $\{z^0 > z\}$ | Prob $\{z^0 > z\}$ Sig. at α=.05 | Prob $\{z^0 > z\}$ Sig at α=0.1 | Mean | *LL* Ratio | *LL* ratio Sig. at α=.05 | *LL* ratio Sig at α=0.1 |
|---|---|---|---|---|---|---|---|---|---|
| Anti-depressant | 0.218 | 0.597 | 0.551 | 0 | 0 | 0.051 | 0.335 | 0 | 0 |
| Nonsteroidal anti-inflammatory agents | 0.333 | 1.469 | 0.142 | 0 | 0 | 0.144 | 2.011 | 0 | 0 |
| Benzodiazepines | -0.133 | -0.404 | 0.686 | 0 | 0 | 0.082 | 0.169 | 0 | 0 |
| Employed (yes) | -0.073 | -0.188 | 0.851 | 0 | 0 | 0.116 | 0.036 | 0 | 0 |
| Feel bored (yes) | 0.153 | 0.503 | 0.615 | 0 | 0 | 0.073 | 0.243 | 0 | 0 |
| Feel depressed (yes) | 0.311 | 0.602 | 0.547 | 0 | 0 | 0.020 | 0.331 | 0 | 0 |
| - Top 2% | 0.024 | 0.033 | 0.974 | 0 | 0 | 0.016 | 0.001 | 0 | 0 |
| - Top 2-5% | 0.471 | 1.348 | 0.178 | 0 | 0 | 0.040 | 1.599 | 0 | 0 |
| - 5-10 percentile | 0.170 | 0.465 | 0.642 | 0 | 0 | 0.054 | 0.206 | 0 | 0 |
| - 10-20 percentile | -0.280 | -0.888 | 0.374 | 0 | 0 | 0.104 | 0.853 | 0 | 0 |
| Back pain | 0.208 | 1.188 | 0.235 | 0 | 0 | 0.445 | 1.411 | 0 | 0 |
| History of glaucoma | 0.097 | 0.331 | 0.740 | 0 | 0 | 0.092 | 0.107 | 0 | 0 |
| Living alone | 0.148 | 0.818 | 0.413 | 0 | 0 | 0.584 | 0.677 | 0 | 0 |
| Age | 0.002 | 0.078 | 0.938 | 0 | 0 | 77.700 | 0.006 | 0 | 0 |
| Full time | -0.283 | -0.395 | 0.692 | 0 | 0 | 0.017 | 0.171 | 0 | 0 |
| Hospital stay | -0.504 | -1.814 | 0.070 | 0 | 1 | 0.166 | 3.722 | 0 | 1 |
| Self-perceived health (good) | 0.013 | 0.057 | 0.954 | 0 | 0 | 0.815 | 0.003 | 0 | 0 |
| Self-perceived health (poor) | -0.166 | -0.281 | 0.778 | 0 | 0 | 0.023 | 0.083 | 0 | 0 |

| Factor | Estimated coefficient | *Z* ratio | Prob $\{z^0 > z\}$ | Prob $\{z^0 > z\}$ Sig. at α=.05 | Prob $\{z^0 > z\}$ Sig at α=0.1 | Mean | *LL* Ratio | *LL* ratio Sig. at α=.05 | *LL* ratio Sig at α=0.1 |
|---|---|---|---|---|---|---|---|---|---|
| Self-perceived health compared to others | 0.040 | 0.188 | 0.851 | 0 | 0 | 0.215 | 0.035 | 0 | 0 |
| Scored high on memory tests | -0.352 | -1.449 | 0.147 | 0 | 0 | 0.888 | 1.935 | 0 | 0 |
| Need help in bathing (yes) | 0.425 | 1.218 | 0.223 | 0 | 0 | 0.044 | 1.321 | 0 | 0 |
| Need help in personal grooming (yes) | -0.033 | -1.288 | 0.198 | 0 | 0 | 0.008 | 1.321 | 0 | 0 |
| Need help in dressing (yes) | -0.911 | -0.905 | 0.366 | 0 | 0 | 0.016 | 1.121 | 0 | 0 |
| Need help in eating (yes) | -0.036 | -0.578 | 0.563 | 0 | 0 | 0.001 | 1.121 | 0 | 0 |
| Need help in transferring (yes) | -0.837 | -0.829 | 0.407 | 0 | 0 | 0.014 | 0.913 | 0 | 0 |
| Need help in toileting (yes) | -1.254 | -1.245 | 0.213 | 0 | 0 | 0.023 | 2.412 | 0 | 0 |
| Need help in heavy housework (yes) | -0.379 | -1.665 | 0.096 | 0 | 1 | 0.249 | 2.978 | 0 | 1 |
| Need help in walking 1/2 mile (yes) | 0.032 | 0.149 | 0.882 | 0 | 0 | 0.221 | 0.022 | 0 | 0 |
| Need help in climbing stairs (yes) | -0.970 | -1.356 | 0.175 | 0 | 0 | 0.036 | 2.550 | 0 | 0 |
| Education (>12 years) | -0.123 | -0.624 | 0.533 | 0 | 0 | 0.276 | 0.396 | 0 | 0 |
| Parkinson's disease (yes) | -1.033 | -1.023 | 0.306 | 0 | 0 | 0.016 | 1.495 | 0 | 0 |
| 1st episode of stroke | -0.964 | -1.898 | 0.058 | 0 | 1 | 0.073 | 4.946 | 1 | 1 |
| 2nd episode of stroke | -0.026 | -0.752 | 0.380 | 0 | 0 | 0.022 | 1.946 | 0 | 0 |
| 3rd episode of stroke | -0.026 | -0.828 | 0.408 | 0 | 0 | 0.005 | 1.346 | 0 | 0 |
| Diabetes | -0.654 | -0.652 | 0.515 | 0 | 0 | 0.014 | 0.532 | 0 | 0 |
| 1st episode of heart attack | -0.003 | -0.410 | 0.682 | 0 | 0 | 0.075 | 0.139 | 0 | 0 |
| 2nd episode of heart attack | -0.215 | -0.367 | 0.714 | 0 | 0 | 0.030 | 0.144 | 0 | 0 |

| Factor | Estimated coefficient | *Z* ratio | Prob {$z^0$> z} | Prob {$z^0$> z} Sig. at α=.05 | Sig at α=0.1 | Mean | *LL* Ratio | *LL* ratio Sig. at α=.05 | Sig at α=0.1 |
|---|---|---|---|---|---|---|---|---|---|
| High blood pressure (yes) | -0.063 | -0.355 | 0.722 | 0 | 0 | 0.414 | 0.127 | 0 | 0 |
| Suspect of arthritis (yes) | -0.024 | -0.630 | 0.529 | 0 | 0 | 0.003 | 0.127 | 0 | 0 |
| Income (increasing) | 0.013 | 0.753 | 0.451 | 0 | 0 | 12.790 | 0.568 | 0 | 0 |
| History of glaucoma | 0.097 | 0.331 | 0.740 | 0 | 0 | 0.092 | 0.107 | 0 | 0 |
| History of cataract | -0.002 | -0.522 | 0.602 | 0 | 0 | 0.559 | 0.100 | 0 | 0 |
| Diagnosed with arthritis | -0.272 | -1.220 | 0.222 | 0 | 0 | 0.844 | 1.408 | 0 | 0 |
| Diagnosed with osteoporosis | -0.009 | -1.487 | 0.137 | 0 | 0 | 0.178 | 0.385 | 0 | 0 |
| Surgery for cataracts (yes) | -0.257 | -0.937 | 0.349 | 0 | 0 | 0.141 | 0.938 | 0 | 0 |
| Retired (yes) | -0.042 | -0.241 | 0.810 | 0 | 0 | 0.483 | 0.058 | 0 | 0 |
| Member of club (yes) | -0.306 | -1.542 | 0.123 | 0 | 0 | 0.781 | 2.265 | 0 | 0 |
| Social support (yes) | 0.383 | 0.840 | 0.401 | 0 | 0 | 0.949 | 0.796 | 0 | 0 |
| Exercise regularly (yes) | -0.157 | -0.670 | 0.503 | 0 | 0 | 0.188 | 0.465 | 0 | 0 |
| Married (yes) | -0.152 | -0.803 | 0.422 | 0 | 0 | 0.367 | 0.656 | 0 | 0 |
| Widowed (yes) | 0.270 | 1.467 | 0.142 | 0 | 0 | 0.574 | 2.205 | 0 | 0 |
| Episode of unconsciousness (yes) | -0.125 | -0.246 | 0.806 | 0 | 0 | 0.033 | 0.063 | 0 | 0 |
| Joint pain (yes) | 0.164 | 0.889 | 0.374 | 0 | 0 | 0.614 | 0.804 | 0 | 0 |
| Stiffness (yes) | 0.170 | 0.963 | 0.336 | 0 | 0 | 0.487 | 0.930 | 0 | 0 |
| Self-perceived memory (good) | -0.127 | -0.385 | 0.700 | 0 | 0 | 0.083 | 0.154 | 0 | 0 |
| Self-perceived memory (poor) | -1.083 | -1.078 | 0.281 | 0 | 0 | 0.023 | 1.709 | 0 | 0 |

| Factor | Estimated coefficient | *Z* ratio | Prob $\{z^0 > z\}$ | Prob $\{z^0 > z\}$ Sig. at α=.05 | Prob $\{z^0 > z\}$ Sig at α=0.1 | Mean | *LL* Ratio | *LL* ratio Sig. at α=.05 | *LL* ratio Sig at α=0.1 |
|---|---|---|---|---|---|---|---|---|---|
| Scored low on word-recall tests | -0.035 | -0.192 | 0.847 | 0 | 0 | 0.642 | 0.037 | 0 | 0 |
| % of incorrect answers in memory tests | -0.415 | -0.376 | 0.707 | 0 | 0 | 0.034 | 0.146 | 0 | 0 |
| % of incorrect answers in word-recall tests | -0.116 | -0.474 | 0.635 | 0 | 0 | 0.255 | 0.228 | 0 | 0 |
| Pulling/pushing large objects (unable) | -0.105 | -0.296 | 0.767 | 0 | 0 | 0.071 | 0.090 | 0 | 0 |
| Stooping, crouching, or kneeling (unable) | -0.135 | -0.446 | 0.656 | 0 | 0 | 0.099 | 0.205 | 0 | 0 |
| Writing or handling small objects(unable) | -0.038 | -0.566 | 0.571 | 0 | 0 | 0.001 | 0.205 | 0 | 0 |
| Lifting/carrying heavy objects (unable) | -0.181 | -0.531 | 0.595 | 0 | 0 | 0.084 | 0.295 | 0 | 0 |
| Consume alcohol (yes) | 0.177 | 0.991 | 0.322 | 0 | 0 | 0.356 | 0.970 | 0 | 0 |
| Difficulty in seeing friend across street (yes) | -1.881 | -1.870 | 0.062 | 0 | 1 | 0.044 | 7.013 | 1 | 1 |
| Difficulty in seeing newspaper print (yes) | -0.743 | -0.737 | 0.461 | 0 | 0 | 0.014 | 0.700 | 0 | 0 |
| | | | | | | | | | |
| No. of significant factors | | | | 0 | 4 | | | 2 | 4 |

## Appendix 2

## Diagnostic Test of Male Crash Model *with* Annual Miles Driven Included

| Factor | Estimated coefficient | *Z* ratio | Prob $\{z^0 > z\}$ | Prob $\{z^0 > z\}$ Sig. at α=05 | Prob $\{z^0 > z\}$ Sig at α=0.1 | Mean | *LL* Ratio | *LL* ratio Sig. at α=05 | *LL* ratio Sig at α=0.1 |
|---|---|---|---|---|---|---|---|---|---|
| Nonsteroidal anti-inflammatory agents | -0.122 | -0.508 | 0.612 | 0 | 0 | 0.119 | 0.266 | 0 | 0 |
| Benzodiazepines | -0.191 | -0.513 | 0.608 | 0 | 0 | 0.050 | 0.277 | 0 | 0 |
| Feel bored | 0.466 | 2.135 | 0.033 | 1 | 1 | 0.098 | 4.116 | 1 | 1 |
| Feel depressed | -0.063 | -0.123 | 0.902 | 0 | 0 | 0.022 | 0.016 | 0 | 0 |
| - Top 2% | -0.813 | -0.810 | 0.418 | 0 | 0 | 0.012 | 0.871 | 0 | 0 |
| - Top 2-5% | 0.576 | 1.723 | 0.085 | 0 | 1 | 0.028 | 2.549 | 0 | 0 |
| - 5-10 percentile | 0.075 | 0.206 | 0.837 | 0 | 0 | 0.042 | 0.042 | 0 | 0 |
| - 10-20 percentile | 0.055 | 0.222 | 0.824 | 0 | 0 | 0.097 | 0.049 | 0 | 0 |
| Back pain | 0.204 | 1.329 | 0.184 | 0 | 0 | 0.382 | 1.748 | 0 | 0 |
| Age (increasing) | 0.021 | 1.311 | 0.190 | 0 | 0 | 77.790 | 1.687 | 0 | 0 |
| Employed - part-time | -0.029 | -0.099 | 0.921 | 0 | 0 | 0.094 | 0.010 | 0 | 0 |
| Employed - full-time | -0.267 | -0.753 | 0.452 | 0 | 0 | 0.053 | 0.596 | 0 | 0 |
| Hospital stay | 0.006 | 0.033 | 0.974 | 0 | 0 | 0.208 | 0.001 | 0 | 0 |
| Self-perceived health (good) | -0.145 | -0.786 | 0.432 | 0 | 0 | 0.788 | 0.604 | 0 | 0 |
| Self-perceived health (poor) | 0.094 | 0.222 | 0.824 | 0 | 0 | 0.030 | 0.048 | 0 | 0 |
| Self-perceived health compared to others | 0.033 | 0.161 | 0.872 | 0 | 0 | 0.164 | 0.026 | 0 | 0 |
| Scored high on memory tests | -0.140 | -0.654 | 0.513 | 0 | 0 | 0.855 | 0.415 | 0 | 0 |
| Need help in walking across a small room (yes) | -0.118 | -0.282 | 0.778 | 0 | 0 | 0.043 | 0.083 | 0 | 0 |

| Factor | Estimated coefficient | *Z* ratio | Prob $\{z^0 > z\}$ | Prob $\{z^0 > z\}$ Sig. at α=05 | Prob $\{z^0 > z\}$ Sig at α=0.1 | Mean | *LL* Ratio | *LL* ratio Sig. at α=05 | *LL* ratio Sig at α=0.1 |
|---|---|---|---|---|---|---|---|---|---|
| Need help in bathing (yes) | 0.009 | 0.022 | 0.982 | 0 | 0 | 0.042 | 0.000 | 0 | 0 |
| Need help in personal grooming (yes) | -0.055 | -0.055 | 0.956 | 0 | 0 | 0.007 | 0.003 | 0 | 0 |
| Need help in dressing (yes) | 0.249 | 0.682 | 0.495 | 0 | 0 | 0.040 | 0.433 | 0 | 0 |
| Need help in eating (yes) | 0.349 | 0.347 | 0.729 | 0 | 0 | 0.005 | 0.108 | 0 | 0 |
| Need help in transferring (yes) | -0.453 | -0.635 | 0.525 | 0 | 0 | 0.019 | 0.469 | 0 | 0 |
| Need help in toileting (yes) | -0.368 | -0.517 | 0.605 | 0 | 0 | 0.016 | 0.302 | 0 | 0 |
| Need help in heavy housework (yes) | -0.009 | -0.042 | 0.967 | 0 | 0 | 0.160 | 0.002 | 0 | 0 |
| Need help in walking 1/2 mile (yes) | 0.097 | 0.450 | 0.653 | 0 | 0 | 0.151 | 0.198 | 0 | 0 |
| Need help in climbing stairs (yes) | 0.495 | 1.377 | 0.168 | 0 | 0 | 0.031 | 1.677 | 0 | 0 |
| Education (> 12 years) | -0.027 | -0.128 | 0.898 | 0 | 0 | 0.171 | 0.017 | 0 | 0 |
| Parkinson's disease (yes) | 0.028 | 0.047 | 0.963 | 0 | 0 | 0.018 | 0.002 | 0 | 0 |
| 1st episode of stroke | 0.135 | 0.598 | 0.550 | 0 | 0 | 0.120 | 0.347 | 0 | 0 |
| 2nd episode of stroke | 0.075 | 0.191 | 0.848 | 0 | 0 | 0.039 | 0.036 | 0 | 0 |
| 3rd episode of stroke | -0.405 | -0.400 | 0.689 | 0 | 0 | 0.010 | 0.183 | 0 | 0 |
| Diabetes | -0.938 | -1.317 | 0.188 | 0 | 0 | 0.025 | 2.399 | 0 | 0 |
| 1st episode of heart attack | -0.006 | -0.723 | 0.470 | 0 | 0 | 0.208 | 0.143 | 0 | 0 |
| High blood pressure (yes) | -0.098 | -0.590 | 0.555 | 0 | 0 | 0.331 | 0.353 | 0 | 0 |

| Factor | Estimated coefficient | *Z* ratio | Prob $\{z^0 > z\}$ | Prob $\{z^0 > z\}$ Sig. at α=05 | Prob $\{z^0 > z\}$ Sig at α=0.1 | Mean | *LL* Ratio | *LL* ratio Sig. at α=05 | *LL* ratio Sig at α=0.1 |
|---|---|---|---|---|---|---|---|---|---|
| Suspect of arthritis (yes) | -0.056 | -0.607 | 0.544 | 0 | 0 | 0.001 | 0.353 | 0 | 0 |
| Income (increasing) | -0.004 | -0.231 | 0.818 | 0 | 0 | 14.410 | 0.053 | 0 | 0 |
| History of cataract | 0.004 | 0.548 | 0.583 | 0 | 0 | 0.428 | -0.081 | 0 | 0 |
| Diagnosed with osteoporosis | -0.115 | -0.253 | 0.800 | 0 | 0 | 0.033 | 0.067 | 0 | 0 |
| Surgery for cataracts (yes) | -0.015 | -0.064 | 0.949 | 0 | 0 | 0.126 | 0.004 | 0 | 0 |
| Retired (yes) | -0.020 | -0.083 | 0.934 | 0 | 0 | 0.882 | 0.007 | 0 | 0 |
| Member of club (yes) | 0.043 | 0.266 | 0.790 | 0 | 0 | 0.629 | 0.071 | 0 | 0 |
| Social support (yes) | 0.291 | 0.847 | 0.397 | 0 | 0 | 0.928 | 0.783 | 0 | 0 |
| Exercise regularly (yes) | 0.258 | 1.508 | 0.131 | 0 | 0 | 0.225 | 2.192 | 0 | 0 |
| Married (yes) | -0.145 | -0.439 | 0.660 | 0 | 0 | 0.812 | 0.191 | 0 | 0 |
| Widowed (yes) | -0.010 | -0.033 | 0.974 | 0 | 0 | 0.137 | 0.001 | 0 | 0 |
| Episode of unconsciousness (yes) | -0.340 | -0.743 | 0.457 | 0 | 0 | 0.041 | 0.613 | 0 | 0 |
| Joint pain (yes) | 0.173 | 1.104 | 0.269 | 0 | 0 | 0.579 | 1.234 | 0 | 0 |
| Stiffness (yes) | -0.096 | -0.614 | 0.539 | 0 | 0 | 0.411 | 0.380 | 0 | 0 |
| Self-perceived memory (good) | 0.308 | 1.246 | 0.213 | 0 | 0 | 0.072 | 1.440 | 0 | 0 |
| Self-perceived memory (poor) | 0.236 | 0.749 | 0.454 | 0 | 0 | 0.051 | 0.526 | 0 | 0 |
| Scored high on word-recall tests | -0.065 | -0.542 | 0.588 | 0 | 0 | 0.001 | 0.526 | 0 | 0 |
| % of incorrect answers in memory tests | 0.046 | 0.054 | 0.957 | 0 | 0 | 0.038 | 0.003 | 0 | 0 |

| Factor | Estimated coefficient | *Z* ratio | Prob $\{z^0 > z\}$ | Prob $\{z^0 > z\}$ Sig. at α=05 | Prob $\{z^0 > z\}$ Sig at α=0.1 | Mean | *LL* Ratio | *LL* ratio Sig. at α=05 | *LL* ratio Sig at α=0.1 |
|---|---|---|---|---|---|---|---|---|---|
| % of incorrect answers in word-recall tests | -0.308 | -1.476 | 0.140 | 0 | 0 | 0.264 | 2.260 | 0 | 0 |
| Pulling/pushing large objects (unable) | 0.496 | 1.241 | 0.215 | 0 | 0 | 0.024 | 1.348 | 0 | 0 |
| Stooping, crouching, or kneeling (unable) | 0.348 | 1.111 | 0.267 | 0 | 0 | 0.050 | 1.119 | 0 | 0 |
| Extending arms above shoulder (unable) | -0.025 | -0.035 | 0.972 | 0 | 0 | 0.011 | 0.001 | 0 | 0 |
| Writing or handling small objects(unable) | -0.040 | -0.650 | 0.516 | 0 | 0 | 0.003 | 0.001 | 0 | 0 |
| Lifting/carrying heavy objects (unable) | -0.097 | -0.212 | 0.832 | 0 | 0 | 0.034 | 0.046 | 0 | 0 |
| Consume alcohol (yes) | -0.035 | -0.226 | 0.821 | 0 | 0 | 0.536 | 0.051 | 0 | 0 |
| Difficulty in seeing friend across street (yes) | -0.206 | -0.404 | 0.687 | 0 | 0 | 0.025 | 0.174 | 0 | 0 |
| Difficulty in seeing newspaper print (yes) | 0.262 | 0.711 | 0.477 | 0 | 0 | 0.032 | 0.469 | 0 | 0 |
| | | | | | | | | | |
| No. of significant factors | | | | 1 | 2 | | | 1 | 1 |

# Appendix 3

## Diagnostic Tests of Gender-Combined Crash Model *with* Annual Miles Driven Included

| Factor | Estimated coefficient | $Z$ ratio | Prob $\{z^0 > z\}$ | Prob $\{z^0 > z\}$ | | Mean | $LL$ Ratio | $LL$ ratio | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Sig.at α=.05 | Sig at α=0.1 | | | Sig. at α=.05 | Sig at α=0.1 |
| Anti-depressant (female only) | 0.158 | 0.433 | 0.665 | 0 | 0 | 0.029 | 0.179 | 0 | 0 |
| Nonsteroidal anti-inflammatory agents | 0.061 | 0.368 | 0.713 | 0 | 0 | 0.133 | 0.134 | 0 | 0 |
| Benzodiazepines | -0.149 | -0.603 | 0.546 | 0 | 0 | 0.068 | 0.379 | 0 | 0 |
| Feel depressed | 0.154 | 0.429 | 0.668 | 0 | 0 | 0.021 | 0.175 | 0 | 0 |
| - Top 2% | -0.358 | -0.616 | 0.538 | 0 | 0 | 0.014 | 0.427 | 0 | 0 |
| - Top 2-5% | 0.545 | 2.270 | 0.023 | 1 | 1 | 0.035 | 4.440 | 1 | 1 |
| - 5-10 percentile | 0.097 | 0.375 | 0.708 | 0 | 0 | 0.049 | 0.137 | 0 | 0 |
| - 10-20 percentile | -0.070 | -0.361 | 0.718 | 0 | 0 | 0.101 | 0.133 | 0 | 0 |
| Age (increasing) | 0.012 | 0.915 | 0.360 | 0 | 0 | 77.740 | 0.830 | 0 | 0 |
| Employed - part-time | -0.043 | -0.150 | 0.881 | 0 | 0 | 0.078 | 0.022 | 0 | 0 |
| Employed - full-time | -0.262 | -0.824 | 0.410 | 0 | 0 | 0.032 | 0.719 | 0 | 0 |
| Hospital stay | -0.169 | -1.095 | 0.274 | 0 | 0 | 0.184 | 1.243 | 0 | 0 |
| Self-perceived health (good) | -0.074 | -0.520 | 0.603 | 0 | 0 | 0.804 | 0.267 | 0 | 0 |
| Self-perceived health (poor) | 0.037 | 0.108 | 0.914 | 0 | 0 | 0.026 | 0.012 | 0 | 0 |
| Self-perceived health compared to others | 0.050 | 0.339 | 0.734 | 0 | 0 | 0.193 | 0.114 | 0 | 0 |
| Scored high on memory tests | -0.229 | -1.422 | 0.155 | 0 | 0 | 0.873 | 1.923 | 0 | 0 |
| Need help in walking across a small room (yes) | -0.096 | -0.296 | 0.767 | 0 | 0 | 0.035 | 0.090 | 0 | 0 |

| Factor | Estimated coefficient | *Z* ratio | Prob {$z^0$> z} | Prob {$z^0$> z} | | Mean | *LL* Ratio | *LL* ratio | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Sig.at α=.05 | Sig at α=0.1 | | | Sig. at α=.05 | Sig at α=0.1 |
| Need help in bathing (yes) | 0.200 | 0.773 | 0.440 | 0 | 0 | 0.043 | 0.564 | 0 | 0 |
| Need help in personal grooming (yes) | -0.752 | -0.750 | 0.453 | 0 | 0 | 0.007 | 0.733 | 0 | 0 |
| Need help in dressing (yes) | 0.042 | 0.123 | 0.902 | 0 | 0 | 0.027 | 0.015 | 0 | 0 |
| Need help in eating (yes) | 0.197 | 0.196 | 0.845 | 0 | 0 | 0.003 | 0.036 | 0 | 0 |
| Need help in transferring (yes) | -0.560 | -0.963 | 0.336 | 0 | 0 | 0.016 | 1.120 | 0 | 0 |
| Need help in toileting (yes) | -0.722 | -1.243 | 0.214 | 0 | 0 | 0.020 | 1.979 | 0 | 0 |
| Need help in heavy housework (yes) | -0.217 | -1.389 | 0.165 | 0 | 0 | 0.210 | 2.010 | 0 | 0 |
| Need help in walking 1/2 mile (yes) | 0.043 | 0.285 | 0.776 | 0 | 0 | 0.191 | 0.081 | 0 | 0 |
| Need help in climbing stairs (yes) | 0.047 | 0.151 | 0.880 | 0 | 0 | 0.034 | 0.023 | 0 | 0 |
| Education (> 12 years) | -0.074 | -0.520 | 0.603 | 0 | 0 | 0.230 | 0.274 | 0 | 0 |
| Parkinson's disease (yes) | -0.339 | -0.669 | 0.503 | 0 | 0 | 0.017 | 0.500 | 0 | 0 |
| 1st episode of stroke | -0.137 | -0.676 | 0.499 | 0 | 0 | 0.094 | 0.474 | 0 | 0 |
| 2nd episode of stroke | -0.301 | -0.779 | 0.436 | 0 | 0 | 0.030 | 0.666 | 0 | 0 |
| 3rd episode of stroke | -0.686 | -0.681 | 0.496 | 0 | 0 | 0.007 | 0.587 | 0 | 0 |
| Diabetes | -0.842 | -1.448 | 0.148 | 0 | 0 | 0.019 | 2.805 | 0 | 1 |
| 1st episode of heart attack | -0.172 | -1.025 | 0.305 | 0 | 0 | 0.134 | 1.091 | 0 | 0 |

| Factor | Estimated coefficient | *Z* ratio | Prob {$z^0$> z} | Prob {$z^0$> z} | | Mean | *LL* Ratio | *LL* ratio | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Sig.at α=.05 | Sig at α=0.1 | | | Sig. at α=.05 | Sig at α=0.1 |
| 2nd episode of heart attack | -0.023 | -0.106 | 0.916 | 0 | 0 | 0.060 | 0.011 | 0 | 0 |
| High blood pressure (yes) | -0.069 | -0.571 | 0.568 | 0 | 0 | 0.378 | 0.329 | 0 | 0 |
| Suspect of arthritis (yes) | -0.031 | -0.824 | 0.410 | 0 | 0 | 0.002 | 0.329 | 0 | 0 |
| Income (increasing) | 0.006 | 0.468 | 0.640 | 0 | 0 | 13.500 | 0.219 | 0 | 0 |
| History of cataract | -0.000 | -0.098 | 0.922 | 0 | 0 | 0.502 | 0.011 | 0 | 0 |
| arthritis (yes) | 0.078 | 0.485 | 0.628 | 0 | 0 | 0.831 | 0.239 | 0 | 0 |
| Diagnosed with osteoporosis | -0.009 | -1.297 | 0.194 | 0 | 0 | 0.100 | 2.322 | 0 | 0 |
| Surgery for cataracts (yes) | -0.127 | -0.716 | 0.474 | 0 | 0 | 0.134 | 0.529 | 0 | 0 |
| Retired (yes) | -0.086 | -0.631 | 0.528 | 0 | 0 | 0.657 | 0.395 | 0 | 0 |
| Member of club (yes) | -0.079 | -0.629 | 0.530 | 0 | 0 | 0.715 | 0.392 | 0 | 0 |
| Social support (yes) | 0.340 | 1.239 | 0.215 | 0 | 0 | 0.940 | 1.702 | 0 | 0 |
| Exercise regularly (yes) | 0.101 | 0.732 | 0.464 | 0 | 0 | 0.204 | 0.527 | 0 | 0 |
| Married (yes) | -0.172 | -0.753 | 0.452 | 0 | 0 | 0.562 | 0.558 | 0 | 0 |
| Widowed (yes) | 0.213 | 1.055 | 0.291 | 0 | 0 | 0.383 | 1.123 | 0 | 0 |
| Episode of unconsciousness (yes) | -0.261 | -0.768 | 0.443 | 0 | 0 | 0.036 | 0.639 | 0 | 0 |
| Joint pain (yes) | 0.142 | 1.156 | 0.248 | 0 | 0 | 0.599 | 1.350 | 0 | 0 |
| Stiffnes (yes) | 0.003 | 0.022 | 0.983 | 0 | 0 | 0.453 | 0.000 | 0 | 0 |
| Self-perceived memory (good) | 0.152 | 0.773 | 0.439 | 0 | 0 | 0.078 | 0.574 | 0 | 0 |

| Factor | Estimated coefficient | *Z* ratio | Prob {$z^0$> z} | Prob {$z^0$> z} | | Mean | *LL* Ratio | *LL* ratio | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Sig.at α=.05 | Sig at α=0.1 | | | Sig. at α=.05 | Sig at α=0.1 |
| Self-perceived memory (poor) | -0.031 | -0.102 | 0.919 | 0 | 0 | 0.035 | 0.011 | 0 | 0 |
| Scored high on word-recall tests | -0.058 | -0.552 | 0.581 | 0 | 0 | 0.000 | 0.011 | 0 | 0 |
| % of incorrect answers in memory tests | -0.122 | -0.182 | 0.855 | 0 | 0 | 0.036 | 0.034 | 0 | 0 |
| % of incorrect answers in word-recall tests | -0.228 | -1.438 | 0.150 | 0 | 0 | 0.259 | 2.121 | 0 | 0 |
| Pulling/pushing large objects (unable) | 0.156 | 0.597 | 0.550 | 0 | 0 | 0.050 | 0.342 | 0 | 0 |
| Stooping, crouching, or kneeling (unable) | 0.105 | 0.488 | 0.625 | 0 | 0 | 0.078 | 0.232 | 0 | 0 |
| Extending arms above shoulder (unable) | 0.502 | 1.465 | 0.143 | 0 | 0 | 0.018 | 1.855 | 0 | 0 |
| Writing or handling small objects(unable) | -0.032 | -0.731 | 0.465 | 0 | 0 | 0.002 | 1.855 | 0 | 0 |
| Lifting/carrying heavy objects (unable) | -0.125 | -0.466 | 0.641 | 0 | 0 | 0.062 | 0.226 | 0 | 0 |
| Consume alcohol (yes) | 0.034 | 0.289 | 0.772 | 0 | 0 | 0.434 | 0.084 | 0 | 0 |
| Difficulty in seeing friend across street (yes) | -0.791 | -1.746 | 0.081 | 0 | 1 | 0.036 | 3.967 | 1 | 1 |
| Difficulty in seeing newspaper print (yes) | 0.094 | 0.274 | 0.784 | 0 | 0 | 0.022 | 0.073 | 0 | 0 |
| Annual miles driven (male only) | -0.029 | -1.336 | 0.182 | 0 | 0 | 3.638 | 1.704 | 0 | 0 |

| Factor | Estimated coefficient | *Z* ratio | Prob $\{z^0 > z\}$ | Prob $\{z^0 > z\}$ | | Mean | *LL* Ratio | *LL* ratio | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Sig.at α=.05 | Sig at α=0.1 | | | Sig. at α=.05 | Sig at α=0.1 |
| Feel bored | 0.366 | 2.080 | 0.038 | 1 | 1 | 0.08385 | 3.963 | 1 | 1 |
| Unable to extend arms over shoulders (female only) | 0.762 | 1.959 | 0.050 | 0 | 1 | 0.01298 | 3.088 | 0 | 1 |
| | | | | | | | | | |
| No. of significant factors | | | | 2 | 4 | | | 3 | 5 |

**Appendix 4**
**Diagnostic Tests of Female Crash Model**
***without* Annual Miles Driven Included**

| Factor | Estimated coefficient | $Z$ ratio | Prob $\{z^0 > z\}$ | Prob $\{z^0 > z\}$ Sig. at α=05 | Prob $\{z^0 > z\}$ Sig at α=0.1 | Mean | *LL* Ratio | *LL* ratio Sig. at α=05 | *LL* ratio Sig at α=0.1 |
|---|---|---|---|---|---|---|---|---|---|
| Anti-depressant | 0.270 | 1.162 | 0.245 | 0 | 0 | 0.041 | 1.252 | 0 | 0 |
| Nonsteroidal anti-inflammatory agents | 0.027 | 0.179 | 0.858 | 0 | 0 | 0.129 | 0.032 | 0 | 0 |
| Benzodiazepines | -0.266 | -1.176 | 0.240 | 0 | 0 | 0.069 | 1.495 | 0 | 0 |
| Feel depressed (yes) | 0.448 | 1.690 | 0.091 | 0 | 1 | 0.023 | 2.506 | 0 | 0 |
| - Top 2% | -0.771 | -1.328 | 0.184 | 0 | 0 | 0.015 | 2.301 | 0 | 0 |
| - Top 2-5% | 0.559 | 2.700 | 0.007 | 1 | 1 | 0.036 | 6.292 | 1 | 1 |
| - 5-10 percentile | 0.212 | 1.049 | 0.294 | 0 | 0 | 0.052 | 1.040 | 0 | 0 |
| - 10-20 percentile | -0.130 | -0.763 | 0.445 | 0 | 0 | 0.106 | 0.602 | 0 | 0 |
| DEPRESL2 | 0.307 | 1.561 | 0.118 | 0 | 0 | 0.051 | 2.250 | 0 | 0 |
| DEPRESL3 | 0.287 | 1.928 | 0.054 | 0 | 1 | 0.103 | 3.495 | 0 | 1 |
| DEPRESL4 | 0.109 | 0.889 | 0.374 | 0 | 0 | 0.209 | 0.777 | 0 | 0 |
| Age | 0.004 | 0.378 | 0.705 | 0 | 0 | 78.250 | 0.143 | 0 | 0 |
| Employed part-time | 0.021 | 0.076 | 0.939 | 0 | 0 | 0.072 | 0.006 | 0 | 0 |
| Employed full-time | -0.191 | -0.631 | 0.528 | 0 | 0 | 0.028 | 0.416 | 0 | 0 |
| Hospital stay | -0.195 | -1.420 | 0.156 | 0 | 0 | 0.190 | 2.100 | 0 | 0 |
| Self-perceived health (good) | -0.087 | -0.714 | 0.475 | 0 | 0 | 0.784 | 0.502 | 0 | 0 |
| Self-perceived health (poor) | 0.080 | 0.293 | 0.770 | 0 | 0 | 0.032 | 0.084 | 0 | 0 |
| Self-perceived health compared to others | 0.043 | 0.318 | 0.751 | 0 | 0 | 0.185 | 0.100 | 0 | 0 |
| Scored high on memory tests | 0.022 | 0.156 | 0.876 | 0 | 0 | 0.857 | 0.024 | 0 | 0 |

| Factor | Estimated coefficient | *Z* ratio | Prob $\{z^0 > z\}$ | Prob $\{z^0 > z\}$ Sig. at α=05 | Prob $\{z^0 > z\}$ Sig at α=0.1 | Mean | *LL* Ratio | *LL* ratio Sig. at α=05 | *LL* ratio Sig at α=0.1 |
|---|---|---|---|---|---|---|---|---|---|
| Scored low on memory tests | -0.031 | -0.456 | 0.648 | 0 | 0 | 0.001 | 0.024 | 0 | 0 |
| Need help in walking across small room (yes) | -0.458 | -1.492 | 0.136 | 0 | 0 | 0.042 | 2.573 | 0 | 0 |
| Need help in bathing (yes) | -0.047 | -0.198 | 0.843 | 0 | 0 | 0.050 | 0.040 | 0 | 0 |
| Need help in personal grooming (yes) | -0.664 | -0.937 | 0.349 | 0 | 0 | 0.010 | 1.105 | 0 | 0 |
| Need help in dressing (yes) | -0.059 | -0.198 | 0.843 | 0 | 0 | 0.031 | 0.040 | 0 | 0 |
| Need help in eating (yes) | -0.582 | -0.580 | 0.562 | 0 | 0 | 0.005 | 0.412 | 0 | 0 |
| Need help in transferring (yes) | -0.758 | -1.505 | 0.132 | 0 | 0 | 0.020 | 2.933 | 0 | 1 |
| Need help in toileting (yes) | -0.803 | -1.596 | 0.111 | 0 | 0 | 0.024 | 3.356 | 0 | 1 |
| Need help in heavy housework (yes) | -0.252 | -1.887 | 0.059 | 0 | 1 | 0.235 | 3.727 | 0 | 1 |
| Need help in walking 1/2 mile (yes) | -0.079 | -0.599 | 0.549 | 0 | 0 | 0.210 | 0.364 | 0 | 0 |
| Need help in climbing stairs (yes) | -0.387 | -1.259 | 0.208 | 0 | 0 | 0.040 | 1.791 | 0 | 0 |
| Education (>12 years) | -0.044 | -0.340 | 0.734 | 0 | 0 | 0.224 | 0.116 | 0 | 0 |
| Parkinson’s disease (yes) | -0.531 | -1.056 | 0.291 | 0 | 0 | 0.019 | 1.333 | 0 | 0 |
| 1st episode of stroke | -0.120 | -0.691 | 0.490 | 0 | 0 | 0.099 | 0.492 | 0 | 0 |
| 2nd episode of stroke | -0.373 | -1.097 | 0.273 | 0 | 0 | 0.030 | 1.353 | 0 | 0 |
| 3rd episode of stroke | -1.059 | -1.056 | 0.291 | 0 | 0 | 0.007 | 1.631 | 0 | 0 |
| Diabetes | -0.933 | -1.609 | 0.108 | 0 | 0 | 0.017 | 3.595 | 0 | 1 |
| 1st episode of heart attack | -0.189 | -1.253 | 0.210 | 0 | 0 | 0.140 | 1.636 | 0 | 0 |

| Factor | Estimated coefficient | *Z* ratio | Prob $\{z^0 > z\}$ | Prob $\{z^0 > z\}$ Sig. at α=05 | Prob $\{z^0 > z\}$ Sig at α=0.1 | Mean | *LL* Ratio | *LL* ratio Sig. at α=05 | *LL* ratio Sig at α=0.1 |
|---|---|---|---|---|---|---|---|---|---|
| 2nd episode of heart attack | -0.004 | -0.021 | 0.983 | 0 | 0 | 0.062 | 0.000 | 0 | 0 |
| High blood pressure (yes) | 0.066 | 0.624 | 0.532 | 0 | 0 | 0.387 | 0.388 | 0 | 0 |
| Suspect of arthritis (yes) | -0.151 | -0.151 | 0.880 | 0 | 0 | 0.003 | 0.024 | 0 | 0 |
| Income (increasing) | 0.002 | 0.215 | 0.830 | 0 | 0 | 13.340 | 0.046 | 0 | 0 |
| History of cataract | -0.045 | -0.429 | 0.668 | 0 | 0 | 0.512 | 0.185 | 0 | 0 |
| Diagnosed with arthritis | -0.012 | -0.085 | 0.932 | 0 | 0 | 0.827 | 0.007 | 0 | 0 |
| Surgery for cataracts (yes) | -0.079 | -0.525 | 0.599 | 0 | 0 | 0.146 | 0.281 | 0 | 0 |
| Retired (yes) | -0.016 | -0.122 | 0.903 | 0 | 0 | 0.667 | 0.015 | 0 | 0 |
| Member of club (yes) | -0.020 | -0.183 | 0.855 | 0 | 0 | 0.692 | 0.034 | 0 | 0 |
| Social support (yes) | 0.221 | 0.984 | 0.325 | 0 | 0 | 0.936 | 1.033 | 0 | 0 |
| Exercise regularly (yes) | 0.079 | 0.622 | 0.534 | 0 | 0 | 0.194 | 0.382 | 0 | 0 |
| Married (yes) | -0.024 | -0.118 | 0.906 | 0 | 0 | 0.560 | 0.014 | 0 | 0 |
| Widowed (yes) | 0.038 | 0.217 | 0.828 | 0 | 0 | 0.384 | 0.047 | 0 | 0 |
| Episode of unconsciousness (yes) | -0.573 | -1.781 | 0.075 | 0 | 1 | 0.042 | 3.817 | 0 | 1 |
| Joint pain (yes) | 0.005 | 0.048 | 0.961 | 0 | 0 | 0.591 | 0.002 | 0 | 0 |
| Stiffness (yes) | -0.063 | -0.598 | 0.550 | 0 | 0 | 0.449 | 0.358 | 0 | 0 |
| Self-perceived memory (good) | 0.229 | 1.333 | 0.183 | 0 | 0 | 0.078 | 1.672 | 0 | 0 |
| Self-perceived memory (poor) | -0.251 | -0.913 | 0.361 | 0 | 0 | 0.039 | 0.900 | 0 | 0 |
| Scored high on word-recall tests | -0.057 | -0.542 | 0.588 | 0 | 0 | 0.000 | 0.900 | 0 | 0 |

| | | | | Prob {$z^0$> z} | | | | *LL* ratio | |
|---|---|---|---|---|---|---|---|---|---|
| Factor | Estimated coefficient | *Z* ratio | Prob {$z^0$> z} | Sig. at α=05 | Sig at α=0.1 | Mean | *LL* Ratio | Sig. at α=05 | Sig at α=0.1 |
| Scored low on word-recall tests | 0.094 | 0.772 | 0.440 | 0 | 0 | 0.719 | 0.605 | 0 | 0 |
| % of incorrect answers in memory tests | -0.568 | -0.931 | 0.352 | 0 | 0 | 0.035 | 0.914 | 0 | 0 |
| % of incorrect answers in word-recall tests | -0.257 | -1.767 | 0.077 | 0 | 1 | 0.242 | 3.226 | 0 | 1 |
| Pulling/pushing large objects (unable) | 0.072 | 0.318 | 0.751 | 0 | 0 | 0.056 | 0.099 | 0 | 0 |
| Stooping, crouching, or kneeling (unable) | -0.055 | -0.275 | 0.783 | 0 | 0 | 0.081 | 0.077 | 0 | 0 |
| Extending arms above shoulders (unable) | 0.109 | 0.321 | 0.748 | 0 | 0 | 0.021 | 0.100 | 0 | 0 |
| Writing or handling small objects(unable) | -0.033 | -1.057 | 0.291 | 0 | 0 | 0.003 | 0.100 | 0 | 0 |
| Lifting/carrying heavy objects (unable) | -0.421 | -1.675 | 0.094 | 0 | 1 | 0.069 | 3.175 | 0 | 1 |
| Consume alcohol | -0.030 | -0.287 | 0.774 | 0 | 0 | 0.431 | 0.082 | 0 | 0 |
| Difficulty in seeing newpaper prints (yes) | 0.327 | 1.157 | 0.247 | 0 | 0 | 0.027 | 1.225 | 0 | 0 |
| | | | | | | | | | |
| No. of Significant factors | | | | 1 | 7 | | | 1 | 9 |

**Appendix 5**
**Diagnostic Tests of Male Crash Model**
***without* Annual Miles Driven Included**

| Factor | Estimated coefficient | *Z* ratio | Prob $\{z^0 > z\}$ | Prob $\{z^0 > z\}$ Sig. at α=05 | Prob $\{z^0 > z\}$ Sig at α=0.1 | Mean | *LL* Ratio | *LL* ratio Sig. at α=05 | *LL* ratio Sig at α=0.1 |
|---|---|---|---|---|---|---|---|---|---|
| Anti-depressant | 0.434 | 1.264 | 0.206 | 0 | 0 | 0.027 | 1.409 | 0 | 0 |
| Nonsteroidal anti-inflammatory agents | -0.134 | -0.601 | 0.548 | 0 | 0 | 0.111 | 0.373 | 0 | 0 |
| Benzodiazepines | -0.188 | -0.604 | 0.546 | 0 | 0 | 0.054 | 0.385 | 0 | 0 |
| Feel depressed (yes) | 0.437 | 1.277 | 0.202 | 0 | 0 | 0.024 | 1.434 | 0 | 0 |
| - Top 2% | -1.259 | -1.255 | 0.210 | 0 | 0 | 0.013 | 2.483 | 0 | 0 |
| - Top 2-5% | 0.255 | 0.936 | 0.349 | 0 | 0 | 0.045 | 0.819 | 0 | 0 |
| - 5-10 percentile | 0.353 | 1.794 | 0.073 | 0 | 1 | 0.093 | 2.985 | 0 | 1 |
| - 10-20 percentile | 0.204 | 1.263 | 0.207 | 0 | 0 | 0.196 | 1.550 | 0 | 0 |
| Age | 0.011 | 0.802 | 0.423 | 0 | 0 | 78.320 | 0.638 | 0 | 0 |
| Employed full-time | -0.292 | -0.835 | 0.404 | 0 | 0 | 0.045 | 0.741 | 0 | 0 |
| Hospital stay | -0.170 | -0.987 | 0.323 | 0 | 0 | 0.217 | 1.009 | 0 | 0 |
| Self-perceived health (good) | -0.059 | -0.374 | 0.708 | 0 | 0 | 0.761 | 0.139 | 0 | 0 |
| Self-perceived health (poor) | -0.044 | -0.129 | 0.898 | 0 | 0 | 0.041 | 0.017 | 0 | 0 |
| Self-perceived health compared to others | 0.004 | 0.018 | 0.985 | 0 | 0 | 0.154 | 0.000 | 0 | 0 |
| Scored high on memory tests | 0.116 | 0.620 | 0.535 | 0 | 0 | 0.834 | 0.395 | 0 | 0 |
| Scored low on memory tests | -0.040 | -0.343 | 0.732 | 0 | 0 | 0.001 | 0.395 | 0 | 0 |
| Need help in walking across a small room (yes) | -0.693 | -1.669 | 0.095 | 0 | 1 | 0.052 | 3.483 | 0 | 1 |

| Factor | Estimated coefficient | *Z* ratio | Prob $\{z^0 > z\}$ | Prob $\{z^0 > z\}$ Sig. at α=05 | Prob $\{z^0 > z\}$ Sig at α=0.1 | Mean | *LL* Ratio | *LL* ratio Sig. at α=05 | *LL* ratio Sig at α=0.1 |
|---|---|---|---|---|---|---|---|---|---|
| Need help in bathing (yes) | -0.359 | -1.048 | 0.295 | 0 | 0 | 0.054 | 1.226 | 0 | 0 |
| Need help in personal grooming (yes) | -0.138 | -0.194 | 0.846 | 0 | 0 | 0.011 | 0.039 | 0 | 0 |
| Need help in dressing (yes) | 0.117 | 0.376 | 0.707 | 0 | 0 | 0.047 | 0.136 | 0 | 0 |
| Need help in eating (yes) | -0.416 | -0.415 | 0.678 | 0 | 0 | 0.008 | 0.198 | 0 | 0 |
| Need help in transferring (yes) | -0.690 | -1.184 | 0.236 | 0 | 0 | 0.026 | 1.769 | 0 | 0 |
| Need help in toileting (yes) | -0.929 | -1.305 | 0.192 | 0 | 0 | 0.022 | 2.350 | 0 | 0 |
| Need help in heavy housework (yes) | -0.232 | -1.272 | 0.203 | 0 | 0 | 0.197 | 1.693 | 0 | 0 |
| Need help in walking 1/2 mile (yes) | -0.125 | -0.676 | 0.499 | 0 | 0 | 0.178 | 0.469 | 0 | 0 |
| Need help in climbing stairs (yes) | -0.081 | -0.236 | 0.814 | 0 | 0 | 0.041 | 0.057 | 0 | 0 |
| Education (> 12 years) | -0.176 | -0.895 | 0.371 | 0 | 0 | 0.164 | 0.835 | 0 | 0 |
| Parkinson's disease (yes) | -0.256 | -0.439 | 0.661 | 0 | 0 | 0.020 | 0.209 | 0 | 0 |
| 1st episode of stroke | 0.034 | 0.167 | 0.867 | 0 | 0 | 0.124 | 0.028 | 0 | 0 |
| 2nd episode of stroke | -0.178 | -0.461 | 0.645 | 0 | 0 | 0.038 | 0.224 | 0 | 0 |
| 3rd episode of stroke | -0.702 | -0.700 | 0.484 | 0 | 0 | 0.010 | 0.624 | 0 | 0 |
| Diabetes | -0.987 | -1.389 | 0.165 | 0 | 0 | 0.022 | 2.729 | 0 | 1 |
| 1st episode of heart attack | -0.203 | -1.170 | 0.242 | 0 | 0 | 0.213 | 1.426 | 0 | 0 |
| 2nd episode of heart attack | 0.002 | 0.010 | 0.992 | 0 | 0 | 0.098 | 0.000 | 0 | 0 |

| | | | | Prob {$z^0$> z} | | | | *LL* ratio | |
|---|---|---|---|---|---|---|---|---|---|
| Factor | Estimated coefficient | *Z* ratio | Prob {$z^0$> z} | Sig. at α=05 | Sig at α=0.1 | Mean | *LL* Ratio | Sig. at α=05 | Sig at α=0.1 |
| High blood pressure (yes) | 0.089 | 0.627 | 0.531 | 0 | 0 | 0.339 | 0.390 | 0 | 0 |
| Suspect of arthritis (yes) | 0.666 | 0.663 | 0.507 | 0 | 0 | 0.003 | 0.358 | 0 | 0 |
| Income (increasing) | -0.005 | -0.345 | 0.730 | 0 | 0 | 14.110 | 0.119 | 0 | 0 |
| History of cataract | -0.045 | -0.326 | 0.744 | 0 | 0 | 0.438 | 0.107 | 0 | 0 |
| Diagnosed with arthritis | 0.175 | 0.940 | 0.347 | 0 | 0 | 0.808 | 0.917 | 0 | 0 |
| Diagnosed with osteoporosis | -0.229 | -0.551 | 0.582 | 0 | 0 | 0.034 | 0.326 | 0 | 0 |
| Surgery for cataracts (yes) | -0.151 | -0.722 | 0.470 | 0 | 0 | 0.137 | 0.540 | 0 | 0 |
| Retired (yes) | 0.076 | 0.328 | 0.743 | 0 | 0 | 0.895 | 0.109 | 0 | 0 |
| Member of club (yes) | 0.016 | 0.114 | 0.909 | 0 | 0 | 0.600 | 0.013 | 0 | 0 |
| Social support (yes) | 0.176 | 0.638 | 0.523 | 0 | 0 | 0.926 | 0.429 | 0 | 0 |
| Exercise regularly (yes) | 0.236 | 1.520 | 0.128 | 0 | 0 | 0.207 | 2.222 | 0 | 0 |
| Married (yes) | 0.278 | 0.953 | 0.341 | 0 | 0 | 0.801 | 0.918 | 0 | 0 |
| Widowed (yes) | -0.298 | -1.141 | 0.254 | 0 | 0 | 0.147 | 1.296 | 0 | 0 |
| Episode of unconsciousness (yes) | -0.799 | -1.756 | 0.079 | 0 | 1 | 0.044 | 3.999 | 1 | 1 |
| Joint pain (yes) | -0.046 | -0.328 | 0.743 | 0 | 0 | 0.572 | 0.107 | 0 | 0 |
| Stiffness (yes) | -0.218 | -1.540 | 0.124 | 0 | 0 | 0.413 | 2.410 | 0 | 0 |
| Self-perceived memory (good) | 0.336 | 1.520 | 0.129 | 0 | 0 | 0.073 | 2.117 | 0 | 0 |
| Self-perceived memory (poor) | -0.097 | -0.322 | 0.747 | 0 | 0 | 0.053 | 0.107 | 0 | 0 |
| Scored high on word-recall tests | -0.061 | -0.518 | 0.604 | 0 | 0 | 0.001 | 0.107 | 0 | 0 |

| Factor | Estimated coefficient | *Z* ratio | Prob $\{z^0 > z\}$ | Prob $\{z^0 > z\}$ Sig. at α=05 | Prob $\{z^0 > z\}$ Sig at α=0.1 | Mean | *LL* Ratio | *LL* ratio Sig. at α=05 | *LL* ratio Sig at α=0.1 |
|---|---|---|---|---|---|---|---|---|---|
| Scored low on word-recall tests | 0.293 | 1.571 | 0.116 | 0 | 0 | 0.792 | 2.629 | 0 | 0 |
| % of incorrect answers in memory tests | -0.210 | -0.289 | 0.773 | 0 | 0 | 0.038 | 0.085 | 0 | 0 |
| % of incorrect answers in word-recall tests | -0.248 | -1.324 | 0.186 | 0 | 0 | 0.249 | 1.809 | 0 | 0 |
| Pulling/pushing large objects (unable) | 0.062 | 0.171 | 0.865 | 0 | 0 | 0.031 | 0.029 | 0 | 0 |
| Stooping, crouching, or kneeling (unable) | 0.019 | 0.067 | 0.946 | 0 | 0 | 0.056 | 0.004 | 0 | 0 |
| Writing or handling small objects(unable) | -0.042 | -1.000 | 0.317 | 0 | 0 | 0.004 | 0.004 | 0 | 0 |
| Lifting/carrying heavy objects (unable) | -0.413 | -1.068 | 0.285 | 0 | 0 | 0.043 | 1.297 | 0 | 0 |
| Consume alcohol (yes) | -0.094 | -0.698 | 0.485 | 0 | 0 | 0.535 | 0.487 | 0 | 0 |
| Difficulty in seeing friend across street (yes) | -0.495 | -1.087 | 0.277 | 0 | 0 | 0.031 | 1.381 | 0 | 0 |
| Difficulty in seeing newspaper print (yes) | 0.308 | 1.062 | 0.288 | 0 | 0 | 0.039 | 1.035 | 0 | 0 |
| | | | | | | | | | |
| No. of significant factors | | | | 0 | 3 | | | 1 | 4 |

## Appendix 6.

## Diagnostic Tests of Gender-Combined Crash Model *without* Annual Miles Driven Included

| Factor | Estimated coefficient | *Z* ratio | Prob $\{z^0 > z\}$ | Prob $\{z^0 > z\}$ | | Mean | *LL* Ratio | *LL* ratio | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Sig.at α=.05 | Sig at α=0.1 | | | Sig. at α=.05 | Sig at α=0.1 |
| Anti-depressant | 0.270 | 1.162 | 0.245 | 0 | 0 | 0.041 | 1.252 | 0 | 0 |
| Anti-depressant (male only) | 0.414 | 1.208 | 0.227 | 0 | 0 | 0.012 | 1.294 | 0 | 0 |
| Nonsteroidal anti-inflammatory agents | 0.027 | 0.179 | 0.858 | 0 | 0 | 0.129 | 0.032 | 0 | 0 |
| Benzodiazepines | -0.266 | -1.176 | 0.240 | 0 | 0 | 0.069 | 1.495 | 0 | 0 |
| Feel depressed | 0.448 | 1.690 | 0.091 | 0 | 1 | 0.023 | 2.506 | 0 | 0 |
| - Top 2% | -0.771 | -1.328 | 0.184 | 0 | 0 | 0.015 | 2.301 | 0 | 0 |
| - Top 2-5% | 0.559 | 2.700 | 0.007 | 1 | 1 | 0.036 | 6.292 | 1 | 1 |
| - 5-10 percentile | 0.212 | 1.049 | 0.294 | 0 | 0 | 0.052 | 1.040 | 0 | 0 |
| - 10-20 percentile | -0.130 | -0.763 | 0.445 | 0 | 0 | 0.106 | 0.602 | 0 | 0 |
| Top 5th percentile of depression scale | 0.307 | 1.561 | 0.118 | 0 | 0 | 0.051 | 2.250 | 0 | 0 |
| Top 10th percentile of depression scale | 0.287 | 1.928 | 0.054 | 0 | 1 | 0.103 | 3.495 | 0 | 1 |
| Top 20th percentile of depression scale | 0.109 | 0.889 | 0.374 | 0 | 0 | 0.209 | 0.777 | 0 | 0 |
| Age (increasing) | 0.004 | 0.378 | 0.705 | 0 | 0 | 78.250 | 0.143 | 0 | 0 |
| Employed - part-time | 0.021 | 0.076 | 0.939 | 0 | 0 | 0.072 | 0.006 | 0 | 0 |
| Employed - full-time | -0.191 | -0.631 | 0.528 | 0 | 0 | 0.028 | 0.416 | 0 | 0 |
| Hospital stay | -0.195 | -1.420 | 0.156 | 0 | 0 | 0.190 | 2.100 | 0 | 0 |
| Self-perceived health (good) | -0.087 | -0.714 | 0.475 | 0 | 0 | 0.784 | 0.502 | 0 | 0 |
| Self-perceived health (poor) | 0.080 | 0.293 | 0.770 | 0 | 0 | 0.032 | 0.084 | 0 | 0 |
| Self-perceived health compared to others | 0.043 | 0.318 | 0.751 | 0 | 0 | 0.185 | 0.100 | 0 | 0 |

| Factor | Estimated coefficient | *Z* ratio | Prob $\{z^0 > z\}$ | Prob $\{z^0 > z\}$ Sig.at α=.05 | Sig at α=0.1 | Mean | *LL* Ratio | *LL* ratio Sig. at α=.05 | Sig at α=0.1 |
|---|---|---|---|---|---|---|---|---|---|
| Scored high on memory tests | 0.022 | 0.156 | 0.876 | 0 | 0 | 0.857 | 0.024 | 0 | 0 |
| Scored low on memory tests | -0.031 | -0.456 | 0.648 | 0 | 0 | 0.001 | 0.024 | 0 | 0 |
| Need help in walking across a small room (yes) | -0.458 | -1.492 | 0.136 | 0 | 0 | 0.042 | 2.573 | 0 | 0 |
| Need help in bathing (yes) | -0.047 | -0.198 | 0.843 | 0 | 0 | 0.050 | 0.040 | 0 | 0 |
| Need help in personal grooming (yes) | -0.664 | -0.937 | 0.349 | 0 | 0 | 0.010 | 1.105 | 0 | 0 |
| Need help in dressing (yes) | -0.059 | -0.198 | 0.843 | 0 | 0 | 0.031 | 0.040 | 0 | 0 |
| Need help in eating (yes) | -0.582 | -0.580 | 0.562 | 0 | 0 | 0.005 | 0.412 | 0 | 0 |
| Need help in transferring (yes) | -0.758 | -1.505 | 0.132 | 0 | 0 | 0.020 | 2.933 | 0 | 1 |
| Need help in toileting (yes) | -0.803 | -1.596 | 0.111 | 0 | 0 | 0.024 | 3.356 | 0 | 1 |
| Need help in heavy housework (yes) | -0.252 | -1.887 | 0.059 | 0 | 1 | 0.235 | 3.727 | 0 | 1 |
| Need help in walking 1/2 mile (yes) | -0.079 | -0.599 | 0.549 | 0 | 0 | 0.210 | 0.364 | 0 | 0 |
| Need help in climbing stairs (yes) | -0.387 | -1.259 | 0.208 | 0 | 0 | 0.040 | 1.791 | 0 | 0 |
| Education (> 12 years) | -0.044 | -0.340 | 0.734 | 0 | 0 | 0.224 | 0.116 | 0 | 0 |
| Parkinson's disease (yes) | -0.531 | -1.056 | 0.291 | 0 | 0 | 0.019 | 1.333 | 0 | 0 |
| 1st episode of stroke | -0.120 | -0.691 | 0.490 | 0 | 0 | 0.099 | 0.492 | 0 | 0 |
| 2nd episode of stroke | -0.373 | -1.097 | 0.273 | 0 | 0 | 0.030 | 1.353 | 0 | 0 |
| 3rd episode of stroke | -1.059 | -1.056 | 0.291 | 0 | 0 | 0.007 | 1.631 | 0 | 0 |
| Diabetes | -0.933 | -1.609 | 0.108 | 0 | 0 | 0.017 | 3.595 | 0 | 1 |
| 1st episode of heart attack | -0.189 | -1.253 | 0.210 | 0 | 0 | 0.140 | 1.636 | 0 | 0 |

| Factor | Estimated coefficient | *Z* ratio | Prob $\{z^0 > z\}$ | Prob $\{z^0 > z\}$ Sig.at α=.05 | Sig at α=0.1 | Mean | *LL* Ratio | *LL* ratio Sig. at α=.05 | Sig at α=0.1 |
|---|---|---|---|---|---|---|---|---|---|
| 2nd episode of heart attack | -0.004 | -0.021 | 0.983 | 0 | 0 | 0.062 | 0.000 | 0 | 0 |
| High blood pressure (yes) | 0.066 | 0.624 | 0.532 | 0 | 0 | 0.387 | 0.388 | 0 | 0 |
| Suspect of arthritis (yes) | -0.151 | -0.151 | 0.880 | 0 | 0 | 0.003 | 0.024 | 0 | 0 |
| Income (increasing) | 0.002 | 0.215 | 0.830 | 0 | 0 | 13.340 | 0.046 | 0 | 0 |
| History of cataract | -0.045 | -0.429 | 0.668 | 0 | 0 | 0.512 | 0.185 | 0 | 0 |
| arthritis (yes) | -0.012 | -0.085 | 0.932 | 0 | 0 | 0.827 | 0.007 | 0 | 0 |
| Surgery for cataracts (yes) | -0.079 | -0.525 | 0.599 | 0 | 0 | 0.146 | 0.281 | 0 | 0 |
| Retired (yes) | -0.016 | -0.122 | 0.903 | 0 | 0 | 0.667 | 0.015 | 0 | 0 |
| Member of club (yes) | -0.020 | -0.183 | 0.855 | 0 | 0 | 0.692 | 0.034 | 0 | 0 |
| Social support (yes) | 0.221 | 0.984 | 0.325 | 0 | 0 | 0.936 | 1.033 | 0 | 0 |
| Exercise regularly (yes) | 0.079 | 0.622 | 0.534 | 0 | 0 | 0.194 | 0.382 | 0 | 0 |
| Married (yes) | -0.024 | -0.118 | 0.906 | 0 | 0 | 0.560 | 0.014 | 0 | 0 |
| Widowed (yes) | 0.038 | 0.217 | 0.828 | 0 | 0 | 0.384 | 0.047 | 0 | 0 |
| Episode of unconsciousness (yes) | -0.573 | -1.781 | 0.075 | 0 | 1 | 0.042 | 3.817 | 0 | 1 |
| Joint pain (yes) | 0.005 | 0.048 | 0.961 | 0 | 0 | 0.591 | 0.002 | 0 | 0 |
| Stiffness (yes) | -0.063 | -0.598 | 0.550 | 0 | 0 | 0.449 | 0.358 | 0 | 0 |
| Self-perceived memory (good) | 0.229 | 1.333 | 0.183 | 0 | 0 | 0.078 | 1.672 | 0 | 0 |
| Self-perceived memory (poor) | -0.251 | -0.913 | 0.361 | 0 | 0 | 0.039 | 0.900 | 0 | 0 |
| Scored high on word-recall tests | -0.057 | -0.542 | 0.588 | 0 | 0 | 0.000 | 0.900 | 0 | 0 |

| Factor | Estimated coefficient | *Z* ratio | Prob $\{z^0 > z\}$ | Prob $\{z^0 > z\}$ Sig.at α=.05 | Prob $\{z^0 > z\}$ Sig at α=0.1 | Mean | *LL* Ratio | *LL* ratio Sig. at α=.05 | *LL* ratio Sig at α=0.1 |
|---|---|---|---|---|---|---|---|---|---|
| Scored low on word-recall tests | 0.094 | 0.772 | 0.440 | 0 | 0 | 0.719 | 0.605 | 0 | 0 |
| % of incorrect answers in memory tests | -0.568 | -0.931 | 0.352 | 0 | 0 | 0.035 | 0.914 | 0 | 0 |
| % of incorrect answers in word-recall tests | -0.257 | -1.767 | 0.077 | 0 | 1 | 0.242 | 3.226 | 0 | 1 |
| Pulling/pushing large objects (unable) | 0.072 | 0.318 | 0.751 | 0 | 0 | 0.056 | 0.099 | 0 | 0 |
| Stooping, crouching, or kneeling (unable) | -0.055 | -0.275 | 0.783 | 0 | 0 | 0.081 | 0.077 | 0 | 0 |
| Extending arms above shoulder (unable) | 0.109 | 0.321 | 0.748 | 0 | 0 | 0.021 | 0.100 | 0 | 0 |
| Writing or handling small objects(unable) | -0.033 | -1.057 | 0.291 | 0 | 0 | 0.003 | 0.100 | 0 | 0 |
| Lifting/carrying heavy objects (unable) | -0.421 | -1.675 | 0.094 | 0 | 1 | 0.069 | 3.175 | 0 | 1 |
| Average annual miles driven (male only) | 0.000 | 0.429 | 0.668 | 0 | 0 | -85.450 | 0.188 | 0 | 0 |
| Unable to extend arms above shoulder (female only) | 0.521 | 1.340 | 0.180 | 0 | 0 | 0.014 | 1.544 | 0 | 0 |
| Consume alcohol | -0.030 | -0.287 | 0.774 | 0 | 0 | 0.431 | 0.082 | 0 | 0 |
| Difficulty in reading newspaper prints (yes) | 0.327 | 1.157 | 0.247 | 0 | 0 | 0.027 | 1.225 | 0 | 0 |
| | | | | | | | | | |
| No. of significant factors | | | | 1 | 7 | | | 1 | 9 |