THE UTILITY OF USEFUL FIELD OF VIEW TESTING AND DRIVER PERFORMANCE MEASUREMENT IN PREDICTING DRIVER SAFETY

By

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ABSTRACT

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Statement of Purpose

The purpose of this study was to assess the utility of Useful Field of View (UFOV) testing and Driver Performance Measurement (DPM) evaluation for predicting the safety of drivers based upon their driving history, comprised of crash, violation, and offense data as well as information usually contained in individual driving records.

Procedural Methods

Individual subjects were given a battery of laboratory vision tests, a driving habits survey, a vehicle inspection, a road test utilizing DPM criteria, and a post-road test questionnaire.

The UFOV testing is comprised of four sections (Processing Speed, Divided Attention, Selective Attention, and Overall Score) yielding four scores. The DPM process also yields four scores (Direction Control, Speed Control, Search, and Overall Score). The UFOV vision testing, road test, and driving history data were analyzed for relationships between the category components. Procedures utilized in the analysis included: Analysis of Variance (ANOVA); Statistical Means and Standard Deviations; Direct Comparison; and Trend Analysis. Comparisons between younger and older subjects were done to account for age effects of the different testing processes as well as general performance differences.

I dedicate this work to my wife, Cheryl Kane, who has been my biggest supporter and to whom I owe a debt of gratitude which will be difficult to repay.

Findings

The analyses covered three areas: UFOV performance related to driving history; DPM performance related to driving history; and the utility of UFOV and DPM testing.

The UFOV performance scores related minimally to the driving history categories (i.e., UFOV was not a good predictor of crash involvement). UFOV performance was most closely related to the age of the subjects.

The DPM performance scores were not related to crash involvement but were more strongly related to driving offenses. There was also a relationship between DPM performance and the age of the subjects, with older subjects having generally lower DPM scores.

The evaluation of the utility of UFOV and DPM performance for predicting driver safety showed that while there is a relationship between the UFOV and DPM performance and offenses in the driving history, the important relationship between crash involvement and UFOV and DPM performance was not established.

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KEY TO SYMBOLS AND ABBREVIATIONS

ANOVA	Analysis of Variance.
AMD	Age-Related Macular Degeneration.
DMV	Department of Motor Vehicles.
DPM	Driver Performance Measurement.
MDOS	Michigan Department of State.
NCHRP	National Cooperative Highway Research Program.
SPSS	The Statistical Package for the Social Sciences.
TRB	Transportation Research Board.
UFOV	Useful Field of View.

INTRODUCTION

Whenever there is a traffic crash involving an older driver who has made a catastrophic error, such as running up onto a sidewalk and killing several pedestrians, the question is raised about whether or not there is a serious older driver problem. Based upon the absolute number of crashes involving drivers age sixty-five and older, this group has the smallest percentage of total collisions (Cerelli, 1989). However, this group also travels fewer miles than any other age group except teenagers (sixteen to nineteen years old). While their crash involvement rate, when based on age group population, is the lowest of any other age group, older drivers are over-represented in crashes when their crash rate is based on miles traveled (i.e., crashes per million vehicle miles of travel). In general, the crash rate based on miles traveled is relatively flat for age groups between twenty-five and sixty-five, staying near four and one-half to five crashes per 100 million vehicle miles of travel. After age sixty-five, this crash rate increases moderately up to age seventy-five (to about seven crashes per 100 million vehicle miles of travel). After age seventy-five, the crash rate increases sharply, rising to about fifteen crashes per 100 million vehicle miles of travel by age eighty, then to about thirty-eight crashes per 100 million vehicle miles of travel by age eighty-five (Cerelli, 1989). Different methods for determining the relative crash rates (i.e., based on different methods of exposure) of drivers have been developed and tested such as the "innocent victim" concept used by Maleck and Hummer (1986). Figure 1 shows the crash involvement rate for drivers across all ages using an innocent victim methodology.

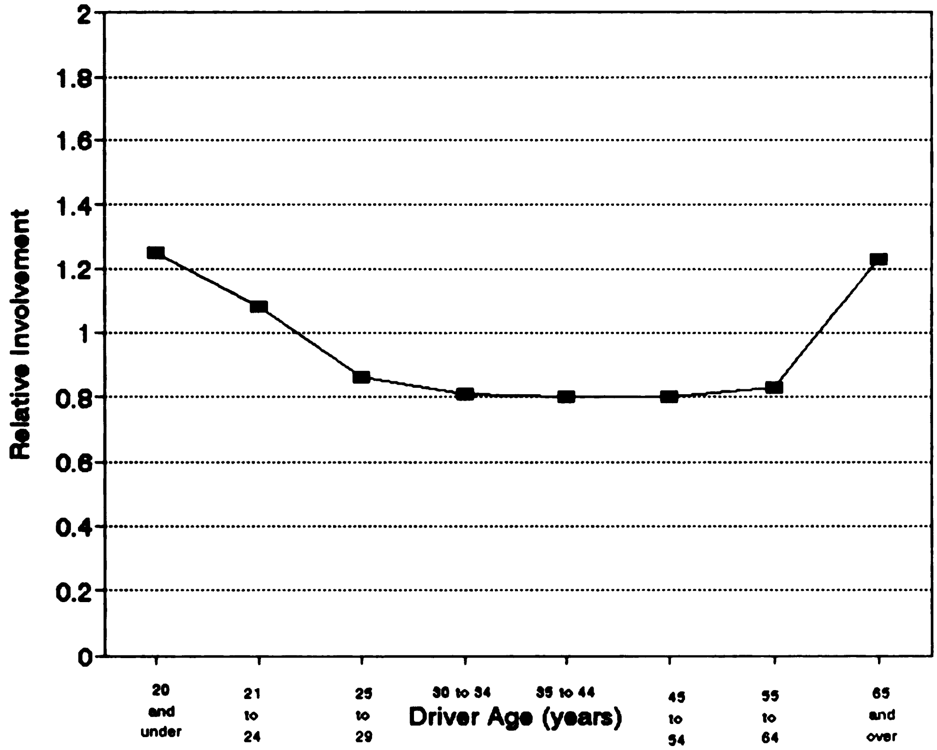

Figure 1.
Relative Crash Involvment
Source: Maleck and Hummer, Transportation Research Record 1059 (1986)

It is also interesting to note that the population of older individuals in the United States is growing faster, in both proportional and absolute terms, than any other age cohort. In 1900, only 4 percent of the population in the United States lived to be sixty-five years old or more. By 1984, this population cohort had increased to 12 percent. Census Bureau predictions indicate that by the year 2000, thirteen percent of the population will be over sixty-five, and by the year 2030, twenty percent (TRB Special Report 218, 1988).

When older drivers are involved in multiple-vehicle collisions they are more often cited as being the "at-fault" driver (i.e., the driver most responsible for the crash), when compared to younger age groups of drivers. Older drivers are more often cited for failing to yield right-of-way, illegal turns, and improper lane usage (McKelvey and Stamatiadis, 1989). Results from other older driver research efforts (e.g., Planek and Fowler, 1971; Lerner and Ratte', 1991) are quite similar to the results of McKelvey and Stamatiadis. A similar increase in the fatality rate of older drivers has also been observed (Evans, 1991).

As humans age, changes to their physical and mental capacities occur. These changes are often exhibited by decreases in the flexibility of the skeletal system; by increasing conditions or diseases in visual functions (e.g., cataracts, glaucoma); and decreased auditory ability (i.e., hearing). Mental deficits are often manifested by slower reaction (recognition) times and memory loss. There is concern that highways are becoming less safe as a higher percentage of this large, older age cohort shows more of the physiological deficits which numerous researchers have documented as appearing to relate to higher crash involvement and poorer performance on driving-related tasks (Ketron, 1989). Before a person is granted a license to operate a motor vehicle, they must first pass both a knowledge test and a driving performance test. Additionally, the applicant must also pass a vision test to ensure that they meet the baseline vision requirements of the licensing agency. Vision is necessarily one of the more important, if not the most important, physiological characteristics related to the driving task. As individuals age, vision generally degrades due to factors such as cataracts, glaucoma, astigmatism, and other eye diseases.

However, research also indicates that correlations between standard vision screening scores and crash involvement and/or violations are quite weak (Hills and Burg, 1977). Of a more positive note, recent research efforts assessing the performance of individuals on a more comprehensive visual screening examination, which includes information processing and is called useful field of view (UFOV), have shown a much stronger correlation to the driving performance history (i.e., crash involvement and driving violations) of the examined persons (Ball and Owsley, 1991). UFOV is a concept first presented by researchers in the late 1800's (James, 1890) which tried to estimate how much visual information is acquired and processed in dynamic situations (i.e., how much can be seen and how much can be reacted to in complex situations). The relationship to driving, obviously a dynamic situation, is self-evident: a person with a "poor" UFOV would acquire and process less information than a person with a "good" UFOV and, therefore, may make decisions with less than adequate information. UFOV testing may be a reliable method of assessing, in a laboratory setting, an individual's ability to safely operate a motor vehicle.

Depending on how they are evaluated, some older drivers are among the safest drivers on the road and some older drivers are among the least safe. The problem locations for older drivers as they relate to crash involvement are reasonably well known, and include, for example, intersections and freeway exit and entrance ramps. Development of a test which would help identify problem drivers before they are involved in a crash is desirable. Unfortunately, present screening tests do not reliably indicate which older drivers are more likely to be crash-involved. Early research results of UFOV testing indicate that it may be an off-the-road test procedure that will more accurately detect potential problem drivers.

Another approach to identifying problem drivers is on-road testing. However, because of the costs and logistics involved in on-road driver assessment, most of the research to date which addresses the interaction between drivers and the surrounding environment has been conducted in laboratory settings. While the laboratory offers a controlled environment with the opportunity to use video monitoring equipment as well as other physiological measurement devices, field studies conducted under actual driving conditions are needed to validate the laboratory studies and their results. One approach to undertaking such on-road studies is to use Driver Performance Measurement (DPM).

DPM is a process which involves drivers operating a standard vehicle (i.e., no special attachments or equipment), which is usually their own, on regular roads and streets. Trained observers evaluate and record the interaction of the vehicle operator with the surrounding environment (Forbes et al., 1973). DPM was developed at Michigan State University (MSU) to assess the effectiveness of high school driver education programs and has been used at MSU and other universities for evaluation of driver performance (Tarawneh et al., 1993).

Based upon the aforementioned problems and issues, the research proposed here can be generally described as an evaluation and comparison of the performance of subjects in on-road and laboratory settings. The research is separated into three basic areas:

1. Assessing the performance of subjects on the UFOV screening apparatus and comparing it to their crash and violation history;

2. Assessing the on-road performance of the subjects using DPM and comparing it with their crash and violation history;

3. Developing and assessing the relationships between DPM and UFOV performances.

Previous research efforts (Ball et al., 1993) have shown UFOV performance test to be effective in identifying subjects with a history of poor driving performance based on crash involvement. Other research efforts have shown the DPM process to be effective in the evaluation of driver performance. The research effort here is directed to identifying the relationship among UFOV performance, DPM performance, and driver history. If appropriate relationships can be shown to exist, UFOV testing may be useful in identifying potential problem drivers before they are involved in a traffic crash.

It should be noted that the research reported here was undertaken as an adjunct to a project funded by the National Cooperative Highway Research Program (NCHRP). The NCHRP project was concerned with the assessment of the effects of design and location of traffic control devices (i.e., signs, signals and markings) for older drivers. The subjects in both projects were the same.

LITERATURE REVIEW

The research conducted for this project encompassed traditional transportation engineering areas as well as some non-traditional engineering topics. The crash history of drivers (and particularly older drivers) is a subject that has been well researched and there is much information pertaining to crash involvement. Demographics were considered in this research because of the recent census trends which show the average age of the population increasing. This means there are going to be more older people and, therefore, more older drivers. The census data also indicate that the older population is not necessarily migrating to traditional retirement areas. This means that the problems of older drivers are of concern in all locations and not just in the "sun-belt." Medical factors pertaining to vision and mental processing speed are also of interest in this project--hence the interest in the UFOV testing process. Other medical information used in this project dealt primarily with the aging process and the application to operation of a motor vehicle.

CRASH INVOLVEMENT CHARACTERISTICS OF OLDER DRIVERS

As previously stated, the crash history data of drivers over the age of sixty-five can be interpreted to show that this age group of drivers is either one of the better performing groups or one of the worst performing groups (TRB Special Report 218, 1988). Based upon the number of crashes per age group, drivers over the age of sixty-five have lower numbers of actual involvements than any other age group (the twenty-five to thirty-five year old age group has the highest). However, interpreting the crash data in this way ignores the fact that the sixty-five and older age group travels fewer miles than any other age group, with the exception of the sixteen to nineteen year old age group. By using exposure information to adjust crash involvement figures, a more realistic picture of the situation for older drivers is presented (as well as for the youngest group of drivers). When adjusted for miles traveled (exposure), drivers over the age of sixty-five become the second worst group of crash-involved drivers. Figure 2 shows the differences between the number of crashes in each age group (with drivers over 75 separated from the 65 and over group) and the number of crashes adjusted for miles driven.

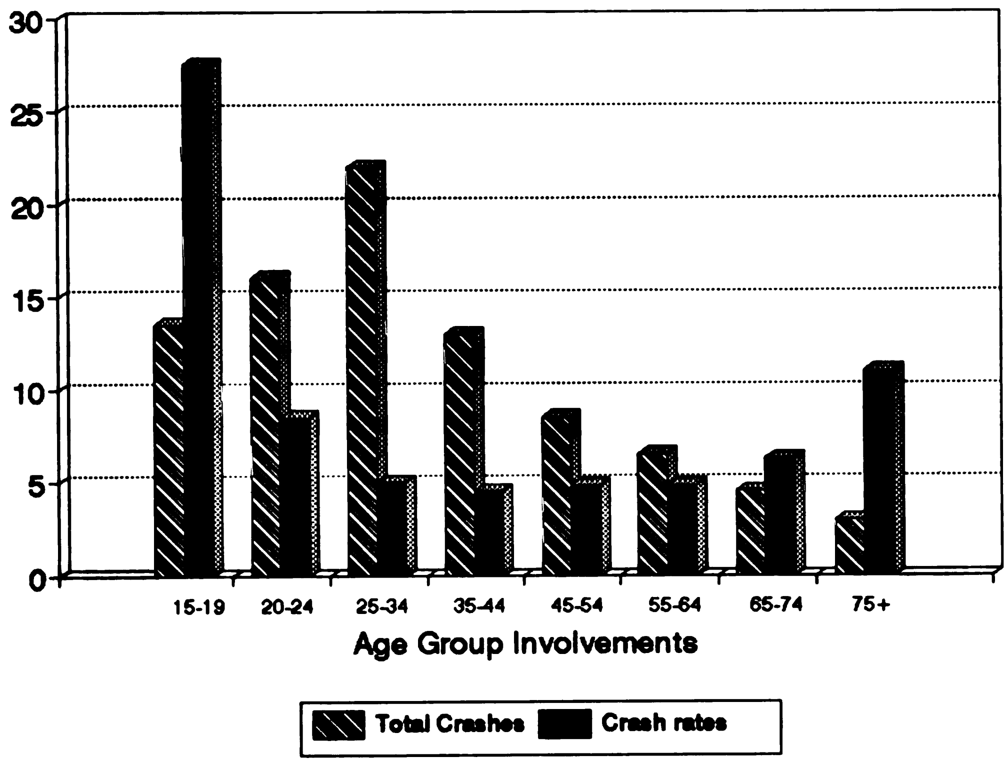

Figure 2.
Crashes and Crash Rates by Age
Source: Transportation in an Aging Society, TRB Special Report 218 (1988)

Unfortunately, the reliability of miles driven can be called into question because travel estimates are often self-reported and collected infrequently from relatively small samples. An alternative method to miles driven for calculating exposure to crash risk is "induced exposure" (Lyles et al., 1991). Briefly, induced exposure is estimated by calculating an involvement ratio, which is the number of crashes attributed to drivers in an age group divided by the number of crashes not attributed to drivers in the same age group. The argument being that exposure is proportional to the number of crashes where the age group members are not at-fault (i.e., "innocent victims"). When the ratio is greater than one, the members of that age group are at-fault in crashes more often than when the members of the age group are innocent victims. Using this methodology, drivers in the youngest (age sixteen to twenty-four) and oldest (over age sixty-five) age groups had involvement ratios greater than one (1.18 and 1.24, respectively, McKelvey et al., 1987). While the induced exposure method may be more accurate than miles driven in calculating an exposure level, this method still has the potential for bias against the youngest and oldest drivers.

If the perception exists that the youngest and oldest drivers are more accident prone, a reporting officer may be more likely to assign responsibility (at-fault driver) for crashes to drivers in these age groups. A segment of the research effort by McKelvey et al. (1987) focused on results from right-angle crashes, where responsibility is less ambiguous, to determine if such a bias against the youngest and oldest drivers existed. The results were similar to other research efforts using the induced exposure method, supporting the validity of this methodology. Using either exposure method presented, older drivers are over-involved in traffic crashes.

Older drivers are also more likely to be involved in specific types of crashes. For example, they are over-involved in crashes where geometric configurations are more complex, particularly locations such as intersections and freeway entrance and exit ramps. Other types of crashes where older drivers are over-involved are backing, parking, and in head-on collisions (Maleck and Hummer, 1986).

Older drivers are also cited more often for certain offenses when compared to other age groups of drivers. Failure to yield the right-of-way is a violation where older drivers are more often cited than other age groups (Partyka, 1983). Older drivers are also more often cited than drivers in other age groups for improper turns, improper backing, and following too closely.

Data analyses from several research efforts support the contention that older drivers do have problems operating motor vehicles in certain situations. This has led some to suggest that "problem drivers" be restricted or encouraged/required to use other modes of transport (e.g., buses, taxis). Some drivers (not just older drivers) would likely be safer if they were to utilize a different mode of transportation. Unfortunately, alternative forms of transportation are typically not available to those who need it, making the automobile the only means available to satisfy their mobility needs.

Using reasonable methods of exposure to determine crash-involvement, there is an apparent problem of over-involvement in crashes of drivers in the older age groups.

In the interest of improving highway safety, the need exists to identify those drivers in the older population that are more prone to be crash-involved before they become crash-involved. The UFOV test has shown promise as a laboratory test which can help identify potential problem drivers. The history and development of the UFOV testing is covered in greater detail in the section titled "Useful Field of View Testing" later in this report.

DEMOGRAPHICS OF THE AGING POPULATION

The Mobility Needs of Older Persons

While older persons travel less distance, they still travel as often as their younger counterparts (TRB Special Report 218, 1988). Older persons use medical services more frequently and actually make more non-work trips (e.g., social) per capita than younger persons. It is evident that older persons desire to remain mobile (and independent) as long as possible. A common misconception about older persons is how many older persons live in extended-care facilities.

Currently, only about five percent of the population over age sixty-five lives in an extended-care situation (Hess and Markson, 1991). While the older population has been growing rapidly over the past thirty years, the percentage of persons in living in extended-care situations has not changed. This is an indication that the older population will continue to live in their communities and use the services that they presently use.

The older population has been growing the fastest in suburban and rural areas, a trend that will likely continue (U.S. Census, 1980, State and Metropolitan Area Data

Book, 1991). Living in these types of environments usually necessitates the use of the private automobile as the means of transportation, since other modes of transportation, such as transit, are not always available or thought to be convenient. In order to continue using the private automobile to meet their mobility needs, older drivers may need to adjust their driving behavior to compensate for deteriorating physical capabilities, as well as their perception of their own mental capabilities, to safely operate a motor vehicle. The section of this report detailing some of the characteristics of aging will examine problems related to operation of a motor vehicle and age-related physical and mental deficits.

Environmental Factors

Aside from the documented information on the collision and violation history of older drivers, there is a school of thought pertaining to the tendency of older drivers to avoid higher stress situations such as rush hour, night, and complicated geometry (Persson, 1993). This compensating behavior is usually referred to "self-testing-off" the system (or parts of the system). This behavior is often mentioned in research efforts on the subject of older drivers. Much of the information is anecdotal in nature, coming from comments on surveys and from phone interviews. While research is being done on this issue, "self-testing" behavior is mentioned here only for clarification and reference purposes and will not be included as a part of this research effort.

Persons adjust their behavior because of the realization that they are unable or unwilling to participate in certain activities (Hess and Markson, 1991). This realization may come from the advice of their doctor or from self-awareness of difficulty in accomplishing certain tasks. Some of the awareness may be from physical indications and some may be from awareness of mental difficulties as a result of the aging process.

CHARACTERISTICS OF AGING

General Physiological and Psychological Aspects of Aging

There are obvious, and not so obvious, changes that occur to the human body as it ages (e.g., bones become more brittle, muscles start to atrophy). Aging affects the body in five general areas: the skeletal system (i.e., muscles and bones), the nervous system, vision and hearing, the gastrointestinal system, and the cardiopulmonary system. The visual, skeletal, and nervous systems are of special interest in highway safety since functions in these areas are vital to operation of a motor vehicle, as well as other complex tasks.

Aging Effects on Vision

As humans age, changes occur in the physical characteristics of the eye. These changes include light sensitivity of the eye which decreases with age caused primarily by the hardening and yellowing of the lens (Kart et al., 1992). The yellowing decreases the amount of light passing through the lens and therefore reduces the amount of light which reaches the retina of the eye, where images are formed. Also because of the yellowing of the lens, colors such as blue, green, and violet become harder to differentiate. The hardening of the lens is a factor which reduces the eye's ability to focus on near objects. The pupil of the eye also generally becomes smaller with age, losing some of its ability to dilate (Bailey and Sheedy, 1988). Dilation is, in turn, related to the ability to see at night and also to increased glare sensitivity.

Over the age of sixty-five, the occurrence of glaucoma and cataracts is approximately eight times more likely than the occurrence of glaucoma and cataracts in the general population (Sekuler and Owsley, 1982). Glaucoma manifests itself when the eye is unable to eliminate nutrient fluid which increases pressure in the eye. This pressure is transferred to the optic nerve leading to irreparable damage. Glaucoma is the second leading cause of blindness in adults in the United States (Leske, 1983). One of the early signs of glaucoma is the gradual loss of peripheral vision which is key to operating a motor vehicle, especially in complex situations.

Cataracts are the most common disability of the aged eye. Cataracts cause the lens of the eye to lose some of its transparency, reducing the amount of light the retina of the eye receives. The presence of cataracts usually is manifested by blurred or misty vision and an increased sensitivity to glare.

Although not well understood, age-related macular degeneration (AMD) is the leading cause of legal blindness among older adults in the United States. AMD is the result of damage done to the focusing area of the retina, which is manifested by a decline in central vision, making discrimination of detail difficult to impossible. AMD, with glaucoma and cataracts, represent the most common visual problems of the older population (Kart et al., 1992). The increased sensitivity to glare among the elderly population, which is a result of being afflicted by one (or more) of the aforementioned eye diseases, and its relationship to the driving task has been well documented in other research on vision problems (Wolf, 1960). Glare sensitivity during night driving is especially problematic for those afflicted. Since it takes longer for the eye to recover from exposure to bright lighting, there is a longer period in which the operator of a motor vehicle has more difficulty in seeing the roadway environment. This places the driver (and others) at a higher risk because of missed visual cues which contribute to the safe operation of the vehicle.

Aging Effects on the Nervous System (Mental Processing Speed)

The cognitive performance of individuals slows with age, particularly the speed of information processing (TRB Special Report 218, 1988). Even though research findings indicate reduced mental processing performance with age, they also indicate an increasing amount of variability in performance with age, i.e., the slowing of the cognitive performance affects people at different ages, meaning a person at age eighty-five may perform better on the same cognitive performance test than another person at age sixty-five (and the sixty-five year old may perform better than a forty-five year old).

There have been attempts to relate the mental processing ability of individuals to their ability to operate a motor vehicle. This has been primarily done with individuals who have suffered brain injuries and those suffering from forms of dementia (e.g., Alzheimer's disease). Engum et al. (1989) developed extensive testing procedures for individuals suffering from brain injuries. While these tests are extensive, they are also exhaustive and time consuming.

Since it is known that there are age-related declines in mental processing abilities, the suitability of these mental tests for use as a general screening procedure for driving ability was evaluated (Engum et al., 1989). The assessment of the suitability of these tests for general screening purposes of the driving population indicates they do not sufficiently select individuals who, in fact, can be shown to have a reduction in their cognitive processing ability. The performance of the subjects tested from a sample of the normal (i.e., not brain damaged) older population demonstrated that the differences between brain damaged individuals and normal older individuals are significant, rendering the developed screening procedures unsuitable for general testing purposes. The aging process may affect the mental processing abilities of a person differently than aging affects the physical systems of the same person.

Aging Effects on the Skeletal System

As adults age, the skeletal system suffers diminished bone and muscle mass, and joints (e.g., knees, hips, neck) also undergo change. For persons age sixty-five and older, arthritis and allied bone and muscular conditions are among the most common of all disorders (Kart et al., 1992). Arthritis generally means an inflammation of a joint, usually accompanied by pain. When an individual is suffering from a form of arthritis (there are over 100 different forms), movement of the affected joint is usually painful which may increase the amount of time required to accomplish tasks such as moving one's foot from the accelerator to the brake or turning one's head to the left or right to check for vehicles in the adjacent lane on a freeway. Afflictions such as arthritis may affect the driving performance of any individuals suffering from the disease.

Summary of Age-Related Characteristics

Logic suggests that deficits in areas such as those just mentioned (vision, mental processing speed, and the skeletal system) relate directly to the ability to operate a motor vehicle. However, simple visual acuity testing conducted by licensing bureaus is not sufficient to identify individuals with problems other than visual acuity. The time limit on written testing procedures is long enough so that processing speed should not be a factor in completing the typical written test. Cursory assessment of an individual's skeletal flexibility would likely occur only during a road test, which is typically not required by licensing bureaus. While it does not assess an individual's skeletal integrity, the UFOV test procedure does assess visual function and some mental processing function and, therefore, may be a useful method to assess an individual's ability to operate a motor vehicle.

USEFUL FIELD OF VIEW TESTING

History and Development of UFOV

Review of psychological and physiological research dating back to the 1890's indicates an interest in the relationship between vision, the visual field, and the measurement of attention (James, 1890). Most of the research conducted between the 1890's and the early 1960's dealt with defining the different aspects of attention and stimuli and establishing methods to measure the different aspects. In 1963, A. F. Sanders reviewed much of the research in this area and promulgated some definitions regarding vision and the visual field. There were three vision areas described: the stationary field, the eye field, and the head field. These are described as "functional visual fields" and defined as follows:

> Stationary field is described as the extent of the display angle where a given task (e.g., identification of an object) can be performed with peripheral vision only (i.e., no eye movement). The angle covered under this definition is approximately thirty-five (35) degrees.
>
> Eye field is described as the visual field where the peripheral activity must be supplemented by eye movements. The angle covered under this definition is approximately seventy (70) degrees.
>
> Head field is described as the visual field where the peripheral activity must be supplemented by not only eye movements but also head movements. Research results indicated that the angle covered under this definition is the area greater than seventy (70) degrees. The upper limit of the head field was not established.

The functional visual field combines aspects of the three separate fields with the mental processing of what is observed. The maneuverability of the head and eyes work together to adjust the position of the stationary field so that a person is able to acquire information from the surrounding environment (i.e., this is the physical aspect of observation). The individual must then "process" the information that is presented in the functional visual field. What is actually processed by the observer is based upon the internal prioritization of the information. Objects and/or situations that the observer does not need to utilize for the required task are ignored, or at least given a low priority. In relation to the driving task, the information that the driver requires to safely operate the vehicle will be the higher priority information. Sanders (1963) indicated that information in the stationary field (i.e., central vision area) is processed with the highest priority. The functional visual field in combination with the amount of information that can be processed from that field has been referred to as the "functional" or "useful" field of view. The "useful field of view" (UFOV) designation will be used herein.

Recent Research Involving UFOV Assessment

Recent UFOV assessment research has produced results of interest to the highway safety community (Ball et al., 1993). One of the research efforts evaluating the UFOV test used a sample of 294 subjects and indicated the UFOV screening process was effective in sorting the subjects into two groups: those who had been involved in a crash (or crashes) in the past five years; and those who had not. The score an individual received on the UFOV test (range: 0 to 90) was an indication of the percent reduction in their useful field of view. Therefore, higher scores indicate increasingly poor useful field of view. The crash-involvement information was from official records rather than self-reported. Analytical measures utilized in the development of the UFOV testing research are defined as follows:

> Sensitivity. Given that an individual has been involved in a crash, what is the likelihood (i.e., probability) that the individual has a UFOV score which indicates a visual/cognitive problem.
>
> Specificity. Given that an individual has not been involved in a crash, what is the likelihood (i.e., probability) that the individual has a UFOV score which does not indicate a visual/cognitive problem.

The researchers adjusted the pass/fail criterion for the UFOV test so as to establish a score that would place the highest number of subjects into the proper categories, related to crash involvement. This point was determined to be 40 (percent reduction). Given that a subject had been crash-involved, the probability of having a UFOV reduction of greater than 40 percent was 0.89 (sensitivity). Given that a subject had not been crash-involved, the probability of having a UFOV reduction of less than or equal to 40 percent was 0.81 (specificity). From these results, the UFOV screening process showed promise as a tool to help identify drivers who may be at a higher risk to be involved in a traffic crash. The referenced results are summarized in Table 1.

Table 1. UFOV Performance and General Crash Involvement

UFOV Category	Crash Category	
	$\geq$ 1 Crashes	0 Crashes
Reduction > 40 Sensitivity = 89%	142	25
Reduction $\leq$ 40 Specificity = 81%	18	109

Source: Investigative Ophthalmology & Visual Science, Oct. 1993

In similar research (Owsley et al., 1991) conducted with similar equipment and a different group of subjects, fifty-three people were evaluated with the UFOV screening protocol. Twenty-seven passed the UFOV screening (score $\leq$ 40) while twenty-six failed (score > 40). The subjects were categorized according to their involvement in crashes at intersections. In relation to <u>intersection</u> crashes, the subjects who failed the UFOV screening were responsible for all but one of the crashes attributable to this group. The results of this research effort are summarized in Table 2. It should be noted that one person was eliminated from the analysis due to a severe glare disability.

Table 2. UFOV Performance and Intersection Crash Involvement

UFOV Category	Crash Category	
	≥ 1 Crashes	0 Crashes
Reduction > 40 Sensitivity = 92%	11	14
Reduction ≤ 40 Specificity = 65%	1	26

Source: Visual Perceptual/Cognitive Correlates of Vehicle Accidents in Older Drivers, paper submitted to Transportation Research Board 70th Annual Meeting, Jan. 1991

In this research, the individuals who failed the UFOV screening were 15.6 times more likely to have been involved in an intersection crash (Owsley et al., 1991) than those who passed. This is all the more interesting since intersections have been identified by highway safety researchers as locations which require heightened driver attention because more information needs to be processed by a vehicle operator, when compared to non-intersection locations (Planek and Fowler, 1971). Crash statistics also indicate over-involvement in intersection accidents by drivers from the older (≥ 65) age groups (Lerner and Sedney, 1988). The older age cohorts also have a higher percentage of individuals with vision problems and/or mental processing deficits than younger age cohorts, which likely contributes to the over-involvement in crashes of drivers from the older groups.

It should be noted that the subject selection process for the earlier evaluations of the UFOV test (Owsley et al., 1991, Ball et al., 1993) was conducted to ensure that crash-involved persons from several categories were included. The construction of the sample for the earlier UFOV evaluation was not intended to produce a representative random sample of the driving population. The construction of the sample for the earlier UFOV work is explained in greater detail later in this report in the section covering the sampling process.

There presently is a research project underway in California being conducted by the California Department of Motor Vehicles (DMV) to collect a large sample of drivers and assess their performance on the UFOV test. The subjects are selected at random from persons renewing their driving license at one of three locations. Participation in the project is voluntary. Preliminary results indicate that the UFOV testing is <u>not</u> sensitive for younger subjects (i.e., under age 55). The UFOV test does appear to identify some subjects from older age groups (over age 70) who have been crash-involved (Hennessy, 1995).

The UFOV screening protocol is designed to evaluate increasing informational processing requirements, similar to what is required of drivers at intersections or other situations with high information loads. While relating UFOV performance to driving history is one way to validate the usefulness of the testing process, identifying individuals who show behaviors which are characteristic of crash involvement <u>before</u> they are involved in a crash would be even more desirable. Evaluation of an individual's on-road driving performance at the same time they are evaluated with the UFOV test may provide an indication of the suitability of the UFOV test to identify potential "problem drivers."

Associated Use of UFOV Testing

The UFOV test has been used as part of a process to evaluate the suitability of persons recovering from medical conditions (e.g., stroke victims) to operate a motor vehicle (Engum et al., 1989). For these types of evaluations, the UFOV test appears to be a valuable tool. Because the UFOV test does identify vision and/or mental processing speed deficits, its use appears to have value as part of a secondary testing process to evaluate the suitability of persons to operate a motor vehicle. On-road testing is, likewise, useful in this regard.

DRIVER PERFORMANCE MEASUREMENT

Development of Driver Performance Measurement (DPM)

The specific objective of DPM research was to develop a reliable method of evaluating driver performance to be used in place of accident records. It was developed as a method for "observing dynamic driver behavior patterns" (Nolan et al., 1973). The methodology for DPM was developed with input from experts from various disciplines including:

1. driver education,
2. driver licensing,
3. traffic engineering,
4. traffic enforcement,
5. driver behavior,
6. applied experimental psychology, and
7. statistics.

The research team reviewed literature from their areas of expertise as it related to driver performance measurement and reached the conclusion that there was a recurring need expressed for a real-life research index of driving performance which can be substituted for an individual driver's crash and violation records.

The primary problems with the use of crash records were (and are) the need to use several years (usually three to five) of crash data to acquire some stability in the driving performance history of individuals. Even with the stability of several years of crash records, seventy to eighty percent of crashes that occur in a subsequent three to five year period happen to previously crash-free drivers. It was determined that a measure of hazardous driving behavior patterns should be developed.

The procedure for evaluating driver behavior was developed based on three primary factors:

1. The suitability of the total driving behavior pattern as related to non-interference with other traffic and avoiding potential hazards including: speed control, direction control, and suitable visual search behavior.

2. The relative timing of the behavior components of the driving behavior pattern related to the traffic situation and avoiding potential hazards.

3. Certain psychological functions judged from the observed occurrence and relationships of behaviors in the driving process. Some examples are: searching patterns, vehicle control exhibiting judgments of relationships to other vehicles, speeds of other vehicles, alertness to potential hazards, and awareness of hazards.

By utilizing the three primary factors, observation of traffic and drivers at a specific location will yield a "checklist" of hazards at the location and behavior of drivers necessary to identify and compensate for the hazards. The hazards may be fixed (e.g., structures, blind driveways) or potential (e.g., other traffic, pedestrians). The behaviors are the observable actions necessary to negotiate the location safely while perceiving the conditions of traffic and the rest of the environment in and around the vehicle. Once the necessary driver behaviors are observed and hazards are identified, personnel can be trained to observe individual drivers as they traverse the specific location and to rate their performance.

The original DPM procedure was evaluated in four separate studies (Forbes, 1973). The drivers were evaluated by <u>two</u> in-vehicle observers so that the performance of the <u>observers</u> could be analyzed for agreement and consistency. The reliability coefficients between the two independent observers ranged from the middle 0.80's to the high 0.90's (1.00 indicating perfect agreement). It was concluded by the research team that DPM is an effective method for evaluating driver behavior and, when used properly, for small group research using careful experimental design and thoroughly trained observers.

Application of DPM to the Proposed Research

As previously mentioned, use of crash records to analyze driver behavior only gives an indication of what has already happened to a driver, and is not necessarily a good predictor of how a particular driver will behave in the future. DPM is a method of assessing a driver's performance in real time, not based upon the individual's driving history. This allows for an assessment of an individual's present driving behavior characteristics, which a review of crash records cannot accomplish. Potential problem behaviors, which have been identified as indicators of increased propensity for driving errors which could lead to a crash, can be noted and appropriate corrective actions can be taken. However, it also seems likely that good or bad DPM performance should be correlated with crash and violation history.

Although DPM will be used to assess the current driving behavior of the subjects, the relationship between DPM performance and driving history will also be analyzed, which has not been done before. This will be a valuable exercise because it relates DPM to a "traditional" method of evaluating driver characteristics.

LITERATURE REVIEW SUMMARY

Medical science has shown that many of the functions of the human body deteriorate with age. Reflexes slow down, the range of motion of joints decreases, and hearing and vision degrades to name a few body functions that are affected as we age. Medical science also has shown the aging process affects everyone differently. This means that there is not any specific chronological age where the different body functions deteriorate past some threshold value (e.g., night visual acuity drops below 20/50). This also means there is a great deal of variation in the functional capabilities of the older population.

There has been much research pertaining to crashes and older drivers, and the types of driving problems that are characteristic of older drivers are well documented. There is also a great deal of variability in some of the measures pertaining to crash involvement of the older population. While vision and mental processing speed are two apparently important aspects involved in the safe operation of a motor vehicle, the vision screening procedure employed by most states is, unfortunately, not effective in identifying those drivers with a higher propensity to be involved in a crash. The knowledge test administered by most states does not provide a measure of processing speed or the reaction speed of an individual.

Because UFOV can be used to test vision and mental processing speed, it offers hope of a practical process which can identify potential poor drivers before they are involved in a crash. The UFOV procedure is relatively simple to administer and involves a minimal amount of preparation time for the person being tested. The process could identify potentially poor drivers of all ages--not just older drivers.

The DPM evaluation recognizes both good and bad driving behaviors. The process can be designed to be flexible enough so that the driver can be evaluated for similar static situations. The ability to make multiple observations of similar situations will allow the observer the opportunity to conduct a thorough evaluation.

While DPM is used to evaluate the present performance of drivers, UFOV is used to test their present vision and processing speed status. The two testing procedures should be related to one another.

RESEARCH HYPOTHESES

The proposed research will involve the evaluation of the relationships between driving history, UFOV performance, and DPM performance. Previous research efforts have indicated that UFOV performance is related to crash involvement. This research effort will also be directed to the assessment of the relationship between DPM performance and driving histories (including crash involvement). This will be done to ascertain what patterns, if any, exist based upon driving histories and present driving behaviors. Additionally, this research effort will assess the relationship between UFOV and DPM performance, two measures which are conducted in real time. Even though DPM testing has shown that it can identify poor driving behaviors, it is still very time consuming and expensive for use as a screening device for vehicle operators. UFOV is a much quicker procedure. The relationship between UFOV and DPM performance will be analyzed to evaluate whether UFOV testing can be used in lieu of DPM testing for identifying potential problem drivers. The research effort will involve three major undertakings:

1. Analysis of the relationship between UFOV performance and driving history of the subjects. This step is a method of validation for the UFOV procedure for use in identifying drivers who are likely to be crash-involved. It also serves to extend earlier work since the sampling used here is more technically sound.

2. Analysis of the relationship between DPM performance and driving history of the subjects. This step is to identify the relationship of present driving performance with the past driving performance of the subjects. DPM has not been previously validated in this way.

3. Analysis of the relationship between UFOV performance and DPM performance. This step is to assess the suitability of UFOV testing to identify potential problem drivers in lieu of on-road testing. The relationships between these two potential screening mechanisms have not previously been addressed.

The evaluation of UFOV performance and driving history should produce results with <u>indications</u> similar to the previous UFOV testing assessment (Ball et al. 1993). Because of the differences in the composition of the samples between the work reported here and the previous UFOV research efforts, the strength of the relationship between UFOV and driving history reported here will likely not be as strong as the relationship reported in the previous work. However, a positively correlated, statistically significant relationship is expected to be found.

The analysis of the DPM performance compared to driving history should produce results which can identify those subjects with a driving history with indications of poor performance. The DPM performance scores should be most strongly correlated with the subjects whose driving record contains citations or crashes which indicate some form of vehicle control error.

The process of evaluating the relationship between UFOV and DPM performance will produce an indication of the suitability of UFOV testing as a means of predicting driver performance as it relates to the ability to acquire and process (i.e., react to) information. Should UFOV testing prove to be reliable in assessing driver behavior, it could be utilized as a screening procedure by licensing agencies for persons wishing to acquire or renew their driving privileges.

RESEARCH METHODOLOGY

To facilitate the analysis of the previously defined relationships, the data from each area (UFOV, DPM, driving history) need to be described. The methods used to compare the data also need to be defined.

ASSESSMENT OF DRIVER HISTORIES

The subjects for this research were selected using a stratified sampling technique from licensed drivers living in the greater Lansing (Michigan) metropolitan area of Ingham, Eaton, and Clinton Counties. An analysis of the driving population of the metropolitan area compared to the state-wide driving population was conducted and the results indicated the characteristics of drivers in the three-county area are similar to the characteristics of the state-wide driving population. The breakdown of the sample characteristics is described in greater detail in the **sampling techniques** section.

The driver history records were obtained from the Michigan Department of State (MDOS) and were analyzed for offense and violation types as well as crash involvement. The offense data were used to place the subjects into three categories: **no offenses, vehicle control offenses,** and **speed offenses**. In the MDOS data, violation data are associated only with crash involvement (i.e., only the subjects with a crash on their driving record have an entry in the violation category). The violation data were used to separate the subjects into three categories related to crash involvement: **no crash, not-at-fault crash,** and **at-fault crash**. To clarify the difference between offenses and violations, an example is offered: a person who has received a speeding ticket will have an entry in an **offense** category in their driving record and no entry in a violation category.

The procedure for placing subjects into the three <u>offense</u> categories involved determining which offenses constituted a vehicle control offense and which offenses constituted a speed offense. The offenses which were categorized as vehicle control offenses were determined by analyzing the MDOS classifications and include:

1. reckless driving,
2. careless driving,
3. disobeyed traffic control device,
4. failed to yield,
5. followed too closely,
6. improper turn,
7. wrong way on one way street,
8. improper lane use,
9. drove left of center,
10. disobeyed traffic signal,
11. disobeyed stop sign,
12. improper passing.

The MDOS files were analyzed for the types of classifications which could reasonably be described as speed offenses and they include:

1. drag racing,
2. speeding,
3. violation of the energy speed.

As a result of this categorization, the subjects were divided between the three classifications as follows: 166 subjects had no offenses, 33 subjects had vehicle control offenses, and 46 had speed offenses.

A similar method was utilized to place the subjects into the three crash categories. The first category, **no-crash**, is self-evident. A subject was categorized **at-fault** if there was a crash recorded in their driving record and there was an associated violation recorded which indicated that the subject was cited for one of the following violations:

1. speed too fast,
2. failed to yield right-of-way,
3. disregard of traffic control,
4. drove wrong way,
5. drove left of center,
6. improper turn,
7. improper backing,
8. following too closely,
9. unable to stop in assured clear distance ahead,
10. failed to use due care and caution,
11. other hazardous action.

If the subject had a crash on their driving record but did not have an associated violation (code not equal to 1-11) for the crash, they were categorized as **not-at-fault**.

The number of subjects in each of the crash categories is as follows: 164 subjects had no crashes, 39 subjects are not-at-fault crash involved, and 42 subjects are at-fault crash involved.

The data were used to assess the relationship between driving history and UFOV performance as well as the relationship between driving history and DPM performance. The Statistical Package for the Social Sciences (SPSS) was used for the statistical analysis of the driving history data.

UFOV TESTING

The procedure for analyzing UFOV using the Model 2000 Visual Attention Analyzer was developed using the documentation provided by the manufacturer of the UFOV analyzer, Visual Resources, Inc. The subject being tested sat in front of a video screen and placed their chin and forehead on a frame. The position of the frame is designed to provide an approximate seventy degree field of vision with the screen.

The screen is touch sensitive so the subject responded by touching the appropriate section of the screen. The seventy degree field of view is in agreement with the earlier functional field of view research conducted by Sanders (1963). The subject was presented a series of displays on the screen of varying duration and complexity. The duration of each display ranged from a minimum of 40 milliseconds to a maximum of 240 milliseconds. The complexity of the display progressed from a simple display in the center of the screen of either a car or a truck (**UFOV- Processing Speed**) to a more complex display which added a second vehicle at various distances from the center display (**UFOV-Divided Attention**), to the most complex display which added distracting images (inverted triangles) in concentric circles around the center of the screen in which the second vehicle was imbedded (**UFOV-Selective Attention**). The task of the subject was to identify the type of vehicle in the center of the screen and the location of the second vehicle as it related to the center of the screen. Each subject received four scores from the UFOV test which are as follows (with range of possible scores which is the percent reduction of the useful field of view--that is, higher scores are "worse"):

1. UFOV-Processing Speed (0-30),
2. UFOV-Divided Attention (0-30),
3. UFOV-Selective Attention (5-30),
4. UFOV-Overall score (5-90) which is the summation of the three component scores.

The reason for the score of 5 being the best possible score has to do with the testing time involved and the model of the software for the UFOV test. The procedure selected did not strenuously test and retest subjects at the minimum display duration and at the maximum complexity, although the subjects were tested in this area. This testing procedure was selected with the recommendation of the manufacturer and input from Dr. Karlene Ball, one of the developers of the UFOV test. The purpose of the UFOV test in this research effort was to identify the subjects with "failing" UFOV scores, which have previously been defined as scores greater than 40. To test subjects more strenuously at the minimum display duration and maximum complexity would not add to the discrimination of the test (i.e., only those subjects with scores of 5 could improve their score with the more rigorous testing protocol), and it would take more time.

When a subject arrived for the testing, time was taken to inspect the subject's vehicle. Once inside the lab, the subject completed an entry questionnaire and four separate vision tests (including UFOV). After the laboratory procedures, a two and one-half to three hour road test was followed with an exit interview. It was obvious that time savings were needed and using a shorter version of the UFOV test did not have a negative impact on the results. Of the 245 subjects in this study, eighteen received a score of 5. Whether any of these eighteen would have scored a 0 on the test is not important to the research effort since a score of 0 or 5 would place an individual in the same (good) performance category.

Analysis of the UFOV performance of the subjects included using the pass/fail criterion used in the previous UFOV research efforts as well as adjusting the pass/fail criterion to maximize the performance of the UFOV test with the sample of subjects from this research. The UFOV performance was analyzed with the offense and crash related subjects using population frequencies (i.e., how many subjects in different categories) and T-test probabilities.

DPM TESTING

The driving route was established to meet the requirements for assessing different traffic control device treatments (e.g., signs) for the NCHRP project. Forty-one different evaluation sequences were selected for suitability for the traffic control device evaluation and analyzed using the procedures established in previous DPM research efforts (Forbes et al., 1973). The in-vehicle observers were trained by Fred Vanosdall, who helped to develop the procedures in the original DPM research efforts at MSU (Nolan et al., 1973).

While there are forty-one separate evaluation sequences, there are nine different categories of traffic control devices tested. This was a part of the designed redundancy involved in the general testing of the NCHRP sign treatments. Because of the number of sites and the redundancy of site types, evaluation of driving performance can be done using several stratifications including: entire route, urban section, rural section, and site type.

The data collected at each sequence for each subject were placed into the established DPM categories of Search, Speed Control, Direction Control, and Overall Performance. The data were then transferred to a database using the "Data Entry" procedure available as part of SPSS. Each subject's performance could then be analyzed in a myriad of stratifications to ascertain what patterns and relationships existed within the data.

The relationships between DPM performance and driving history (crashes and offenses) were also analyzed. This was done to try to establish a methodology similar to the one used to assess UFOV performance and driving history. This process would help in the comparative analysis of DPM and UFOV performance.

UFOV PERFORMANCE AND DPM PERFORMANCE

Once the UFOV and DPM data were analyzed as they relate to driving histories, the analysis of the relationship between UFOV and DPM performance was conducted. The reason for this analysis was to establish the strength of the relationship between UFOV and DPM performance and assess whether UFOV testing is a suitable laboratory procedure for use in driver license screening. The DPM-Overall Performance of the subjects was compared with the component UFOV scores, including the UFOV-Overall score. The comparison of the UFOV and DPM scores were stratified by crash-involvement, offense types, age groups, and by DPM site type.

The relationships were evaluated for trends and correlations using the SPSS statistical software package and included analysis of variance (ANOVA), population distributions, T-tests, and discriminant analysis. The discriminant analysis is especially useful because the data are in different forms. Some of the data are continuous, such as DPM and UFOV scores. Other data are essentially dichotomous (i.e., yes/no). Discriminant analysis is the process utilized to construct models similar to linear regression by facilitating the combination of these different types of data.

SUMMARY

Data were collected about each subjects's driving history, their UFOV test performance, and their driving performance using the DPM criteria. Data analyses were conducted to reproduce previous procedures and to establish relationships to generally accepted categories of driving performance (e.g., crash history). The collected data were analyzed for general relationships in the following ways:

1. driving histories and performance on the UFOV test,
2. driving histories and performance on the DPM road test, and
3. UFOV performance and DPM performance.

SAMPLING TECHNIQUES

The pool of potential subjects was drawn from the Michigan Department of State files of licensed drivers in the three-county, greater Lansing, MI metropolitan area (Ingham, Clinton, and Eaton counties). The sample was not purely random. The design of the NCHRP research project required that two-thirds of the subjects come from the sixty-five years old and older group and one-third from twenty to fifty-five years old age group. The reason for the ten-year gap between subject groups is to provide for a distinct separation based upon the reported studies showing an increase in the crash-involvement rate starting around age fifty-five (Persson, 1993) and some other studies which show the crash-involvement rate increasing starting at about age sixty-five (Planek and Fowler, 1971). The age gap eliminates potential subjects from the "gray" area between age fifty-five and sixty-five. However, the initial identification of potential subjects within the age groups was purely random. Some of the driving characteristics of the sample and characteristics of the actual subjects who agreed to participate in the research effort are summarized in Table 3. With the exception of the male/female distribution in the Young and Older categories, the distribution of subjects is within acceptable tolerances.

Because the male/female distributions are just outside of the acceptable ranges, characteristics of the male and female subjects in both the **young** and **older** categories were examined to see if gender made a difference in the other three categories (offenses, crashes, violations). For **violations**, gender did not make a difference (i.e., the male and female subjects were the same) in both the younger and older categories.

For **offenses**, gender did not make a difference for the younger group. However, the older female subjects were less likely to have an offense on their record, albeit just barely (Chi-square significance 0.048 versus 0.050). For **crash** involvement, gender was not a factor for the younger subjects. However, the older female subjects were less likely to be crash-involved than the general population. These test results are shown in appendix A.

Table 3. General Driver Characteristics

	Sample (N=4029)	Subjects (N=245)	Young (N=75)	Older (N=170)
Female/ Male	52.2% 47.8%	48.6% 51.4%	65.3% 34.7%	41.2% 58.8%
Offenses	35.6%	32.2%	40.0%	28.8%
Crashes	32.4%	33.1%	38.7%	30.6%
Violations	16.2%	12.7%	14.7%	11.8%

Tested for Chi-square goodness of fit (0.05).
All categories within the <u>Subjects</u> heading are within the acceptable range of values established from the whole sample.
The male/female distribution in both the <u>Young</u> and <u>Older</u> category are outside the acceptable range of values.

There are no significant differences in the younger subjects in regard to gender in their driving history and UFOV performances. While the driving history of the older subjects show differences in relation to gender, when the entire older group of subjects is analyzed with their driving history characteristics, they are statistically the same as the general population. Without regard to gender, the UFOV performance scores of the older subjects are statistically the same. Because males of all age groups have higher crash-involvement rates (or conversely, females have lower crash-involvement rates), this situation is not believed to be an aberration in the data. Therefore, the older group will be analyzed without regard to gender.

As previously stated, violations recorded in a driving record are related directly to crash-involvement. Examples of violations include: failed to yield right-of-way, improper turn, and failed to use due care and caution. Subjects who have a recorded crash on their driving record from the past five years are categorized as crash-involved.

Offenses recorded in the driving record are not directly related to crash-involvement. Examples of offenses include: improper lane use, disobeyed traffic signal, and reckless driving.

As previously stated, the distribution of subjects in the two age groups was designed to be 33% from the twenty to fifty-five years old age group and 67% from the sixty-five years old and older age group. The actual distribution of individuals used for the data analysis in this research effort is 30.6% (75/245) from the younger group and 69.4% (170/245) from the older group. The actual distribution is reasonably close to the desired distribution of 33% younger and 67% older. The reasonableness of the distribution was confirmed with Pearson's chi-squared test for goodness of fit with a computed chi-square value of 0.89 as compared to the tabular value of 3.84 for the 0.05 significance level, which indicates that the distribution of 30.6 percent younger subjects and 69.4 percent older subjects is within the range allowable using the 95 percent confidence interval (Bhattacharyya and Johnson, 1977).

The subjects in the younger group have a higher involvement rate of crashes, violations, and offenses, based upon incidents per population. The data from the MDOS files are not adjusted for exposure (e.g., miles traveled), so this situation is not unexpected. The characteristics of the subjects who participated in the project compared to the state-wide and Lansing area population characteristics (Zhou, 1994) are summarized in Table 4.

Table 4. Comparison of Crash-Involved Driver Characteristics from State-wide, Lansing Area, and Participating Drivers

Categories	State-wide	Lansing Area	Participants
Gender (M/F)	48.6%/51.4%	52.3%/47.7%	51.4%/48.6%
Crash Rates Younger (20-55)	34.8% (accident involved in last 5 years, all ages)	32.4% (accident involved in last 5 years, all ages)	38.7% (5-years)
Crash Rates Older (65-98)			31.2% (5-years)
Violations	37.2%	34.8%	35.5%

The distributions of the data were tested to confirm that the subjects were representative of the population from which the sample was drawn. Using the 0.05 level of significance, the sample was analyzed using the Chi-square goodness-of-fit procedure. All of the subject data were determined to be within the acceptable error limits.

Based upon studies of crash involvement, the occurrences of accidents for persons in the twenty to fifty-five year old age group is relatively consistent and stable. Also, this group is the most mobile in terms of miles travelled per year, and is below average in crash involvement when adjusted for miles traveled (McKelvey and Stamatiadis, 1989).

It was expected that the actual participants would be "better" drivers than would be expected from a purely random sample. This was due, in part, to the presumed reluctance to participate in the project by drivers who perceive their driving skills to be deteriorating (i.e., poor drivers). Even though potential subjects were told at every step of the process that participation in the project would have no affect on their driving privileges, persons who believe that they might be in danger of having their driving restricted would likely decline to participate. However, based upon the previously discussed characteristics of the subjects, the sample appears to be reasonably representative of the general driving population in the three-county sampling area.

Recruiting Subjects for Participation

The potential subjects were first contacted by letter which solicited their involvement in the research project. Seven to fourteen days after the letters were sent, the potential subjects were contacted by telephone. This process had four possible outcomes:

1. no contact made (e.g., letter returned, no answer to repeated phone calls);
2. contact made, subject declines to participate at all;
3. contact made, subject declines to participate, answers driver habits survey; and
4. contact made, subject agrees to participate.

The overall response rate with respect to all initial contact letters sent (subjects who participated divided by the total number of subjects) was approximately seven percent. The next step for the scheduled subjects was to keep their appointment and go through the testing procedure. Once they arrived at the designated parking area, they were met by the assigned observers, their vehicle was inspected, and they were escorted to the testing area inside the building. There, a person trained in the laboratory procedures provided the subject with a release form to sign, a brief information survey, and conducted the four vision screening tests. The vision tests included the MDOS static acuity test (20/40 pass/fail threshold), two contrast sensitivity tests (Pelli-Robson and Ginsberg), and the UFOV test. The in-vehicle observers did not participate in any part of the vision screening process. This was done to prevent the observers from knowing the performance of the subjects in the laboratory testing and possibly forming an opinion about the subject's abilities.

At the conclusion of the laboratory testing, the subjects were escorted back to their vehicle and the in-vehicle observers directed the subject through the driving portion of the experiment. The in-vehicle performance of the subjects was evaluated by the two observers riding with the subject on a route through areas of East Lansing, Lansing, and rural Ingham County, Michigan. The route was approximately seventy-two miles in length and took from two to three hours to complete. Subjects were allowed to terminate the driving test at any time for any reason, if they so desired. At the conclusion of the driving test, the subject was given a survey about their driving habits in general and specific questions about the driving test just completed. The subject was then thanked for their participation, given twenty-five dollars for their time, and sent on their way. This was the process used to collect the data on all of the subjects.

Subject Selection In Previous UFOV Research Efforts

As a point of comparison, the subjects used in previous UFOV research efforts (Owsley, 1991, Ball et al., 1993) were identified and selected differently. The sample for the Ball et al. (1993) work was generated by first defining a three by seven (21 cell) matrix. There were seven age groups (55-59, 60-64, 65-69, 70-74, 75-79, 80-84, and 85 and older) and three crash frequency groups (0, 1-3, and 4 or more). The desired population of each cell was determined and, using state (Alabama) public safety crash data, the cells were filled with subjects who met the desired characteristics. Potential subjects were recruited until the cells were populated at the desired level. The final sample had 294 subjects, 33% were crash free (or 67% were crash-involved) in the previous five years, 49% had been involved in one to three crashes, and 18% had been involved in four or more crashes in the previous five years.

Compared to the sample for this research, there are roughly twice as many crash-involved subjects (67% versus 31.1%), and many more multiple crash-involved subjects (53 versus 1 in the four or more crashes category) in the Owsley and Ball research effort. Because the previous UFOV research efforts used samples which were designed to be populated with crash-involved subjects (i.e., known problem drivers) and the sample in this research is much more representative of the driving population, it was expected that the results here would not be as striking as in the previous UFOV test research efforts.

ANALYSIS OF DRIVER HISTORIES AND USEFUL FIELD OF VIEW PERFORMANCE

RESULTS FROM PREVIOUS UFOV RESEARCH EFFORTS

The analyses of the data involved examining the information to determine what, if any, relationships exist between UFOV performance and driving histories. Previous research efforts by Ball et al. (1993) have produced results showing a reliable relationship between UFOV performance and crash involvement. The results from two efforts by Ball et al. (1993, 1995) resulted in sensitivity scores of 0.89 and 0.94, and specificity scores of 0.81 and 0.64, respectively. To reiterate, sensitivity is defined as the probability of a UFOV score greater than 40 for crash-involved subjects; and specificity is defined as the probability of a subject being crash-free if their UFOV score is less than 40. It should be noted again that the individuals reported on in the earlier (1993) work were not drawn from a random sample. Indeed, the crash-involved individuals were purposely over-represented (Ball et al., 1993). This was done as part of the verification process of the UFOV testing in which known problem drivers are tested, and the accuracy of the UFOV test to identify the problem drivers (by failing the UFOV test) is evaluated.

Evaluation of the UFOV test is also being conducted by the California Department of Motor Vehicles on a large sample of drivers (Hennessy, 1995). Persons renewing their license at one of three locations are asked to volunteer to take the UFOV test. Their results are then compared to their driving history. Preliminary results indicate that the UFOV test is not sensitive for younger drivers (i.e., under 55). The preliminary results also show increased sensitivity with increasing age above age fifty-five.

ANALYSIS OF SUBJECTS IN THIS RESEARCH EFFORT

Crash-Involved Relationship

The crash-involved individuals in the sample from the NCHRP project used for this analysis comprise 33.1% of all the subjects. Some of the subjects had been involved in more than one crash in the last five years (30/245) but the majority of crash-involved individuals have been in only one crash (51/245). Using the criterion utilized by Ball and Owsley (1991) of a UFOV pass/fail point of 40, the UFOV testing resulted in a sensitivity score of 0.11 (of 81 crash-involved subjects, 9 had UFOV score > 40) and a specificity score of 0.89 (146 out of 164 possible). These results indicate that there are significant differences from the results of Ball et al. Additionally, given that approximately 33% of the subjects have been crash-involved, a random sampling of the 81 crash-involved subjects of the NCHRP project should "capture" 27 persons who have been crash-involved, three times as many as the UFOV testing. The results of the two previously mentioned UFOV studies, these from the MSU effort, and sensitivity and specificity using random selection are summarized in Table 5.

Table 5. Results From UFOV Research Efforts

Study Cited	Sensitivity	Specificity
Ball/Owsley (1993)	0.89 (142/160)	0.81 (109/134)
Ball (1995)	0.94 (n/a)	0.64 (n/a)
Michigan State (1994)	0.11 (9/81)	0.89 (146/164)
Random Sampling (MSU)	0.33 (27/81)	0.67 (110/164)

Additional stratification of the subjects was done to ascertain if the sensitivity would improve with the identification of those individuals deemed to be at-fault when involved in a crash. The determination of at-fault status was accomplished by evaluation of the type of violation directly associated with a crash-involved subject, which was defined in the **research methodology** section of this report. From this stratification, the UFOV testing resulted in a sensitivity score of 0.14 (6 out of 42 possible) for the at-fault subjects (approximately 17% of the subjects); a sensitivity score of 0.08 (3 out of 39 possible) for the not-at-fault subjects; and no change for the specificity score (0.89) of the non-crash-involved subjects. Combining the not-at-fault subjects with the non-crash-involved subjects increased the specificity score to 0.90 (186 out of 203 possible). It may be reasonable to combine the non-crash-involved subjects with the not-at-fault subjects if the not-at-fault subjects can be considered to be "innocent victims" who have been involved in an crash through no fault of their own. Using the criterion established by Ball et al. (1993) to analyze the relationship of UFOV performance and driving history yields results that can be classified as "poor." Since a random sample of forty-two subjects should "capture" 7 subjects (versus 6 identified by the UFOV testing) categorized as at-fault by virtue of their driving history, the UFOV test performs no better than sampling randomly.

Adjustment of the UFOV Pass/Fail Point

The data were also analyzed using a different UFOV score as the pass/fail criterion. This score, 25.5, is the mean score of all the subjects tested in the research project. Again, related to crash involvement, the sensitivity score was 0.33 (27/81), which is the same percentage as a random sampling, and the specificity score was 0.63 (103/164) for this stratification. Further stratification of the crash-involved subjects into at-fault and not-at-fault categories resulted in a sensitivity score of 0.38 (16/42) for the at-fault subjects, and a sensitivity score of 0.28 (11/39) for the not-at-fault subjects. The specificity score of 0.63 does not change. Combining the not-at-fault subjects with the crash-free subjects resulted in a specificity score of 0.66 (131/203). A summary of the results when using a UFOV score of 25.5 for the pass/fail criterion is shown in Table 6.

Table 6. Results Using UFOV Pass/Fail = 25.5

Category	Sensitivity	Specificity
General Crash Involvement	0.33 (27/81)	0.63 (103/164)
At Fault Crash Involvement	0.38 (16/42)	0.63 (103/164)
Not At Fault Crash Involvement	0.28 (11/39)	
Random Selection	0.33 (27/81)	0.67 (110/164)

The UFOV testing appears to be more accurate in selecting the at-fault subjects when they were separated from all of the crash-involved subjects. Based upon the UFOV performance of the crash-free subjects compared to the not-at-fault subjects and using either the UFOV score of 40 or 25.5 as a reference point, it is reasonable to combine the two groups into one group.

Using the subjects from the research effort (N=245) and assuming a pass/fail criteria of 40 from UFOV testing, the following situation occurs: of the forty-two persons who hopefully will be identified (because of their at-fault crash history) by the testing as potential problem drivers, six will be picked (36 missed); and of the 203 persons who should be categorized by the testing as having no problems, twenty-one will be identified as potential problem drivers. Stated in a different manner, of the twenty-seven people identified as potential problem drivers, twenty-one (78%) will be misidentified. Of the 218 people identified as "passing" the test, thirty-six (16.5%) potential problem drivers will be missed. A summary of the errors and misidentification of the subjects using the two UFOV criteria (40 and 25.5) mentioned is shown in Table 7.

Table 7. Misidentification of Subjects with UFOV Testing

UFOV Criteria Pass/Fail	Problem Drivers Missed	Non-Problem Drivers Selected	Total Incorrect
40	36 out of 42 (86%)	21 out of 203 (10%)	57 (23%)
25.5	26 out of 42 (62%)	72 out of 203 (35%)	98 (40%)

The use of 25.5 as the pass/fail criterion produces better resolution than a random sampling (i.e., 16 compared to 7 picked randomly). However, the application of this test as a primary screening procedure used to identify potential problem drivers appears to have limited value because of the number of incorrectly categorized subjects, based upon the crash involvement of the subjects in this research effort.

Age Effects

Further stratification of at-fault subjects into the younger and older groups produces results showing that the UFOV testing does not identify at-fault subjects in the younger group (1/16) as well as a random sampling of 16 subjects would (approximately 3.5 at-fault subjects would be selected at random). The population of the younger group is seventy-five. Sixteen of the seventy-five subjects have been categorized as "at-fault" using the previously defined criteria. The inability to identify at-fault subjects is true for the UFOV pass/fail score criteria of both 40 and 25.5.

The UFOV testing does perform better than a random sampling when the subjects are chosen from the older group. The population of the older group is 170, including twenty-six who have been categorized as "at-fault." Using the UFOV pass/fail criterion of 40 on the older subjects yields a sensitivity score of 0.19 (5 selected out of 26) and a specificity score of 0.87 (125/144). Using the UFOV pass/fail score criterion of 25.5 improves the sensitivity to 0.58 (15/26) while the specificity declines to 0.51 (74/144). A random sample of twenty-six older subjects, given that approximately fifteen percent of the subjects in the group are at-fault crash involved, should contain four subjects who are indeed at-fault crash involved.

Further age stratification of the older subjects into five year age groups shows that the sensitivity of the UFOV testing improves as age increases. UFOV scores and analysis of the age group stratification of at-fault subjects for the sixty-five and older subjects are shown in Table 8.

While the number of problem drivers correctly identified (sensitivity) improves with age for both pass/fail score criteria, the number of incorrectly categorized subjects, as indicated by the specificity score, also increases. In general, the UFOV scores also increase with age.

When the UFOV pass/fail criterion is 25.5, twelve of the thirteen subjects in the 80-84 group fail the test, but only 3 are categorized as at-fault subjects. All four of the ≥ 85 group have a UFOV score higher than 25.5, although none had been categorized as at-fault and only one had been involved in a crash in the past five years. When the UFOV pass/fail criterion is 40, four of the thirteen 80-84 group fail, including two of the three at-fault subjects. Two of the four subjects in the ≥ 85 group had a UFOV test score higher than 40. Interestingly, the one crash-involved subject from this group "passed" the UFOV test.

Table 8. Sensitivity/Specificity of Older Subjects

Age Group of Subjects	UFOV Pass/Fail = 40		UFOV pass/Fail = 25.5	
	Sensitivity	Specificity	Sensitivity	Specificity
65-69	0.00 (0/5)	0.91 (51/56)	0.20 (1/5)	0.59 (33/56)
70-74	0.09 (1/11)	0.90 (44/49)	0.36 (4/11)	0.61 (30/49)
75-79	0.29 (2/7)	0.78 (18/23)	1.00 (7/7)	0.35 (8/23)
80-84	0.67 (2/3)	0.80 (8/10)	1.00 (3/3)	0.10 (1/10)
85+	N/A*	N/A*	N/A*	N/A*

* No "At-Fault" Subjects in This Group

Analyses With Hybrid Samples

The sample used in previous research efforts (Ball et al., 1993) was constructed differently than the sample for this research. For the purpose of analyzing samples that "look like" the sample used in the previous research, two hybrid samples were constructed from the available data. One sample is composed of <u>all</u> crash-involved subjects with a random sample of the non-crash-involved subjects. This new sample has 67% crash-involved and 33% non-crash-involved subjects, which is the same proportion of subjects as in the previous UFOV work (Ball et al., 1991). A second sample was constructed with only **at-fault** crash-involved subjects together with a random sample from the non-crash-involved subjects to create the 67/33 percent distribution.

Using these two samples, the process of determining the sensitivity and specificity of the UFOV testing was repeated. The results for the UFOV pass/fail criterion of 40 are shown in Table 9.

Table 9. UFOV Performance Scores Using Hybrid Sample: 67% Crash-Involved, 33% Non-Crash Involved. UFOV Pass/Fail = 40

Subject Grouping	Sensitivity	Specificity
All Subjects	0.11 (9/81)	0.79 (31/39)
Younger Subjects	0.03 (1/29)	0.92 (11/12)
Older Subjects	0.15 (8/52)	0.74 (20/27)
Random Sampling	0.67	0.33

The sensitivity score did not improve and it should not have, given the definition of sensitivity (i.e., given that a subject is crash-involved, the probability that their UFOV score is greater than 40). The specificity score for all subjects declined from 0.81 to 0.79, the specificity score for the younger subjects declined from 0.96 to 0.93, and the specificity score for the older subjects declined from 0.88 to 0.74. Given that the sample is skewed towards crash-involved subjects, this result is not unreasonable and, when compared to a random sample, this result is actually better than the specificity score from the "original" sample used for this research. The difference between 0.79 and 0.33 is much larger than the difference between 0.81 and 0.67.

Analysis of the data were also done using the UFOV pass/fail criterion of 25.5. These results are shown in Table 10. The lowering of the UFOV pass/fail threshold to 25.5 does not affect the results for the younger subjects (i.e., their scores are the same as for UFOV pass/fail = 40). Again, while the specificity scores are lower than for the "original" sample, the scores are the same or higher than a random sampling. This represents an improvement over the results from the original sample.

Table 10. UFOV Performance Scores Using Hybrid Sample: 67%Crash-Involved, 33% Non-Crash Involved. UFOV Pass/Fail = 25.5

Subject Grouping	Sensitivity	Specificity
All Subjects	0.33 (27/81)	0.51 (20/39)
Younger Subjects	0.03 (1/29)	0.92 (11/12)
Older Subjects	0.50 (26/52)	0.33 (9/27)
Random Sampling	0.67	0.33

The analysis of the second hybrid sample uses the same criterion as the first hybrid sample. The difference is that only **at-fault** crash-involved subjects and a random sample of non-crash-involved subjects are being analyzed. The results of the analysis with a UFOV pass/fail criterion of 40 are summarized in Table 11.

As before, the sensitivity scores do not change from the scores in the original sample, but the specificity score for all subjects decreased from 0.89 to 0.71. For the younger subjects, the specificity improved from 0.96 to 1.00. The specificity for the older subjects decreased from 0.86 to 0.63. Again, compared to the random sample specificity of 0.33, this represents an improvement from the random sample specificity of 0.67 in the original sample.

Table 11. UFOV Performance Scores Using Hybrid Sample: 67% At-Fault Crash-Involved, 33% Non-Crash Involved. UFOV pass/fail=40

Subject Grouping	Sensitivity	Specificity
All Subjects	0.14 (6/42)	0.71 (15/21)
Younger Subjects	0.06 (1/16)	1.00 (5/5)
Older Subjects	0.19 (5/26)	0.63 (10/16)
Random Sampling	0.67	0.33

The results of analyzing this hybrid sample with a UFOV pass/fail criterion of 25.5 are summarized in Table 12. The sensitivity scores are the same as for the original sample. The specificity score for all subjects declined from 0.63 to 0.52. For the younger subjects, the specificity score increased from 0.96 to 1.00. The specificity score for the older subjects declined from 0.50 to 0.38. Because the random sampling reduces the specificity from 0.67 to 0.33, the changes in the specificity scores are actually an improvement even though the scores are generally lower than the scores in the original sample.

Table 12. UFOV Performance Scores Using Hybrid Sample: 67% At-Fault Crash-Involved, 33% Non-Crash Involved. UFOV Pass/Fail = 25.5

Subject Grouping	Sensitivity	Specificity
All Subjects	0.38 (16/42)	0.52 (11/21)
Younger Subjects	0.06 (1/16)	1.00 (5/5)
Older Subjects	0.58 (15/26)	0.38 (6/16)
Random Sampling	0.67	0.33

The general results from analysis of the hybrid samples are that the sensitivity score is unaffected and the specificity is somewhat improved. However, compared to the results of previous UFOV research efforts, the analysis of the hybrid samples did not show the same (or even close to the same) strong results of the Ball et al. (1993) work, despite constructing the hybrid samples to "look like" the sample in the previous UFOV research.

Statistical Group Differences

The differences in the UFOV performance scores of <u>all</u> the subjects were compared for statistical significance at the 0.95 level for the three crash-related categories and were not found to be significantly different. The mean UFOV-Overall score for the subjects who were not crash-involved was 26.0. The same scores for the not-at-fault and at-fault subjects were 23.5 and 25.7, respectively. That is, UFOV scores for non-crash-involved subjects were somewhat worse (higher) but the difference was not significant. None of the UFOV component scores, **Processing Speed, Divided Attention,** and **Selective Attention** indicated significant differences between the three crash-related categories.

As shown in the sensitivity and selectivity scores, there appears to be an age related degradation in UFOV test performance. The mean UFOV score for the subjects between the ages of 20 and 55 is 14.6. The mean UFOV score for the subjects $\geq$ 65 is 30.3. With the exception of the UFOV-Processing Speed component, the differences are statistically significant. The component UFOV scores for the two age groups are shown in Table 13.

Table 13. Component UFOV Test Scores Comparing Age Groups

UFOV Component	Subjects age 20-55	Subjects $\geq$ 65
Processing Speed	1.2	2.1
Divided Attention*	1.0	5.0
Selective Attention*	12.4	23.2
Overall Score*	14.6	30.3
* Differences statistically significant (0.95)		

In relation to the driving task and vision, the UFOV performance of the younger subjects indicates that, at a distance 500 feet ahead of the vehicle, their visual field is approximately 574 feet wide. The same scenario for the older subjects indicates their visual field is approximately 454 feet wide which is narrower than the younger subjects by 120 feet. At closer distances the potential problems of the narrower field become more obvious. Fifty feet in front of their vehicle, the younger subjects visual field is 57.4 feet wide and the older subjects visual field is 45.4 feet wide. The width of a majority of four-lane urban arterial streets is approximately forty-eight feet (four 12 foot lanes). In this scenario, a pedestrian entering a crosswalk fifty feet ahead of an older subject's vehicle would have a higher probability of <u>not</u> being identified because the pedestrian would be outside of the subject's useful visual field when entering the crosswalk, especially if the subject driver is concentrating directly ahead of the vehicle (i.e., not scanning to the left and right often).

Because of the apparent differences due to subject age, the UFOV performance was analyzed in the crash-related categories <u>after</u> separating the subjects into the previously defined younger and older age groups. None of the comparisons between non-crash, not-at-fault crash, and at-fault crash subjects from the younger group were different, operationally or statistically. The same situation occurs for the subjects from the older age group. These results are summarized in Table 14.

The tabulated data show that there are significant differences in the performance of the subjects in relation to age. However, there is no difference when crash-involvement is considered. Analysis of the data with a 2-way ANOVA indicates that the impact of age is significant on UFOV performance and crash-involvement is not significant. The crash data were examined three different ways: 1) at-fault vs. not-at-fault vs. no-crash; 2) at-fault vs. no-crash combined with not-at-fault; and 3) no-crash vs. at-fault combined with not-at-fault. None of the variations changed the results of

Table 14. Age Group UFOV Performance and Crash Involvement

	Younger Subjects (20-55)			Older Subjects ($\geq$ 65)		
UFOV Component	No Crash	Not-At-Fault	At-Fault Crash	No Crash	Not-At-Fault	At-Fault Crash
Proc. Speed	1.3	0	1.9	2.3	2.3	1.3
Div. Attn.	1.6	0	0.3	4.9	4.0	6.6
Sel. Attn.	12.3	12.9	12.0	23.0	22.4	24.8
Overall Score	15.3	12.9	14.2	30.1	28.8	32.8

the analysis; age is a significant factor in UFOV performance and crash-involvement is not a significant factor. Indeed, although the results are not statistically significant, non-crash subjects generally did worse on average than other subjects with respect to UFOV scores. The interaction between crash-involvement and age is not significant. The ANOVA results are shown in appendix A.

Summary of UFOV Performance and Crash Involvement

The accuracy of the UFOV test in identifying crash-involved drivers from the subject pool is questionable when the testing is analyzed without regard to the age of the subjects. Identifying the at-fault subjects and conducting further analysis improves the performance of the UFOV test, but the UFOV testing still does not select problem drivers as well as random sampling. This situation can be attributed to the performance of the younger subjects on the UFOV test. The subjects were separated into the younger and older groups and the data were analyzed again. The UFOV test did not identify younger subjects who had been at-fault crash involved as well as a random selection process, even when evaluated at the pass/fail criterion of 25.5. The UFOV test was, however, more accurate when identifying the "problem drivers" from the older age groups. However, the accuracy of the UFOV test for the "youngest" old group was poor (see Table 14) and the contribution of age in the identification process appears to be a confounding factor--the strongest effect in explaining UFOV scores is age (e.g., non-crash subjects average UFOV Overall Score: younger=15.3; older=30.1). An analysis strategy using a measure other than crash involvement was developed using the characteristics of the subjects recorded offenses.

ANALYSIS USING DRIVING OFFENSES DATA

Analysis of All Subjects as One Group

Further analysis was conducted to determine if there are other data in the driving record of individuals with which the UFOV test performance would have a stronger positive relation. For example, the MDOS driving history file contains information concerning the number and types of offenses for which some of the subjects have been cited. As previously defined in the **research methodology** (and also in order to have sufficient data for analysis), the offense data were grouped into three categories: no offenses (N=166), vehicle control offenses (N=33) and speed offenses (N=46).

The vehicle control offenses can be related to the UFOV testing using the following rationale: the offenses selected can be reasonably associated with the types of problems that could occur with decreased visual function and/or mental processing speed (i.e., the person was unable to detect and process the information quickly enough to avoid the problem that resulted in the offense cited). For example, a person cited for failure to yield right-of-way could likely have been "overloaded" with information and unable to detect or process an important item of information. This item of information, properly processed, could likely have caused the person to act (or react) differently (more safely?) and possibly avoid the citation received.

The rationale for analyzing the speed offenses separately rests in some of the concepts put forth in the development of UFOV testing. Poorer performance on UFOV testing is an indication of a reduction in visual function and/or mental processing speed. A person with reduced UFOV should experience a general degradation of their overall "comfort level" while performing complex tasks, such as operation of a motor vehicle, due to the reduced ability to obtain and process information. The medical term for this comfort level is homeostasis. To compensate for their reduced comfort level (i.e., to maintain their homeostasis), a person may drive slower and/or change their route choice to minimize complex (i.e., uncomfortable) situations. Persons who are cited for speed offenses could reasonably be assumed to be comfortable driving at higher speeds and would not likely be detected by UFOV testing as having visual or mental processing speed deficits. However, there is a relationship between driver age and offense type. Younger drivers are more often cited for errors consistent with excess speed such as drag racing and more often involved in crashes where excess speed is a contributing factor (McKelvey et al., 1987).

Given the described rationale for the three categories of offenses, it seems logical that the UFOV testing should serve to group the drivers with no offenses and speed offenses in the "pass" category and group the drivers with vehicle control offenses in the "fail" category. The criteria for sensitivity and specificity, as previously defined and used in the analysis of crash involvement and UFOV performance, are applied in this instance by grouping the "no offenses" subjects with the "speed offenses" subjects; the "vehicle control offenses" subjects are the remaining subjects which will hopefully be identified by the UFOV testing (as "failing" the test). The population distribution of the subjects for the UFOV pass/fail criterion of 40 is summarized in Table 15.

Table 15. Subject Population for UFOV/Offenses Analyses. UFOV Pass/Fail = 40

UFOV Score	$\leq$ 40	> 40	All Subjects
No Offenses	148 (68%)	18 (67%)	166 (68%)
Vehicle Control Offenses	27 (12%)	6 (22%)	33 (13%)
Speed Offenses	43 (20%)	3 (11%)	46 (19%)
Totals	218 (100%)	27 (100%)	245 (100%)

* Distributions are within acceptable ranges, tested for Chi-square goodness of fit at 0.05 level.

The criteria for sensitivity and specificity used for the crash-involved analysis was modified for use in this stratification. Sensitivity and specificity were redefined as follows:

1. Sensitivity: given that a subject has a recorded vehicle control offense, it is the probability that their UFOV score is above 40.

2. Specificity: given that a subject does not have a recorded vehicle control offense, it is the probability that their UFOV score is below 40.

Applying the modified criteria to this stratification, the sensitivity was 0.18 (6/33), and the specificity was 0.90 (191/212). A random sampling (N=33) would "capture" 4 or 5 subjects with recorded vehicle control offenses. Therefore, the UFOV test performed only slightly better than a random sample. Analyzing the data using a pass/fail UFOV score of 25.5 yields the data presented in Table 16.

Table 16. Subject Population for UFOV/Offenses Analyses. UFOV Pass/Fail = 25.5

UFOV Score	$\leq$ 25.5	> 25.5	Total
No Offenses	108 (69%)	58 (66%)	166 (68%)
Vehicle Control Offenses	18 (11%)	15 (17%)	33 (13%)
Speed Offenses	31 (20%)	15 (17%)	46 (19%)
Totals	157 (100%)	88 (100%)	245 (100%)
* Distributions are within acceptable ranges, tested for Chi-square goodness of fit at 0.05 level.			

The sensitivity from this stratification is 0.45 (15/33, compared to random sampling of 4.5/33) and the specificity is 0.66 (139/212). The effects of lowering the UFOV pass/fail threshold to 25.5 are to increase the sensitivity score (i.e., more subjects with vehicle control offenses selected), and to lower the specificity score (i.e., more subjects with no offenses are identified as "failing" the UFOV test). The problem now becomes one of establishing what level of error is acceptable.

Age-Related Effects

Because of the nature of the research effort age data were available, and analyses stratified by age groups were also done. The age stratification again used the same two groups: age twenty to fifty-five labeled "younger," and age sixty-five and older labeled "older." The population of the younger group is 75 and the population of the older group is 170. The crash and offense data from both age groups were examined for homogeneity between the groups using the Chi-square goodness-of-fit procedure at the 0.05 level and the distributions were determined to be similar (appendix A). The speed offenses are more prevalent in the younger group, which is not unexpected based upon past research findings (Maleck and Hummer, 1986). The older subjects were cited for vehicle control offenses more often, on average, than the younger subjects (this, also, is not unexpected based upon past research findings (Planek and Fowler, 1971)). Therefore, because the differences between the younger and older subjects are in keeping with past research findings, it is reasonable to use the data to compare the two groups for age-related differences. The populations and percentages of the subjects in the different categories are shown in Table 17.

Analysis of the younger group indicated that the UFOV sensitivity score did not identify any of the potential problem drivers, using either the

Table 17. Characteristics of the Subjects

Category	Age 20-55	Age 65+	Sample
No Offenses (%)	45 60%	121 71.2%	166 67.8%
Vehicle Control Offenses (%)	9 12%	24 14.1%	33 13.5%
Speed Offenses (%)	21 28%	25 14.7%	46 18.8%
Totals (%)	75 100%	170 100%	245 100%

UFOV pass/fail criterion of 40 or 25.5 (sensitivity = 0.00 (0/9) in both cases). The UFOV specificity score using the pass/fail criterion of either 40 or 25.5 was 0.95 (63/66). The maximum UFOV score of any of the nine subjects from the younger group who were in the vehicle control offense category was 17.5. This approach was not accurate in identifying potential problem drivers from the younger age group.

Analysis of the older age group indicated that the UFOV testing was able to identify some potential problem drivers. Using the pass/fail criteria of 40, the UFOV sensitivity score was 0.25 (6/24) and the specificity score was 0.88 (128/146). A random sampling in this age group would "capture" approximately three subjects with vehicle control offenses. The number of subjects categorized incorrectly in this stratification is thirty-six out 170 (21%).

Using the pass/fail criteria of 25.5, the UFOV sensitivity score was

0.62 (15/24) and the specificity score was 0.52 (76/146). While the sensitivity score is much improved, the number of subjects categorized incorrectly is now seventy-nine out of 170 (46%) compared to thirty-six out of 170 (21%). The size of the error from the UFOV testing is an indication that a very large, and likely unacceptable number of persons who are not problem drivers will be still be selected for remedial training (or whatever intervention is necessary to "improve" their performance).

This stratification also reveals age-related bias in the UFOV testing since the offending subjects in the younger group were not identified while the older subjects were identified. Ideally, the reasons for not selecting the potential problem drivers could provide some insight into why the problematic younger subjects are not identified by the UFOV testing. Other items of information about the nine younger subjects who were categorized as at-fault crash-involved were reviewed for indications of characteristics which could pre-dispose them to the type of behavior that leads to the citations for vehicle control offenses. The phone comments were reviewed as well as comments noted during the pre-drive screening tests and comments from the in-vehicle observers for these nine subjects. Two of the subjects had comments during the phone contact: one wanting to know how their name was obtained; and the other expressing concern about having people ride with them as they drove. None of the nine subjects was noted as making significant comments during the pre-screening and vision tests. Only one of the nine subjects reported taking any prescription medication (an antibiotic). Six of the nine subjects wore corrective lenses. Six of the nine subjects have multiple convictions on their driving record. None of the other three vision tests conducted at the same time as the UFOV test indicated any abnormalities among this group. The in-vehicle observers reported no significant comments that could be construed as unique among these nine subjects. There does not appear to be any data items collected during the screening tests for this experiment that would help identify these subjects other than their driving history.

Comparison of Crash-Involved and Offense Type Analysis Methods

The subjects were evaluated using their UFOV performance and comparing that performance to their driving history. The relation to driving history included crash-involvement and also recorded offenses. Comparison of the different methods indicates, for the identification of potential problem drivers as defined by vehicle control offenses, the UFOV pass/fail criterion of 25.5 is the best performer. Unfortunately, this criterion also incorrectly identifies the highest number of subjects who ideally should "pass" the UFOV test, based upon their driving history. Those subjects in the vehicle control offense category, especially in the older age group, were subjects "best" identified by the UFOV testing. The results of these analyses are summarized in Table 18.

Table 18. UFOV Test Performance Comparison

Criteria	Sample Character-istics	Pass/Fail = 40		Pass/Fail= 25.5	
		Sensitiv-ity	Speci-ficity	Sensi-tivity	Specific-ity
Ball/Owsley Studies(2)	Sample Propor-tion	0.89 0.94	0.81 0.64		
Crash Involved	.33	0.11	0.89	0.33	0.63
At Fault Crash	.17	0.14	0.90	0.38	0.66
At Fault Crash-Younger Ages	.21	0.06	0.97	0.06	0.97
At Fault Crash-Older Ages	.15	0.19	0.87	0.58	0.51
Vehicle Control Offenses	.13	0.18	0.90	0.45	0.66
Vehicle Control Younger Ages	.12	0.00	0.95	0.00	0.95
Vehicle Control Older Ages	.14	0.25	0.88	0.62	0.52

Statistical Group Differences

As previously stated, there are significant differences in the UFOV performance between the younger and older subjects. Using the three offense categories, **no offenses, vehicle control offenses,** and **speed offenses,** analyses of the group scores was done before being separated into the younger and older groups to test for statistical difference. The results of this analysis are summarized in Table 19.

Table 19. Comparison of All Subjects and Offense Types

UFOV Component	No Offenses	Vehicle Control Offense	Speed Offense
Proc. Speed	1.8	3.3	1.0
Div. Attn.	3.8	5.8*	2.2*
Sel. Attn.	20.1	22.0*	17.7*
Overall Score	25.7	31.1*	20.9*
* Statistically significant (One-way ANOVA 0.95 level of significance) ANOVA shown in appendix A			

Without regard to the differences attributable to age, the differences in the UFOV performance between the subjects cited for vehicle control offenses and the subjects cited for speed offenses is significant on all parts of the UFOV test with the exception of Processing Speed. If these differences are attributable to age, separate analyses of the younger and older subjects should not show significant differences within each group.

Within the younger group, none of the differences was significant.

The difference in scores on the **Selective Attention** portion of the UFOV test for subjects with speed offenses (score=10.6) and the subjects with vehicle control offenses (score=13.9) would be significant if evaluated at the 0.90 level. This result is similar to the UFOV-Selective Attention scores for the entire subject population as shown in Table 19.

Within the older group the difference between the UFOV-Overall score of those with no offenses compared to those with vehicle control offenses is significant. The differences in scores in the other categories are not significant. The results of the ANOVA testing for these comparisons are shown in appendix A.

Individual T-tests for the different offense categories and UFOV components were run to ascertain differences between UFOV performance scores within the two age groups. Again, the differences between the scores in the three offense categories for the younger subjects were not significant.

The testing of the scores of the older subjects with the T-test showed the differences to be not significant. However, if the confidence level is changed from 0.95 to 0.90, the differences in the scores between older subjects in the no offenses and vehicle control offenses categories are significant in the UFOV-Selective Attention and UFOV-Overall categories. Additionally, the differences in the UFOV scores between subjects in the speed offenses and vehicle control offenses categories are significant in the UFOV-Processing Speed, UFOV-Divided Attention, and UFOV-Overall score categories. The sensitivity of the UFOV testing is better for the older subjects, but only when using a more liberal confidence interval. However, age still appears to be the primary discriminating factor for UFOV test performance.

Other Analyses and Stratifications

The analyses just discussed were concentrated on relationships that could be compared directly previous work and, generally, to confirm the earlier results. In addition, numerous analyses were also undertaken that examined the relationships of UFOV component scores to driving histories. None of the UFOV component scores showed a stronger relationship between driving histories and UFOV performance than the UFOV-Overall score. The primary reason appears to be the additive nature of the component UFOV scores to form the UFOV-Overall score. Individual inconsistencies are aggregated into the total score which can mask potential problems. For example, age-related macular degeneration would likely affect the UFOV-Processing Speed score since the target is centrally located and AMD affects central vision. However, the component UFOV scores did not identify problem drivers as well as the UFOV-Overall score and, therefore, use of component scores in this analysis regimen is not recommended. The majority of the analyses produced results that indicated the relationships between UFOV performance and driving histories were nonexistent or too weak to be of any predictive value. Those analyses where minimal correlations existed include:

1. component UFOV performance compared to general crash involvement of subjects, grouped into five-year age groups.

2. component UFOV performance compared to self-reported crash involvement of the subjects, grouped into five-year age groups,

3. overall UFOV performance stratified by offenses/no-offenses (UFOV-Overall score 24.7 versus 26.0),

4. overall UFOV performance stratified by crash/no-crash (UFOV-Overall score 24.5 versus 26.0).

General Observations From the UFOV Testing

The UFOV testing did identify subjects with visual problems such as cataracts and AMD. Some of the comments from the subjects with these reported visual problems indicated that, because they were aware of their vision problem and the affect of their vision problem on the operation of a motor vehicle, they had adjusted their driving behavior to compensate (e.g., avoided driving at night). This information is anecdotal but interesting nonetheless. It is an indication that educating people about the impacts of vision problems on their driving is an important aspect of highway safety. It is also an indication that when people are aware of the facts, they are able to make rational decisions about adjusting their driving behavior.

CONCLUSIONS: UFOV PERFORMANCE AND DRIVING HISTORY

The sensitivity and specificity criteria set forth in the previous research efforts by Ball et al. (1991, 1993) are straightforward and easily calculated. The results of the analyses here indicate, however, difficulty in attaining the same performance results as in the earlier work. The probable reason for the large difference in performance is due almost entirely to the differences in the subjects in the sample for this project as compared to the subjects in the samples used in previous UFOV work. The subjects from the earlier UFOV research efforts were much more likely to have been crash-involved. The differences in the samples are explained in greater detail in the **sampling techniques** section.

The strongest indicator of UFOV performance is subject age, with the performance of the older subjects worse than the younger subjects. Once age is accounted for, the strongest indicator of UFOV performance is citations for vehicle control offenses among the older drivers, with the subjects cited for the vehicle control offenses performing worse than the non-cited drivers.

Analyses of the data leads to the following conclusions:

1. UFOV testing related to driving history is effective only for subjects age 65 and older,

2. persons over the age of 65 with "poor" UFOV performance are more likely to be cited for vehicle control type offenses,

3. persons over the age of 65 with "poor" UFOV performance are more likely to be determined at-fault when involved in a crash,

4. persons over the age of 65 with citations for speed violations are more likely to have "good" UFOV performance.

HYPOTHESES EVALUATION

The comparison of UFOV performance and driving history was conducted to replicate previous research methodology and analyze the data from a sample more representative of the entire driving population. Because the sample used in this experiment contained far fewer crash-involved subjects, it was expected that the results from the UFOV testing would not show as strong a relationship to crashes and moving violations as the previous UFOV research. In an attempt to produce results that were similar to the previous UFOV work, two hybrid samples were constructed with approximately the same crash distribution as the sample used in the Ball et al. (1993) work. However, analysis of the hybrid samples did not produce results which were even reasonably close to the results of the previous UFOV work. The results from the analysis of the two hybrid samples indicate that the reliability of the UFOV test to identify problem drivers is not good.

Again, the research hypothesis for this part of the research is:

There is a correlation between UFOV performance and driving history defined by crashes and moving violations.

Based upon the results of the analyses, a positive relationship can be shown to exist in some specific instances between the stated measures (e.g, older subjects in the vehicle control offense category). However, even the strongest relationships that were noted are, by most standards, still fairly weak. The UFOV test does not perform well when analyzing subjects from the younger age groups using any of the comparison methods, although the sensitivity does increases for the older group. This indicates the UFOV test is not "age-blind."

Adjusting threshold levels to increase the strength of the correlations (e.g., UFOV pass/fail criterion of 25.5) also produces the undesirable result of placing a large (and likely unacceptable) percentage of subjects into a "false-positive" category (i.e., the test picks more "poor" performers but also picks many more "good" performers). Establishment of the UFOV test pass/fail score threshold would depend on the purpose of the testing and how many false-positive subjects can be tolerated.

As previously stated, a positive relationship can be shown to exist in some specific instances. For this reason it can be stated that the hypothesis is true. However, given the poor performance in many of the areas discussed, it can also be stated that the hypothesis is false. Therefore, the assertion that the hypothesis is true will receive "qualified' support in narrowly defined situations.

In general, there have been discussions which support using the UFOV test as a primary screening procedure to identify potential problem drivers. Given the results of this research effort using a more realistic sample of subjects, the idea of using UFOV testing as a primary screening procedure is not supported. There are a high number of "false positive" scores when attempting to select the potential problem drivers, especially in the younger age groups when using the UFOV test. The results are better in the older age groups. Determining what the age criterion should be for requiring increased testing would be difficult to determine, given the variability of the performance scores from this research. Additionally, requiring a more rigorous testing regimen for older drivers would likely be met with great resistance from agencies and organizations representing older citizens.

This research analyzed <u>past</u> driving history with <u>current</u> UFOV performance. The results indicated the relationship between UFOV performance and driving history was weak at best. A potential extension of this research would be to track the driving history of the subjects into the future (a longitudinal study) to see if <u>current</u> UFOV performance predicts <u>future</u> crash-involvement and/or offenses.

DRIVER HISTORY
AND
DRIVER PERFORMANCE MEASUREMENT

In addition to UFOV testing, the driving performance of the participants in the NCHRP research project were also evaluated using the DPM process. The focus in this section is the relationships between the subjects' DPM performances and their driving histories as recorded in the MDOS data.

THE RELEVANCE OF DPM

One of the primary reasons for the development of the DPM process was the need to assess the effectiveness of high school driver education programs in Michigan. In addition, previous research (Tarawneh, 1993) indicates that DPM is a suitable method for assessing the capabilities of drivers at the time the assessment occurs (i.e., the performance today, not based on driving history). The research conducted here will attempt to establish the extent of the relationship existing between a subject's DPM performance and his/her crash and/or violation history. If this relationship is similar to the relationship between UFOV testing and driving histories, the DPM process and the UFOV process may share an association which would improve the confidence in the direct comparisons between DPM and UFOV performance. While the focus of the NCHRP project was primarily on older drivers, the utility of DPM assessment is not restricted to any age group. If the DPM performance is shown to have a correlation with the driving history of the participants, DPM could be useful for identifying potential driving problems in any group, age-based or not.

Additionally, the DPM performance of the subjects will be useful for analysis even if the relationship to UFOV performance is weak (or nonexistent). As stated earlier, the DPM performance will provide an assessment of a subject's present level of competence for operation of a motor vehicle. Even if a subject does not have any crashes or violations on their record, information gathered from the subject about their driving habits may reveal changes they have made to compensate for vision or other problems associated with driving.

THE SPECIFICS OF DPM

As mentioned in the literature review, during the development of the DPM process, the critical tasks involved with the safe operation of a motor vehicle were identified, categorized, and prioritized. This resulted in three primary categories which cover the tasks required for the safe operation being identified: Search, Speed Control, and Direction Control.

Search involves the assessment the driver's behavioral patterns in terms of looking at the environment outside and inside the vehicle in order to acquire information appropriate for accomplishing the driving task. For example:

1. How well does the driver use mirrors for side and rear searches for potential conflicting vehicles?

2. Are there observable visual search patterns and head movements where the driver scans to the left, to the right, and ahead of the vehicle?

3. Does the driver pay particular attention to the areas around the vehicle which are most important to the impending maneuver (e.g., extensive searching to the left and left-rear prior to making a lane change to the left)?

The observable searching process should also include occasional glances at the instrument panel for assessment of the gauges. Because of the importance of visual information to the driving task, Search was determined to be the most important of the three categories of the DPM process as it is the primary means of information gathering (Forbes et al., 1973).

Speed Control involves the assessment of the operator's behavior relating to accelerating and braking, adjusting speed to merge with other vehicles, adherence to posted speed limits and advisory speeds, and the speed of the operator's vehicle in relation to adjacent traffic. For example:

1. Does the driver accelerate rapidly from a standing start or creep away from an intersection? Both behaviors may interfere with other traffic.

2. Does the driver brake "hard" or abruptly in order to stop or turn at an intersection? This behavior may interfere with vehicles following behind.

3. Does the driver exceed the speed limit by several miles-per-hour, especially in urban and residential areas? This behavior can be hazardous to pedestrians in residential areas, as well as hazardous to the driver.

4. Does the driver generally drive faster than the surrounding traffic and weave across lanes to pass other vehicles? Conversely, does the driver go appreciably slower than surrounding traffic? These behaviors can increase the number of lane changes or cause other traffic to make maneuvers to avoid being stuck behind a slow-moving vehicle.

Direction Control involves the maneuvering of the vehicle in relation to the environment. It also involves operational control which indicates to operators of nearby vehicles the intent of the driver (e.g., using turn signals). For example:

1. Does the driver weave back and forth in the lane? Does the driver cross lane lines when weaving?

2. When does the driver signal for lane changes and turns? Does the driver ever signal for lane changes and turns?

3. Does the driver "tailgate" vehicles ahead?

4. Does the driver "swing wide" or run over the curb when turning at an intersection or entering a parking area?

Since the driving environment is dynamic (i.e., always changing), DPM is particularly useful because the evaluation process takes into account the myriad potential traffic situations. The trained observers are able to concentrate on and identify the behaviors which increase or decrease safety as it relates to the operation of the vehicle. The observers also note the interaction of the subject's vehicle and the surrounding environment.

CHARACTERISTICS OF THE DPM ROUTE.

The driving "test" utilized a seventy-two mile route through urban areas of Lansing and East Lansing, MI, and rural areas of Ingham County, MI. The amount of time required to complete the entire route was normally between two and one-half to three hours. There were forty-one evaluation areas (sequences) on the route. Each sequence usually consisted of two segments, with a few sequences consisting of three segments. One sequence consisted of only one segment. In total, there were eighty-nine segments and subjects were rated at each of the segments. The evaluation areas (sequences) were selected for use in the NCHRP project so that different traffic control devices could be evaluated at similar types of locations (i.e., the geometric configuration of the locations were very similar, but the signs are different). Because of the redundancy designed into the NCHRP project, each of the forty-one evaluation areas are categorized into one of nine types of geometric configurations (site types). The nine site types are:

"A" sites: urban signalized intersections with a 5-lane cross-section on the approach to the intersection. The required maneuver for the subject is a left turn. The signalization type is permitted (i.e., a left-turn-only lane without a separate signal phase for the left-turning vehicles).

"B" sites: urban signalized intersections with a 4-lane cross-section (i.e., no left-turn-only lane) on the approach to the intersection. The required maneuver is a left turn and the type of signalization is permitted.

"C" sites: rural intersections, crossroad required to stop. The subject is not required to stop. The required maneuver is a left turn.

"D" sites: urban intersections, cross-street required to stop. The subject is not required to stop. The required maneuver is a right turn. The driver is requested to locate the street by using the street name signs.

"F" sites: rural 4-way intersections, crossroad traffic is not required to stop. The approach is stop-controlled for the subject. The required maneuver is to safely traverse the intersection.

"G" sites: rural "T" intersections, crossroad traffic is not required to stop. The approach is stop-controlled for the subject. The required maneuver is to safely traverse the intersection.

"I" sites: urban mid-block intersection, 5-lane cross-section on the approach. The subject is requested to locate the intersection by street name sign. The required maneuver is a left turn.

"J" sites: rural intersections, crossroad required to stop. The subject is not required to stop. The subject is requested to locate the crossroad by name sign. The required maneuver is a left turn.

"K" sites: rural area, 2-lane cross-section, horizontal curves.
The required maneuver is to safely traverse the curve.

The data collected from the subjects at the NCHRP evaluation sites also provide the data for this work because they are related to the behavior of the subjects. The driver histories also provide a measure of behavioral data from items such as speed violations and crash involvement. It is this behavioral data that will be analyzed in this section of the research.

ASSESSMENT OF THE EFFECTIVENESS OF DPM

An assessment of the effectiveness of the DPM process for use in this project was one of the research tasks. First, the DPM process was used to identify behaviors which were detrimental to the safe operation of a motor vehicle. Then, the attempt was made to correlate DPM performance to crash involvement and violations. The original development and assessment of the DPM process (Forbes et al., 1973) showed the DPM process to be effective in identifying detrimental behaviors, as well as good behaviors. In this research, the relationship of DPM performance to the driving history of the subjects will be assessed. If the past performance and present performance can be shown to be positively related, this will provide a measure of verification of the DPM process.

DPM Performance and Crash Involvement.

The overall driving performance of the participants, as defined using DPM criteria, was good with the aggregate DPM-Overall score of 94 percent (out of 100 percent possible). At each segment (there are eighty-nine), the subject receives a score of either "satisfactory" or "unsatisfactory." The performance score was arrived at by taking the total number of satisfactory scores from both observers and dividing by two times the number of segments completed. For example, if a subject completed the entire route and had a total of five "unsatisfactory" scores (e.g., two from observer 1 and three form observer 2), the DPM-Overall performance score would be 97 (173/ 178). Scores for the three component DPM categories are calculated the same way. Missed segments and observer errors are not included in the performance score.

Stratifying the analysis by crash-involved and non-crash-involved drivers indicated little difference between the two groups. The performance in the four DPM categories for the whole group and as stratified by crash involvement is summarized in Table 20. None of the differences between non-crash and crash-involved drivers are statistically significant (0.95 confidence level).

Table 20. Aggregate DPM Performance by DPM Category

Subject Category	Overall Score	Search	Speed Control	Direction Control
All Subjects	94	97	77	76
Non-Crash	94	98	76	77
Crash	94	97	77	75
Category score differences are not statistically significant.				

Further stratification of the DPM performance of the participants into non-crash, not-at-fault crash, and at-fault crash categories was also done. The differences between the three categories were larger than the differences based on crash involvement alone, although they are still not statistically significant (ANOVA, 0.95 level).

The results for this stratification are summarized in Table 21.

Table 21. Aggregate DPM Performance, Non-Crash, Not-At-Fault Crash, and At-Fault Crash Involved

Subject Category	Overall Score	Search	Speed Control	Direction Control
Non-Crash	94	98	76	77
Not-At-Fault Crash	96	98	76	74
At-Fault Crash	93	96	79	76
Category score differences are not statistically significant (0.05 level).				

Age Group Stratifications

Comparing the DPM performance of the participants across five-year age groups indicates minor differences between the younger age groups (i.e., under the age of 55). The DPM-Overall performance scores for these groups ranges from 93 to 97). In the older age groups, the performance scores are generally lower and tend to decrease as age increases with the exception of DPM-Speed Control, which indicates a slightly higher average in the older age groups. The five-year age group stratification is summarized in Table 22.

Using analysis of variance tests to assess the differences between scores for each category shows that for DPM-Overall performance only the score for the 80-84 age group is significantly different (statistically) from other, but not all, age group scores. The scores for age groups in the twenty through fifty range are different (higher) than the scores of the 80-84 group. The age group scores of the subjects age sixty-five through eighty are also different (again higher).

For the DPM-Search performance scores, the 80-84 group is again the only group whose scores are significantly different than other age groups. As stated earlier, the Search process of DPM was determined to be the most important category because of the visual nature of the driving task (Forbes, 1973).

The DPM-Speed Control scores reveal an interesting situation in that the "worst" performing group is the 25-29 group. This may be related to the homeostasis (comfort level) concept. The 25-29 group will likely have more confidence in their driving ability based upon ten years of driving experience. This group will more likely be physically fit and mentally alert (Hess and Markson, 1991). Thus given their driving experience and physical and mental fitness, this group may well feel more comfortable driving faster. Other younger groups also have generally lower **speed control** scores when compared to the sixty-five and older subjects. However, the scores are not statistically significant.

The **direction control** scores indicate generally poorer performance in the three oldest age groups. The low number of subjects in the 85 and older group likely prevents their group score from being statistically different from the same groups as for the 75-79 and 80-84 age groups. The lower **direction control** scores for the drivers in the older age groups are primarily the result of lane-line (centerline and/or edgeline) encroachment errors and errors such as weaving within the lane.

Whenever a subject received an unsatisfactory score on any part of the rating form, a written comment from the observer was required on the evaluation form. The

Table 22. DPM Performance, Five Year Age Grouping

DPM Rating Area Performance (# in group)	Overall Performance	Search	Speed Control	Direction Control
Age 20-24 (8)	93*	98*	68	73
Age 25-29 (10)	95*	97*	71**	75
Age 30-34 (10)	97*	99*	74	^86*
Age 35-39 (13)	95*	99*	79	80*
Age 40-44 (14)	97*	99*	72	79*
Age 45-49 (17)	97*	99*	78	^84*
Age 60-64 (2)	95	94	84	82
Age 65-69 (61)	95*	98*	77*	76*
Age 70-74 (59)	95*	98*	79*	^78*
Age 75-79 (28)	91*	96*	77	70^^
Age 80-84 (13)	84**	90**	78	65**
Age 85 & up (4)	92	97	74	71
Ages 50 through 59 have 1 or fewer subjects and are not included in the analysis.				
** & ^^ Indicate group(s) whose performance score is significantly different from other groups (indicated by a single * or ^). Comparisons made within DPM categories only.				

subjects over age sixty-five were marked down for lane encroachment and weaving errors 40.6 percent of the time while the subjects under age fifty-five were marked down for lane encroachment and weaving errors only 28.0 percent of the time. The two youngest age groups (20-24 and 25-29) also had generally lower group performance scores. These lower scores can likely be attributed to these groups being cited more often than other groups for driving behaviors such as following too closely and not signalling for lane changes.

A general observation of the overall performance across the age groups does reveal a pattern similar to the crash involvement rates using the induced exposure and mileage methods for calculating exposure. The youngest age group represented in this research effort, twenty to twenty-four, has the lowest score (i.e., worst performance) of all of the younger age groups (i.e., those age groups below fifty-five). The remaining younger age groups have DPM-Overall performance scores that vary just two points (95 to 97). The DPM-Overall performance of the older age groups (i.e., those over sixty-five) indicates that the performance of the "younger" old is similar to the performance of the twenty to fifty-five age groups. The DPM-Overall performance scores of the older age groups show a decrease as age increases. Although the differences are not statistically significant for any of the age groups, with the exception of the 80-84 group, the scores are generally lower than all of the younger group scores with the exception of the 20-24 group. This performance mirrors the previous research results which analyzed accident involvement based upon exposure methods and driver age (e.g., Planek and Fowler, 1971, Maleck and Hummer, 1986).

The DPM-Overall performance of the subjects across the defined age groups is shown in Figure 3.

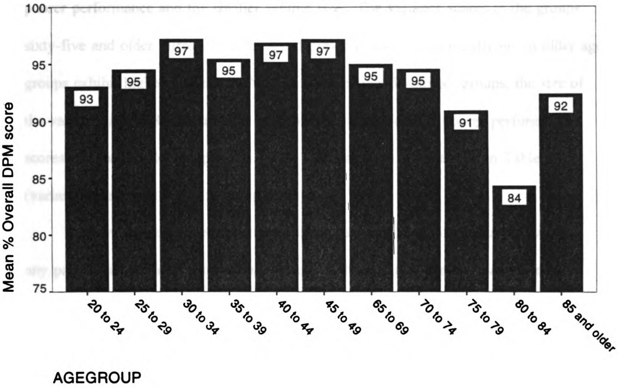

Figure 3.
DPM Performance by Age

The small samples sizes, especially in the younger age groups (N=10-13), raises a point of caution when interpreting the results. However, notwithstanding sample size concerns, the trend is similar to previous research findings. Additionally, the variance of the computed DPM scores follows the pattern established in previous research findings (Lyles et al., 1991). The previous research findings indicated that the variances in the crash involvement rates of drivers were highest in the youngest drivers and in the oldest drivers. In this research effort, the variances in DPM-Overall performance and

DPM-Search are relatively constant in the younger age groups. The higher variances in the 25-29 and 35-39 groups are probably due effect of a subject (or two) with poorer performance and the smaller sample size. The variance scores in the groups sixty-five and older mirror the findings of previous research where drivers in older age groups exhibit higher variances. As with the mentioned younger groups, the size of the variance in the 80-84 group is probably due to one or two poorer performance scores and the smaller sample size. This information is summarized in Table 23 (variances displayed with the group score).

The variances in the **direction control** category does not appear to establish any pattern related to the subject age groups. The **speed control** variances in the younger age groups are generally higher than the variances in the older groups.

There is a trend of higher **speed control** scores in the older age groups which may be indicative of the general tendency of older drivers to drive slower and/or younger drivers to drive faster (Planek and Fowler, 1971). Actual speed data were collected at four separate locations on the test route by the in-vehicle observers recording the speed indicated on the speedometer. The age group speed data from the four locations is summarized in Table 24.

Few of the speeds recorded at the four different locations are statistically different. Nonetheless it seems reasonably clear that the trend of the speeds is to generally decrease as age increases. This is true at all four locations and supports the theory that, in general, people drive slower as they get older.

Table 23. DPM Scores and Standard Deviations From All Age Groups

Age Group (# in grp)	Overall Performance score/sd	Search score/sd	Speed Control score/sd	Direction Control score/sd
20-24 (8)	93/2.51	98/2.93	68/11.64	73/9.53
25-29 (10)	95/3.89	97/3.07	71/10.35	75/11.49
30-34 (10)	97/2.04	99/1.45	74/7.91	86/4.79
35-39 (13)	95/4.27	99/1.12	79/8.58	80/10.06
40-44 (14)	97/2.51	99/1.33	72/10.15	79/11.69
45-49 (17)	97/2.53	99/1.47	78/6.34	84/7.57
65-69 (61)	95/3.76	98/1.92	77/6.34	76/10.86
70-74 (59)	95/3.52	98/2.18	79/8.25	78/9.56
75-79 (28)	91/7.93	96/5.20	77/7.17	70/10.39
80-84 (13)	84/21.39	90/14.12	78/7.34	65/14.27
85 + (3)	92/2.52	97/3.51	74/1.73	71/15.89

There is only one subject in the 50-54 age group.
There are no subjects in the 55-59 age group.
There are only two subjects in the 60-64 age group.

Table 24. Spot Speeds (mph) for Different Age Groups

Age Group	College Road	Every Road	Meridian Road	Sandhill Road
20-24	52.8	61.2*	59.5*	59.0
25-29	49.9	53.4	57.2	53.4
30-34	51.4	53.5	57.8*	52.9
35-39	48.1	52.9	52.6	50.0
40-44	51.7	53.4	57.5*	52.8
45-49	49.0	50.4	50.4	48.0
65-69	49.0	51.6	53.6*	49.6
70-74	49.4	51.7	53.7*	48.2
75-79	47.8	49.8	51.0	47.2
80-84	46.2	48.7*	45.9**	45.6
85+	48.2	53.5	49.0	41.5

* Differences in speeds are statistically significant.
At the Meridian Road location speeds indicated by a single asterisk are significantly different from the speed score indicated by the double asterisk.
(Significance level 0.05) Comparisons within locations only.

Age-Related Crash Involvement and DPM Performance

Analysis of the DPM performance scores of the subjects between the ages of twenty and fifty-five indicates they are not statistically different (see appendix B for details). Because the scores are equivalent (statistically), the five-year age groups between the ages of twenty and fifty-five will be combined and analyzed as one group. This helps to simplify the analysis process. The 65-69 group and the 70-74 group contain a relatively large number of subjects and will not be combined. The DPM scores of the 75-79 group, the 80-84 group, and the 85 and older group are different enough to warrant <u>not</u> combining them together or with any other group. These combinations result in there being six groups of subjects belonging to specified age groups.

Using the three previously defined categories of not-crash-involved, at-fault crash-involved, and not-at-fault crash-involved, the DPM performance of the subjects was analyzed. The results from this analysis are summarized in Table 25.

As shown in Table 25, the only group with significant differences in DPM performance scores are the no-crash subjects. While not statistically significant, the trends in the scores for not-at-fault and at-fault crashes are to decrease as age increases.

While the data indicate that the scores for the at-fault crash-involved are generally lower than subjects in the no-crash and not-at-fault crash categories, the differences between the crash categories in all age groups are not statistically significant. Additionally, the performance of the subjects in the two oldest age groups should be analyzed with caution due to the small number of observations in some of the categories.

Table 25. Overall DPM Performance and Crash Involvement within Age Groups

	Crash Involvement Last Five Years		
Crash Category ->	No Crashes	Not-At-Fault Crash	At-Fault Crash
Age Category			
Ages 20-55	96*	97	95
Ages 65-69	95*	96	95
Ages 70-74	95*	94	93
Ages 75-79	91*	94	88
Ages 80-84	84**	94 (n=1)	83 (n=3)
85 and up	92 (n=2)	92 (n=1)	N/A
* & ** Within the group, differences are significant (ANOVA, 0.05 level, appendix B).			

Crash History, DPM Performance, and Site Characteristics

As previously described, there are forty-one evaluation locations which are classified as one of nine different site types (see page 80). Through location development, engineering evaluation, and from comments from the in-vehicle observers, the relative "difficulty" of the different site types could be ascertained. However, there is not a numerical rating which can be established for each site type. The dynamic nature of the driving environment will change the relative difficulty of any site for any particular subject. The level of difficulty for each subject will vary, depending upon a range of situations. Nevertheless, given the number of observations for each site, it is reasonable to assess the relative difficulty of each site type.

Not surprisingly, the most difficult sites are located in the urban areas. The most difficult site type appears to be the mid-block left-turn (type "I" sites). The next most difficult site type was the left-turn at signalized intersections with a separate left-turn lane (type "A"), followed by the left-turn at signalized intersections without a separate left-turn lane (type "B"). The right-turn onto a residential street (type "D") was deemed the next most difficult due to the requirement of the driver to locate the street using street name signs. These signs are small and many subjects commented on how difficult it was to locate them. Due to the low volume of traffic and the simplicity of the sites, the differences in difficulty at the rural sites were considered to be minimal and the general difficulty approximately the same. The DPM performance of the subjects at the different site types based upon crash involvement is summarized in Table 26.

The difficulty of the mid-block left-turn ("I") sites is apparent from the scores as shown in Table 26. The performance scores from the rest of the site types are generally lower for the crash-involved subjects, but the differences are not statistically significant. While not statistically significant, an interesting trend is indicated by the higher scores for those subjects in the **not-at-fault** category at the more difficult urban sites (mid-block left-turn, signalized intersections, and urban right-turn) compared to the other two crash categories.

Table 26. Crash Involvement and DPM Performance Stratified by Site Type (A-K, Ranked in Order of Difficulty).

Site Type	Crash Involvement Last Five Years		
	No Crashes	Not-At-Fault Crash	At-Fault Crash
Mid-block left-turn	58	70	55
Signalized Int w/Left Turn Lane	96	97	94
Signalized Int w/o Left Turn Lane	98	99	96
Urban Location, right-turn	93	95	93
Rural Location, left-turn	98	96	97
Rural X intersection, Stop	99	99	98
Rural T intersection, Stop	100	100	100
Rural Location, left-turn	97	97	97
Rural Location, Horizontal Curve	99	98	99

* None of the differences <u>between</u> crash categories are statistically significant (ANOVA, 0.05 level, appendix B).

Age Differences and Site Type

Comparison of the DPM performance of the younger subjects with the older subjects across the different site types was done to discern the differences due to age. The performance of the two groups is summarized in Table 27.

The performance scores of the older drivers in the urban areas (site types A, B, D, and I) are generally lower than the scores for the younger drivers. The lower performance scores indicate that the older subjects have more difficulty on the more complex portions of the driving route. Although the differences are statistically significant, any conclusions resulting from the analysis based on age group performance must be carefully presented. The standard deviation (sd) of the scores indicates the variance in the performance of the older subjects on the complex portion of the driving route is higher than the younger subjects. This result is similar to previous research findings which indicated increasing variability in measures of performance (e.g., crash involvement) with increasing age (McKelvey and Stamatiadis, 1989).

The performance scores of the younger and older subjects on the rural sites reveal some interesting trends. The performance scores of both groups on the rural portion of the route (site types C, F, G, J, and K) indicate the performance of the two age groups is roughly the same. However, the standard deviations of the performance scores do not indicate the same higher variance for the older subjects as the standard deviations from the urban sites. These findings are somewhat similar to the findings of Maleck and Hummer (1986) in that the differences between younger and older drivers in rural areas were minimal.

Table 27. DPM Performance at Different Site Types, Stratified by Age Group

Site Type	20-55	65-69	70-74	75-79	80-84	*85+
	score/sd	score/sd	score/sd	score/sd	score/sd	score/sd
I	<u>75/25</u>	**59/30**	**53/30**	**47/31**	**35/33**	14/25
A	**98/4.5**	**97/4**	**96/5.5**	<u>92/12</u>	93/9	89/5
B	**99/2.5**	**99/3**	**98/3**	**95/8.5**	<u>87/23</u>	97/3
D	95/10	92/12	95/11	92/12	88/21	92/14
C	96/14	98/6	97/8	97/10	100/0	96/7
F	99/3.5	98/5	99/4.5	99/3	95/10	100/0
G	99/2	99/2	99/1	99/1	100/0	100/0
J	97/12	97/9	97/11	96/9	94/13	92/14
K	98/4	99/2	99/2.5	99/2	98/4	100/0

* There are only 3 observations in the 85+ category.
Within the rows (site type) the **highlighted** scores are significantly different from the <u>underlined</u> score.
The **65-69** group and the **80-84** group score differences are significant in the **I site** category. (ANOVA, 0.05 level).

The DPM performance of the younger and older subjects on the urban portions of the driving route indicated that the performance scores of the older group were consistently lower than the performance scores of the younger group. The performances of the younger and older subjects on urban, mid-block left-turns ("I" sites), stratified by accident involvement, are summarized in Table 28. In addition to the age effects, the similarity of the scores in the No-Crash and At-Fault-Crash categories is an interesting result. This pattern was observed in the results from other locations as well. No reason for this result is offered in this research. The scores for the other three urban site types are summarized in appendix B.

In general the performance scores of the older subjects are lower than the performance scores of the younger subjects in the same category. Within the younger age group, the performance scores are not significantly different between the crash categories. Within the older group, the performance scores in the at-fault crash categories on three of the four urban site types are lower (appendix B), with the exception of the right-turn using navigation by street name sign ("D" sites). Perhaps the most intriguing results are the higher performance scores in the not-at-fault crash category at the mid-block left-turn ("I" sites). The required tasks at these sites are generally considered to be the most complex of the observed maneuvers. The reason for the higher scores in both the younger and older age groups are not readily apparent.

Table 28. Crash Involvement and DPM Performance of Subjects on the Urban Mid-Block Left-Turn Sites ("I" sites).

Age Group	No-Crash	Not-At-Fault	At-Fault Crash
20-55	73**	83	73^
65-69	57*	67	57
70-74	55*	62	44
75-79	42*	79	47
80-84	40*	n/a	19^
85+	21	n/a	n/a

** Differences are significant between this score and the scores marked *.
^ Scores are significantly different (ANOVA, 0.05 level).

Summary of DPM Performance Related to Crash-Involvement

While there are some trends evident in the DPM performance scores in the older drivers, the relatively small size of the differences makes it difficult to arrive at definitive conclusions about the relationship to crash involvement. As with the UFOV performance, the age of the subject appears to have the greatest impact of any individual component on the DPM performance scores. DPM performance scores at the relatively more difficult urban sites indicate lower DPM-Overall performance in all age groups. The older age groups have generally lower performance scores on the urban sites compared to the younger subjects.

DPM PERFORMANCE RELATED TO DRIVING OFFENSES

The DPM performance of the subjects was also analyzed in relation to the incidence of one or more offenses on their driving record. As with general accident involvement there appears to be only minor differences in all of the DPM performance categories. However, the differences for the subjects with recorded offenses are of greater magnitude than the differences in the crash-involved DPM scores. The results of the comparison of DPM performance between subjects with no offenses and those subjects with one or more offenses are summarized in Table 29.

Table 29. Subject's DPM Performance, No Offenses, One or More Offenses on Record

DPM Category -> / Offenses	Overall Perfor-mance	Search	Speed Control	Direction Control
No Offenses	95	98	76	77
One or More Offenses	92	96	77	76
* Differences not statistically significant. (T-test, 0.95 level).				

The DPM-Overall performance of the subjects with one or more recorded offenses was lower than the subjects with no offenses, indicating that there may be a stronger relationship for the DPM performance and offenses than the relationship for DPM performance and crash-involvement. Further stratification of the data should reveal the source of the differences.

Offense Type Stratifications

Analyzing the DPM performance of the subjects using the previously defined offense types of **no offenses, vehicle control offenses,** and **speed offenses** reveals some differences between the subjects in these categories. Subjects in the **vehicle control offenses** category have DPM performance scores worse than subjects in the other two categories. This situation is true for DPM performance measures of Overall performance, Search performance, and Direction Control performance. The results of this stratification are shown in Table 30.

Table 30. DPM Performance Stratified by Offense Types.

Offense	Overall Performance	Search	Speed Control	Direction Control
No Offense	95*	98*	76	77
Vehicle Control Offense	89**	93**	78	73
Speed Offense	95*	98*	76	78
** Differences are significant (ANOVA, 0.05).				

The differences in the DPM-Overall and DPM-Search categories were significant while the differences in the DPM-Speed and DPM-Direction Control categories were not. As previously stated, the Search component of the DPM process was determined to be the most important aspect in regards to the safe operation of a motor vehicle (Forbes et al., 1973). The significantly (statistical) poorer performance of the subjects in the vehicle control offense category establishes the relationship between the historical measure (driving record) and the present day measure (DPM performance).

Age Group Stratifications

As stated earlier, because of the homogeneity of the performance of the younger age groups, they have been combined into one group which includes all of the subjects between the ages of twenty and fifty-five. Also stated earlier was the reasoning for separating offenses in to the three categories of **no offenses**, **vehicle control offenses**, and **speed offenses**. The results of the analysis of DPM performance related to the different categories of offenses are summarized in Table 31.

The DPM performance scores of the older subjects are generally lower than the younger subjects in the **no offense** and **vehicle control offenses** categories. The subjects in the 75-79 and 80-84 age groups who have been cited for vehicle control offenses have decidedly lower DPM performance scores. Only subjects in the 75-79 group have significant differences in their **no offense** and **vehicle control offense** categories. There appears to be an age effect within the **no offense** and **vehicle control offense** categories. However, these results are not consistent with those in the **speed offense** category.

Between categories only one age group shows significant differences. Utilizing a 2-way ANOVA for DPM-Overall performance with age groups and offense types shows that there are contributions to the variance in the DPM performance scores by both offenses and age group. The results of the ANOVA are shown in appendix B.

Table 31. Age Group Overall DPM Performance Compared to Offense History

	Offense History Last 5 Years		
Offense Category -> / Age Category	No Offenses	Vehicle Control Offenses	Speed Offenses
Ages 20-55	96*^	95*	95
Ages 65-69	95*	94*	95
Ages 70-74	95*	94*	93
Ages 75-79	92**	84*	94
Ages 80-84	92^	59**	N/A
85 and up	91 (n=2)	n/a	95 (n=1)

^ Differences are significant between the indicated scores.
The differences between scores indicated with a single asterisk and scores indicated with a double asterisk are significant in the No Offenses and Vehicle Control Offenses categories.
Underlined score differences are significant between offense categories (ANOVA, 0.05 level, appendix B).

DPM Performance and Offense Types at Different Sites

Further stratification was done to analyze the DPM performance at the different types of sites (A-K) and the relationships to the three offense categories. This analysis is summarized in Table 32.

The results of the comparison of DPM performance from the different site types stratified by offense types shows the subjects with vehicle control offenses consistently scoring lower than the subjects with either no recorded offenses or subjects with speed offenses on their driving record. However, the differences in the scores at the urban signalized intersections with two approach lanes (type "B" sites) are significant. Lowering the significance testing level to 0.10 would add the "A" and "C" sites to the "significantly different" list. However, lowering the significance level also lowers the confidence in the results (i.e., the probability of reaching the wrong conclusion is greater). Nevertheless, the trends do show that the subjects with vehicle control offenses scoring lower which appears to create a link between DPM performance and driving history.

Table 32. Offense Types and DPM Performance Stratified by Site Type (A-K, Ranked in Order of Difficulty).

Site Type	Offenses Last Five Years		
	No Offenses	Vehicle Control Offenses	Speed Offenses
I	58	54	68
A	96	94	96
B	98*	92**	99*
D	94	91	93
C	98	94	96
F	99	97	99
G	100	99	100
J	96	96	98
K	99	98	99

* Score differences significant (ANOVA, 0.05 level, appendix B).

Age Differences, Urban Sites, and Offenses

The DPM performance scores at the urban sites (types A, B, D, and I) were generally lower for all subjects in the vehicle control offense category. Further analysis was conducted to ascertain if there were any age-related effects associated with the performance at the urban sites as well. The stratification of DPM performance at urban signalized intersections with two approach lanes (type "B" sites) with offense types and age group differences is summarized in Table 33. The other three urban site types are shown in appendix B.

Table 33. DPM Performance at Signalized Intersections With Two Approach Lanes, Stratified by Age Groups.

Age Group	No Offenses	Vehicle Control Offenses	Speed Offenses
20-55	99	100*	99
65-69	99	98*	99
70-74	99^	96*^	99
75-79	96^	87*^^	100^
80-84	96	46** (n=2)	n/a
85+	97 (n=2)	n/a	n/a

* Score differences within the offense category are significant
^ ^^ Differences between offense categories are significant

The DPM performance scores of the younger group are consistent for all three offense categories (and all four site types, see appendix B). The scores are generally lower for all subjects in the vehicle control offense categories with the exception of the youngest subject group. The very low score (46) in the 80-84 group under vehicle control offenses comes from only two observations and its reliability may be questionable even though statistically significant.

Another interesting result is the performance score for the subjects in the 75-79 age group who are in the speed offense category. This group has higher performance scores at three of the four urban site types with the exception of the signalized intersection sites with separate left-turn lanes. While the number of subjects in this category is small (n=5), the standard deviation scores for this group are much smaller than for the subjects of the same age group in the other two offense categories, with the exception of the subjects with vehicle control offenses at the right-turn sites navigating by street name signs ("D" sites). These results are shown in Table 34. For example, the standard deviation scores at the mid-block left-turn sites are: 30, 31.5, and 17, for the no offense, vehicle control offense, and speed offense categories, respectively. These higher scores for the 75-79 age group could be a surrogate indicator of the confidence of the subjects in their driving ability which is also reflected in their willingness to drive faster.

Table 34. DPM Performance at Urban Sites, 75-79 Group, by Offense Types.

Site Type	No Offenses score/sd	Vehicle Control Offenses score/sd	Speed Offenses score/sd
I	*40/30	41/31.5	*79/17
A	95/9.5	85/17	88/10.5
B	*96/6.5	*87/14.5	**100/0
D	91/13.5	95/3.5	96/8.5
* ** Differences are significant between offenses types (ANOVA, 0.05 level).			

As previously mentioned, the speeds of all of the subjects were recorded at four specific locations on the driving route. These speeds were stratified to check for differences between the offense types by age group of the subjects. The scores for this stratification are shown in Table 35. The number of observations in each cell becomes small as the number of stratifications increase reducing the reliability of the results. There does not appear to be any trends established from the data. Because the populations of the cells are small in many instances, assessment of results should be interpreted with caution.

Table 35. Spot Speeds by Offense Types. Each Cell has 3 Speeds: No Offenses (NO), Vehicle Control Offenses (VCO), Speed Offenses (SO), Respectively.

Age Group	College Road NO¦VCO¦SO	Meridian Road NO¦VCO¦SO	Every Road NO¦VCO¦SO	Sandhill Road NO¦VCO¦SO
20-55	50¦47¦50	54¦54¦54	53¦44¦53	50¦54¦50
65-69	48¦54¦50	53¦54¦55	52¦52¦50	49¦48¦52
70-74	49¦54¦48	53¦56¦54	52¦53¦51	48¦47¦52
75-79	47¦50¦48	50¦53¦52	48¦51¦53	48¦44¦47
80-84	48¦34¦n/a	47¦40¦n/a	49¦n/a¦n/a	47¦39¦n/a
85+	46¦n/a¦52	44¦n/a¦58	46¦n/a¦61	37¦n/a¦51

No significant differences (ANOVA, 0.05 level).
n/a indicates cells with population of less than 5

Summary of DPM Performance and Recorded Offenses

There is a general trend for the DPM-Overall performance scores to be lower for the subjects who have been cited for vehicle control offenses in the last five years. The standard deviation of the DPM-Overall performance scores shows little consistency with regards to increasing age. The standard deviation scores in some of the older age groups are smaller in some offense stratifications than in younger age groups. For example, the standard deviation score for the 75-79 age group in the speed offenses category is 3.58 which is better than the score of 4.24 in the 20-55 age group.

For DPM-Search, the most important component of the DPM process, the lower performance scores are also evident, with the differences between vehicle control offenses and the other two offense categories being significant. The trend of lower scores is more evident (i.e., decline faster) in the older age groups. Additionally, the standard deviations in the scores of the older subjects are larger, when compared to the younger subjects. There appears to be some age-related effects <u>within</u> the different analysis categories which are indicated by the generally lower DPM performance scores for the older subjects.

Conversely, the DPM performance scores of the subjects in the speed offense category do not decline with age. The DPM performance scores at three of the four urban site categories for subjects with speed offenses indicate these higher performance scores.

Although there is a general trend for the DPM performance scores to decrease as age increases, there is little consistency when different stratifications such as offense type are applied. The scores for the subjects in the two remaining DPM categories, **speed** and **direction control** do not appear to establish any trends which would lead to conclusions about the performance of the subjects.

Based upon the results of these analyses, subjects with recorded vehicle control offenses would be the best candidates for additional testing to assess their driving capabilities because of their generally lower DPM performance scores. Subjects with speed offenses appear to be the least likely candidates for additional testing based upon their DPM performance.

CONCLUSIONS REGARDING DPM AND DRIVING HISTORY

Comparing DPM performance to past crash history shows that there is not a strong relationship between general crash involvement and DPM performance. When the crash involvement is stratified by **no crash, not-at-fault,** and **at-fault** crash involvement the relationships improve for the subjects in the **at-fault** category, although the differences between the crash types are not significant.

Comparing DPM performance to past offense history shows that there are statistically significant differences for subjects with **vehicle control offenses** as compared to subjects with **no offenses** and **speed offenses.** Within the defined age groups, the difference between DPM scores in the offense type stratifications shows significance only in one age group (75-79 group).

There are age effects within the offense categories with older drivers generally receiving lower DPM scores than younger drivers. The one exception is in the **speed offenses** category where the decline in DPM scores as age increased was not observed.

Analysis of the data leads to the following conclusions:

1. The relationship between general crash involvement and DPM performance does not establish any trend.

2. The relationship between **no-crash, not-at-fault,** and **at-fault** crash involvement and DPM performance shows that **at-fault** subjects have generally lower performance scores, although not statistically significant.

3. The relationship between recorded offenses and DPM performance indicates that the subjects with offenses have generally lower DPM performance scores, although not statistically significant.

4. The relationship between offense types and DPM performance indicates that subjects with **vehicle control offenses** have lower DPM performance scores than subjects with **speed offenses** or **no offenses** and the differences are statistically significant.

5. There are age effects. Older subjects have generally lower DPM performance scores. However, these differences were significant only within the **no offenses** category.

6. Subjects with **speed offenses** had DPM performance scores as good as and sometimes better than the subjects with **no offenses.** Additionally, increasing age did not appear to affect the DPM performance of the subjects with speed offenses.

HYPOTHESES EVALUATION

The comparison of DPM performance with driving history was conducted to ascertain the relationship between past and present measures of performance. Establishing a link between driving history and DPM would help to authenticate the DPM process as a viable method for driving evaluation. Should a suitable relationship be established, the DPM process could be used as part of an intervention program which could use driving history to identify potential problem drivers and use DPM to assess the subject's deficits. Corrective action could then be taken to improve the driving performance of the subject. The research hypothesis for this part of the research is:

There is a correlation between DPM performance and driving history defined by crashes and moving violations.

In a strict interpretation of the results, this hypothesis is false. However, a positive correlation can be shown with **vehicle control offenses** and DPM performance. The relationship is statistically significant, even when age is considered. In an interpretation of the results pertaining to moving violations and DPM performance it can be stated that the hypothesis is true. The process of identifying persons with vehicle control offenses is quite simple. The DPM process identifies those behaviors which can be associated with vehicle control errors. Potential problem drivers can be identified and their negative behaviors addressed.

USEFUL FIELD OF VIEW, DRIVER PERFORMANCE MEASUREMENT, AND DRIVER HISTORY

This section is focused on the utility of using UFOV and DPM performance as predictors of driving performance based upon the historical data from the subjects' driving records. The question to be answered is whether either or both of these measures show significant ability in predicting the occurrence of crashes and/or driving offenses.

Information about UFOV and DPM was discussed in previous chapters. It can safely be said that the pass/fail criterion (score=40) for the UFOV test is an arbitrary measure. The process for identifying this pass/fail criterion in earlier research (Owsley et al., 1991) was to adjust the pass/fail point until the "best" cell populations occurred. In the research conducted here, the UFOV score of 40 corresponds to a point on the range of possible scores approximately one standard deviation above the mean score of 25.5. While this is still an arbitrary criterion, it was arrived at through a different process which helps support the continued use of the pass/fail criterion of 40.

While not utilized in the analysis of DPM performance measures, a pass/fail criterion for the DPM test would also be useful because the nature of most road tests is that a driver either passes or fails the test. The person administering the road test must determine through training and experience what performance level must be attained for the driver to pass the test. This, too, is an arbitrary measure. In the research conducted here, a DPM pass/fail criterion which equated to one standard deviation below the group average was utilized. This relates the DPM pass/fail criterion to the UFOV pass/fail criterion. Greater detail about the development of the

DPM pass/fail criterion will be covered later.

The importance of mentioning both the UFOV and DPM pass/fail criteria at this juncture is in preparation for the analysis to be presented here. Previous chapters dealing separately with UFOV and DPM performance were concerned with the relationship to crash involvement and offenses on driving records. Crashes and driving offenses are not arbitrary measures--a driver has either been involved in a crash or not. The same situation is true for offenses--drivers either have offenses on their driving records or they do not. This chapter will be addressed to the relationships between the UFOV and DPM measures as well as their relationship to the objective measures of crashes and offenses.

UFOV AND DPM

The UFOV research by Owsley et al. (1991) indicated a relatively strong relationship between UFOV performance and the crash and violation history of the tested individuals. However, the strong relationship between UFOV performance and crash involvement was not confirmed in this research effort. Still, the UFOV test may have utility in assessing the performance capability of an individual's driving ability because UFOV testing assesses present performance as does DPM. Eliminating the past/present time comparison component removes the need to allow for medical changes (e.g., cataract removal), educational impacts (e.g., a safe driving course), and behavioral changes (e.g., no night driving). This situation allows for easier direct comparison of UFOV and DPM performance since the analysis is concerned with two "present time" measures.

Direct Comparison

The UFOV testing conducted in previous research established a pass/fail point of 40 (Owsley et al. , 1991). The results of the testing here indicated the score of 40 is approximately one standard deviation away from the average score of all tested subjects (25.5). As previously discussed, because of arriving at a pass/fail criterion of 40 utilizing two different methods (best cell population and one standard deviation from the mean score), a pass/fail score of 40 will continue to be used. Using this pass/fail point there were 218 subjects who passed and 27 who failed the UFOV test.

The average overall score for all subjects from the DPM performance analysis was approximately 94 percent with a standard deviation of approximately 7 points. Following the example of the pass/fail criterion being one standard deviation from the mean score used for the UFOV testing, a pass/fail point for the DPM testing was established at 87, which is one standard deviation below the mean DPM-overall score. Since direct comparison between UFOV and DPM performance is being done, this criterion makes intuitive sense.

The process utilized to determine the "best" UFOV score by Ball et al., (1993) was to adjust the pass/fail criterion until the best cell populations were obtained. Part of this research effort was to follow this process to determine the best UFOV score. Several different UFOV pass/fail scores were analyzed. The UFOV score of 25.5 was evaluated because it was the mean score of all tested subjects. The UFOV score of 50 was evaluated because this criterion resulted in a number of subjects failing the UFOV test (17) approximately equal to the number of subjects failing the DPM test (16).

Comparing the three UFOV criteria (25.5, 40, and 50) indicated that the UFOV score of 40 produced the "best" results.

Further evaluation of the UFOV pass/fail criterion was conducted by analyzing the results of UFOV pass/fail scores of 37.5 and 42.5. The differences in the results when comparing the three UFOV scores (37.5, 40, and 42.5) indicated that the score of 42.5 produced the best results. However, the results from using the UFOV pass/fail criterion of 42.5 was that only one more subject was correctly categorized than when the pass/fail criterion of 40 was used (210/239 vs. 209/239). The tables showing the results of the evaluation of the different UFOV pass/fail criteria (25.5, 37.5, 42.5 and 50) are contained in appendix C.

As stated before, there are data from 245 subjects. Because some subjects did not complete the DPM portion of the testing, there is a total of 239 subjects for whom both UFOV and DPM performance scores are available. Of the six subjects who did not complete the DPM portion of the testing, five were due to the failure of their vehicle to pass the inspection. The one remaining subject did not complete the DPM portion because of the failure to pass the Michigan Department of State vision screening test (i.e., visual acuity of 20/40 or better).

The results of the direct comparison of UFOV and DPM performance using the pass/fail criterion of 40 are summarized in Table 36. This process results in correctly classifying 87.4 percent of all the cases. "Correct" classification means that a failure on UFOV testing corresponds with DPM failure and passing the UFOV test corresponds with passing the DPM test. Correct classifications are on the diagonal in the matrix in Table 36.

Table 36. Direct Comparison of UFOV and DPM Performance Scores. UFOV Pass/Fail Criterion of 40.

	DPM > 87 (Pass)	DPM ≤ 87 (Fail)	Totals
UFOV ≤ 40 (Pass)	203 91.0%	10 62.5%	213
UFOV > 40 (Fail)	20 9.0%	6 37.5%	26
Totals	223	16	239
Percentages are based on predicting DPM category by UFOV performance. 209 out of 239 (87.4%) cases are categorized correctly.			

More importantly, while only 6.7 percent (16/239) of all the subjects failed the DPM portion, the UFOV test identified 37.5 percent (6/16) of the failing subjects. To illustrate: In a situation knowing that 6.7 percent of a population are defined as "poor" drivers, and using a process of randomly selecting people for increased testing, only one of every sixteen drivers would, on average, be classified as a "poor" driver, using the DPM criteria. The UFOV test correctly identified six out of sixteen. Based upon this result, the UFOV test performs much better than a random selection process in identifying drivers with a low DPM score.

The general results of the evaluation of the different UFOV pass/fail criterion are summarized in Table 37. These results indicate that selecting the "best" UFOV pass/fail criterion is a difficult task. The pass/fail criterion of 25.5 produces the highest number of failing subjects but also gives the lowest overall percent correct.

Since the number of incorrectly categorized subjects is high, with seventy-two subjects incorrectly categorized by the UFOV score as "failing," the utility of the UFOV criterion of 25.5 is substantially reduced.

Table 37. Prediction of DPM Pass/Fail Performance Using Different UFOV Pass/Fail Criteria.

UFOV pass/fail Criterion	Correctly Predicted Passing out of 223	Correctly Predicted Failing out of 16	Number Correct out of 239	Overall Percent Correct
25.5	151	13	164	68.6%
37.5	195	8	203	84.9%
40*	203	6	209	87.4%
42.5	204	6	210	87.9%
45	210	5	215	90.0%
50	210	4	214	89.5%

*Criterion from previous research

The UFOV pass/fail criterion of 50 produces the best overall results. Unfortunately, this criterion identifies only four of the sixteen failing subjects. The objective of the testing process is to identify potentially poor drivers and this criterion misses too many subjects in the failing category.

The UFOV criterion of 37.5 identifies one-half of the failing subjects which is a 33.3 percent increase from the number of failing subjects identified using 40 as the UFOV pass/fail criterion. Unfortunately, there is a corresponding increase of 40 percent in the number of incorrectly categorized passing subjects (from 20 to 28). The overall performance at this criterion is lower than the overall performance using 40 as the pass/fail criterion.

At this juncture, deciding which UFOV score provides the "best" results is not entirely clear. However, the argument can be made for the continued use of 40 as the pass/fail criterion. Using 40 provides consistency with previous research efforts (Owsley et al., 1991) and is the criterion which is one standard deviation from the mean score of 25.5.

Conclusions from Direct Comparison

As mentioned before, previous research efforts have established the UFOV pass/fail criterion of 40 (Owsley et al., 1991). Based on the results of the analysis of the data used in this research, a pass/fail criterion of 37.5, 40, or 42.5 could reasonably be employed because of the number of correctly categorized subjects. However, the differences in the results of the analyses at the UFOV pass/fail criteria of 37.5, 40, and 42.5 are small. For the purposes of consistency with previous research, the UFOV pass/fail criterion of 40 will continue to be used in this research effort.

Utilizing the UFOV pass/fail criterion of 40 yields an overall performance score of 87.4 percent. Only six of the sixteen subjects who failed the DPM test are identified by the UFOV test. There are also twenty subjects who passed the DPM test who are categorized as failing by the UFOV test. The number of subjects incorrectly identified by the UFOV test as failing is cause for concern because only 23.1 percent of the subjects identified by the UFOV test as failing were actually poor performers on the DPM test. The UFOV test identifies a higher percentage (37.5%) of "poor" drivers as determined by the DPM performance scores than the UFOV test identifies when "poor" drivers are identified by at-fault crash involvement (14.3%). Using UFOV performance in conjunction with other measures may identify a higher percentage of poor drivers as identified by crash involvement, which is less arbitrary than DPM performance when determining poor driving behavior.

ANALYSES OF CRASH INVOLVEMENT

Since crash involvement is a more acceptable measure of poor driving performance, it was desirable to assess different combinations of the previously identified measures (UFOV, DPM, offenses, and age) to determine if a model (or models) could be developed that would use the available data to predict crash involvement.

Discriminant Analysis

The data collected for this research are in different forms. Some data, such as UFOV and DPM scores, are continuous. Other data, such as crash involvement and offenses, are essentially dichotomous (i.e., yes/no). To evaluate the different combinations of data, discriminant analysis was employed to determine which combinations provided the "best" models for predicting membership in different groups (e.g., crash-involved or not-crash-involved). Predicting membership in the two crash-related groups (i.e., **crash/no crash** and **at-fault/not-at-fault/no crash)** were the most important results from this area of the research effort. Crash involvement is the most severe situation that occurs in the driving environment and, therefore, predicting crash involvement is a high priority in highway safety related research.

After conducting analysis using data from the individual categories, combinations of different data were also analyzed. Some of the data from the individual categories were directly related to other data categories, such as the UFOV components of Processing Speed, Divided Attention, and Selective Attention being directly related to the UFOV total score. Care was taken not to conduct analyses using the component scores and the total scores in the same process. This was done to eliminate over-counting the effects of the different data.

General Crash Involvement

In previous sections, the general evaluation process focused on predicting crash involvement. The same evaluation process was utilized in this section for the prediction of crash involvement using different combinations of data. Each variable considered potentially important was compared with crash involvement individually before the analyses of combinations of variables were attempted.

The process using discriminant analysis was repeated for each variable of importance. A detailed description will be provided for the prediction of crash involvement using offense data. The rest of the data considered were analyzed using the same process. Examples of the discriminant analysis procedures are shown in appendix C.

Prediction of General Crash Involvement

General crash involvement (dependent variable) has two potential outcomes: crash-involved and not-crash-involved. The offense data (independent variable) are grouped into three categories: speed offenses, vehicle control offenses, and no offenses. The discriminant analysis process begins by determining the population of the subjects in the crash-involved and not-crash-involved categories. The output from the first step of the discriminant analysis follows:

Number of cases by group

	Number of cases		
CRSH	**Unweighted**	**Weighted**	**Label**
0	**164**	**164.0**	**no crashes**
1	**81**	**81.0**	**1 or more crashes**
Total	**245**	**245.0**	

The next step in the discriminant analysis process is to determine the statistical relationship between crash involvement (dependent variable) and offenses (independent variable). The output gives a value for Wilks' Lambda and an F value. These values are a measure of the strength of the relationship between the variance in the dependent variable (crashes) and the independent variable (offenses). The output of this step follows:

Wilks' Lambda (U-statistic) and univariate F-ratio with 1 and 243 degrees of freedom

Variable	Wilks' Lambda	F	Significance
OFFENSE	**.85132**	**42.4379**	**.0000**

The value of the F-statistic indicates that there is a strong relationship between the dependent (crash involvement) and independent (offenses) variables. The value of the Wilks' Lambda is an indication of the discriminating power of the variable used in this process. A value close to 1 (range = 0 to 1) is an indication that the group means (crash/no crash) are nearly equal. While the Wilks' Lambda value is relatively high, it is still statistically significant and this variable is not excluded from the analysis. The Wilks' Lambda and F-statistic values are used to determine the tolerance for using the data in the rest of the analysis. For example, the minimum value (tolerance) for the F-statistic to be significant is 3.84. The value shown here (F=42.44) is significant.

Based on the value of the discriminant function, a probability score is determined. To determine to which group an observation belongs, since there are two groups in this example, there will be two probability scores computed, one score for group 1 and another score for group 2. The higher probability score of the two determines to which group the observation will be assigned. The entire process is repeated using all the data and adjusting the weighting of the independent variable until the best discrimination (i.e., classification) between the two groups occurs. The classification using offense data to predict crash involvement follows:

Classification results -

Actual Group	No. of Cases	Predicted Group Membership 0	1
Group 0 no crashes	**164**	**132** 80.5%	**32** 19.5%
Group 1 one or more crashes	**81**	**34** 42.0%	**47** 58.0%

Percent of "grouped" cases correctly classified: 73.06%

Using recorded offenses to predict crash involvement produces the correct categorization approximately seventy-three percent of the time. Since it is more important to identify poor (i.e., crash-involved) drivers, it is more desirable to identify a high percentage of crash-involved drivers. In this case, fifty-eight percent of the crash-involved drivers were correctly categorized; eighty and one-half percent of the non-crash-involved drivers were correctly categorized; and, overall, out of the 245 subjects, sixty-six (27%) were incorrectly categorized.

Whether the level of incorrectly categorized subjects is acceptable or not depends upon the use of the data. For example: if it were decided to require persons with recorded offenses to complete additional training in order to retain their drivers license, this process would select seventy-nine persons from this subject pool. Of those seventy-nine subjects, forty-seven (59.5%) would be crash-involved while the other thirty-two subjects would be non-crash-involved. Is it necessary to require all of the seventy-nine persons to complete further training based upon their crash history? This question is beyond the scope of this project and is one that does not have an easy answer.

The results of this discriminant analysis procedure (using offenses to predict crash involvement) indicates that offenses are statistically significant as a predictor of crash involvement. Operationally, the level of incorrectly categorized subjects may be too high for practical applications.

It should also be noted that, intuitively, a person who is defined as at-fault in this research would likely have an accompanying recorded offense. Many, but not all, of the at-fault subjects did have recorded offenses. Some of the at-fault subjects had no recorded offenses. Unfortunately, the format of the data were such that it was not possible to identify which subjects had recorded offenses which were related to at-fault crash-involvement. Therefore, since there is a level of separation between the at-fault subjects with offenses and at-fault subjects without offenses, the analyses will continue with recognition that the level of statistical independence between at-fault crash-involvement and recorded offenses may be questionable.

The discriminant analysis process to predict crash involvement was repeated using UFOV scores, DPM scores, age, and age group data as the independent variables. The predicted group membership and percentage of correctly categorized cases using the independent variables individually (i.e., not grouped) are summarized in Table 38.

The only individual variable which had a significant relationship with crash involvement was **offenses**. The offense data were used for the analysis in two different forms: 1) offenses/no offenses, and 2) no offenses/speed offenses/vehicle control offenses. The categorical and overall percentage results are the same for either of the combinations of offense data.

While none of the UFOV or DPM scores were significant in predicting crash involvement, variables such as UFOV-Processing Speed, UFOV pass/fail, and DPM-Search identified a large percentage of either crash-involved or non-crash-involved subjects. This indicates that these variables could be significant if used in combination with other variables for predicting crash involvement.

Differences Between Speed and Vehicle Control Offenses

To ascertain if there was a difference between speed offenses and vehicle control offenses, additional analyses were conducted. The subjects were separated into three categories (no offenses, speed offenses, and vehicle control offenses) and analyses conducted. Again, this was done to ascertain what impact speed offenses and vehicle control offenses have individually on crash involvement. The results are

Table 38. Discriminant Analysis Predictions of Crash Involvement

	No Crashes		Crash Involved			
Variable Name	Actual	Predicted	Actual	Predicted	% Correct	Significant
Offenses (type)	164	132 80.5%	81	47 58.0%	73.06%	YES
Offenses (yes/no)	164	132 80.5%	81	47 58.0%	73.06%	YES
DPM Overall	161	67 41.6%	78	48 61.5%	48.12%	NO
DPM Search	161	121 75.2%	78	32 41.0%	64.02%	NO
DPM Speed	161	84 52.2%	78	46 59.0%	54.39%	NO
DPM Direction Control	161	89 55.3%	78	44 56.4%	55.65%	NO
UFOV Total	164	61 37.2%	81	54 66.7%	46.94%	NO
UFOV Sel.Attn	164	80 48.8%	81	43 53.1%	50.20%	NO
UFOV Div.Attn	164	63 38.4%	81	52 64.2%	46.94%	NO
UFOV Proc.Spd	164	24 14.6%	81	73 90.1%	39.59%	NO
AGE	164	117 71.3%	81	29 35.8%	59.59%	NO
Young/Old	164	118 72.0%	81	29 35.8%	60.00%	NO
DPM pass/fail	164	151 92.1%	81	9 11.1%	65.31%	NO
UFOV pass/fail	164	146 89.0%	81	9 11.1%	63.27%	NO

summarized in Table 39. They indicate that subjects with speed offenses or vehicle control offenses on their driving record are equally likely to be identified as crash-involved using this process.

Table 39. Discriminant Analysis Prediction of Crash Involvement Using Specific Offense Data

	No Crashes		Crash Involved		
Variable	Actual	Predicted	Actual	Predicted	% Correct
No Offenses/ Speed Offenses	153	132 86.3%	59	25 42.4%	74.06% 157/212
No Offenses/ Vehicle Control Offenses	143	132 92.3%	56	22 39.3%	77.39% 154/199
Both predicting models are statistically significant.					

Predictions Using Combinations of Variables

The variables which were used individually in the analysis were also combined in different ways to determine whether the combined efforts would perform better in terms of prediction of crash involvement. There are four primary categories of variables used in the prediction of crash involvement: DPM performance; UFOV performance; age; and offenses. While component scores of, for example, UFOV performance were also examined, in no instance was the overall UFOV score used in the same models as the component scores.

After all of the analyses were conducted, the only variable which significantly explained the prediction of crash involvement was offenses. This situation was true for either of the groupings of the offense data: offenses/no offenses or speed offenses/vehicle control offenses/no offenses.

At-Fault Crash Involvement

The analysis of crash involvement was further broken down to identify the subjects who were determined to be at-fault, those who were not-at-fault, and those subjects who were not-crash-involved. The process of comparing the variables one at a time is still useful because some potential combinations of variables may become more apparent. The results of the individual comparison processes are summarized in Table 40. As was the case for predicting general crash involvement, only **offenses** is significant for prediction of crash involvement when fault is assigned.

Predictions Using Combinations of Variables

Combining variables from the four general areas (offenses, age, UFOV, and DPM) to create a predictive model using several variables resulted in offenses being the only significant variable in any equation. This is the same situation as for general crash involvement. By dividing the crash-involved subjects into three categories, the predictive power of the **offenses** variable actually decreases from 73.1 to 66.5 percent correct categorization.

While age as a single independent variable was not a significant contributor to the prediction of crash involvement, it was noted in the UFOV section as being significant in predicting UFOV scores. Because of the concern about age, further analysis of crash involvement will be done by analyzing the younger subjects and older subjects separately.

Table 40. Discriminant Analysis Predictions of No Crash, At-Fault, and Not-At-Fault Crash Involvement

	No Crashes		At-Fault Crash		Not-At-Fault Crash	
Variable	Actual	Predicted	Actual	Predicted	Actual	Predicted
Offenses (type)	164	132 80.5%	42	31 73.8%	39	0 0%
Offenses (yes/no)	164	132 80.5%	42	31 73.8%	39	0 0%
DPM Overall	161	12 7.5%	39	17 43.6%	39	28 71.8%
DPM Search	161	16 9.9%	39	13 33.3%	39	26 66.7%
DPM Speed	161	11 6.8%	39	26 66.7%	39	20 51.3%
DPM Direction Control	161	89 55.3%	39	3 7.7%	39	22 56.4%
UFOV Total	164	61 37.2%	42	1 2.4%	39	27 69.2%
UFOV Sel.Attn	164	80 48.8%	42	0 0%	39	22 56.4%
UFOV Div.Attn	164	0 0%	42	18 42.9%	39	28 71.8%
UFOV Proc.Spd	164	24 14.6%	42	0 0%	39	35 89.7%
AGE	164	117 71.3%	42	16 38.1%	39	0 0%
Young/Old	164	118 72.0%	42	16 38.1%	39	0 0%
DPM pass/fail	164	0 0%	42	8 19.0%	39	37 94.9%
UFOV pass/fail	164	0 0%	42	6 14.3%	39	36 92.3%

Contribution of Age

Predicting the crash involvement of the younger group (age 20-55) using discriminant analysis showed that the only variable with significant predicting power was offense. Also, because this process did not predict any subjects to be in the not-at-fault category and because earlier results showed similar characteristics between the non-crash and not-at-fault crash subjects, these two categories were combined into a single category. The offense variable does appear to identify the at-fault crash-involved younger drivers quite well (13 of 16). The overall percentage of correctly categorized subjects was 73.3 percent. No other variable approached the level of significance necessary to enter the step-wise process.

Predicting the crash involvement of the older subjects (age 65 and older) using the discriminant analysis procedure showed that the only independent variable with significance was offenses. As was the case with the younger subjects, the non-crash and not-at-fault crash-involved subjects were combined into a single variable. The offense variable identified two-thirds of the at-fault crash-involved subjects in the older group (18 of 27). Overall, the percentage of correctly identified subjects was 76.5 percent. No other independent variable approached the level necessary for it to enter the step-wise process.

Conclusions Regarding Crash Involvement Prediction

Using discriminant analysis to construct a model from the collected data to predict the crash involvement of the subjects resulted in data from **offenses** being the only significant variable. While some of the UFOV and DPM testing results indicated some trends toward predicting crash involvement, none were sufficiently strong to be included in any of the univariate or multi-variate models constructed with the discriminant analysis procedure.

ANALYSES OF OFFENSES

The prediction of the occurrence of a recorded offense on a subject's driving record was attempted in the previous sections covering UFOV and DPM processes. The same prediction using discriminant analysis was done here to employ a statistical process to help in the modeling process. The results of predicting offenses with individual variables (as described earlier) are summarized in Table 41. The first attempt at predicting offenses with this process was to try to predict whether or not (yes/no) a subject had a recorded offense on their driving record.

Types of Offenses

As described earlier, subjects have been separated into three categories based on offense data: no offenses, speed offenses, and vehicle control offenses. Discriminant analysis was again employed to determine which variables yield the best predictions of subjects' recorded offenses in one of three groupings. The results of this analysis are summarized in Table 42. Individually, there are no variables which are statistically significant in predicting recorded offenses. The individual variable which yields the "best" results is DPM pass/fail. However, the majority of the correctly placed subjects is in the **no offenses** category, and only eight subjects are placed in **vehicle control offenses** category and no subjects are placed in the **speed offenses** category. The individual variable which identifies the highest percentage of subjects in

Table 41. **Discriminant Analysis Predictions of Recorded Offenses: No Offenses and One or More Offenses**

	No Offenses		One or More Offenses			
Variable Name	Actual	Predicted	Actual	Predicted	% Correct	Significant
DPM Overall	163	113 69.3%	76	30 39.5%	59.83%	NO
DPM Search	163	122 74.8%	76	31 40.8%	64.02%	NO
DPM Speed	163	78 47.9%	76	38 50.0%	48.54%	NO
DPM Direction Control	163	86 52.8%	76	39 51.3%	52.30%	NO
UFOV Total	166	58 34.9%	79	49 62.0%	43.67%	NO
UFOV Sel.Attn	166	81 48.8%	79	42 53.2%	50.20%	NO
UFOV Div.Attn	166	63 38.0%	79	50 63.3%	46.12%	NO
UFOV Proc.Spd	166	143 86.1%	79	9 11.4%	62.04%	NO
AGE	166	120 72.3%	79	30 38.0%	61.22%	NO
Young/Old	166	121 72.9%	79	30 38.0%	61.63%	NO
DPM pass/fail	166	156 94.0%	79	12 15.2%	68.57%	NO
UFOV pass/fail	166	148 89.2%	79	9 11.4%	64.08%	NO

Table 42. Discriminant Analysis Predictions of Recorded Speed and Vehicle Control Offenses

	No Offenses		Speed Offenses		Vehicle Control Offenses	
Variable Name	Actual	Predicted	Actual	Predicted	Actual	Predicted
DPM Overall	163	101 62.0	45	9 20.0%	31	11 35.5%
DPM Search	163	59 36.2%	45	25 55.6%	31	11 35.5%
DPM Speed	163	11 6.7%	45	23 51.1%	31	16 51.6%
DPM Direction Control	163	20 12.3%	45	27 60.0%	31	17 54.8%
UFOV Total	166	19 11.4%	46	30 65.2%	33	13 39.4%
UFOV Sel.Attn	166	0 0%	46	28 60.9%	33	19 57.6%
UFOV Div.Attn	166	0 0%	46	32 69.6%	33	15 45.5%
UFOV Proc.Spd	166	0 0%	46	42 91.3%	33	5 15.2%
AGE	166	1 0.6%	46	21 45.7%	33	24 72.7%
Young/Old	166	121 72.9%	46	21 45.7%	33	0 0%
DPM pass/fail	166	156 94.0%	46	0 0%	33	8 24.2%
UFOV pass/fail	166	0 0%	46	43 93.5%	33	6 18.2%

the speed and vehicle control offenses categories is UFOV pass/fail. Performing analysis using this variable identifies forty-three subjects in the speed offenses category and six subjects in the vehicle control offenses category (i.e., 49 of the 79 subjects are identified). Unfortunately, this variable does not place any subjects into the no offenses category so the overall performance using this variable is quite low (20% correct). The reason for predicting the high number of subjects with speed-related offenses may be related to the homeostasis effect. Homeostasis is the "comfort level" of an individual in given situations, such as operating a motor vehicle. Every individual internally assesses the situation and adjusts their behavior to maintain their comfort level. The subjects with recorded speed offenses may feel more comfortable driving at higher speeds for a variety of reasons including: excellent judgement of the traffic situation, good vision and good search behavior, and good decision making processes. The subjects with recorded speed offenses have a lower mean UFOV-Overall score and a smaller standard deviation than the subjects in both the no offense and vehicle control offense categories. The UFOV-Overall mean score and standard deviation for each offense group is shown in Table 43. This topic was covered in the chapter on UFOV performance.

Analysis Using Combinations of Variables

Using the procedure for combining variables that was described in the section regarding prediction of crash involvement, several analyses were performed with different combinations. The discriminant analysis procedure used the step-wise process where the variable with the strongest relationship to the offense data (i.e., largest F-statistic value) entered the process first. After the first variable was selected, no other variables had a value large enough to enter the process. None of the combinations was able to improve the predictive power of the individual variables. No combination of variables was statistically significant in predicting recorded offenses.

Table 43. UFOV Overall Score and Standard Deviation for Subjects in the Three Offense Categories

Variable	UFOV Overall Mean Score	Standard Deviation	Minimum/ Maximum
No Offenses	25.7	15.8	5/90
Vehicle Control Offenses	31.1	20.6	5/90
Speed Offenses	20.9	12.2	5/47.5

Conclusions in Regard to Predicting Recorded Offenses

The analyses of the data indicates that none of the UFOV test results, driving test information, or age data are significantly related to the occurrence of recorded offenses on a subjects driving record.

ANALYSES OF COMBINED CRASH/OFFENSE DATA

Because the data from predicting crash involvement indicate a relationship with offenses, the recorded data pertaining to crash involvement and recorded driving offenses were combined for the purpose of discriminant analysis. These data are defined as driver error data since crashes and offenses can be identified as resulting in crashes or citations. The subjects were placed in one of four groups: 1) no crashes/no offenses; 2) crash-involved/no offenses; 3) no crashes/recorded offenses; and 4) crash-involved/recorded offenses. The results of these analyses are summarized in Table 44. There were no individual variables which proved to be statistically significant in categorizing the data. The DPM-search performance scores gave the best overall results with 49.4 percent of the subjects correctly categorized. The majority of the subjects in the correct category was in the no crashes/no offenses category with 76 percent correct. However, this variable only correctly placed 20 of a possible 110 subjects into the remaining three categories. The DPM-Direction Control performance scores gave the best results for placing subjects into the three "problem" categories, with 48 of a possible 110 subjects placed into the proper categories. Unfortunately, only 6 of a possible 129 subjects were placed into the no crashes/no offenses category, which gave an overall performance score for DPM-Direction Control of 22.6 percent.

Analysis Using Combinations of Variables

Combinations of the different variables were used to predict which subjects belong in each of the four crashes/offenses categories by use of the step-wise discriminant analysis procedure. There were no combinations of variables which would perform the prediction process better than the "best" performing individual variables.

Conclusions Regarding Combined Crash and Offenses Analysis

Earlier analyses indicated that recorded offenses are a good predictor of crash involvement. By combining crash and offense data as driver error data and using that to define group membership, it was hypothesized that there was a potential for other data to be used to correctly predict which subjects should be in the driver error

Table 44. Discriminant Analysis of Combined Crash and Offense Data.

	No Crashes No Offenses	Crash Involved No Offenses	No Crashes Recorded Offenses	Crash Involved Recorded Offenses
Variable Name	Act/Pred %	Act/Pred %	Act/Pred %	Act/Pred %
DPM Overall	129/24 18.6%	34/19 55.9%	32/8 25%	44/7 15.9%
DPM Search	129/98 76.0%	34/0 0%	32/5 15.6%	44/15 34.1%
DPM Speed	129/0 0%	34/1 2.9%	32/19 59.4%	44/25 56.8%
DPM Direction Control	129/6 4.6%	34/1 2.9%	32/21 65.6%	44/26 59.1%
UFOV Total	132/49 37.1%	34/23 67.6%	32/2 6.2%	47/0 0%
UFOV Sel.Attn	132/64 48.5%	34/0 0%	32/0 0%	47/26 55.3%
UFOV Div.Attn	132/53 40.2%	34/24 70.6%	32/0 0%	47/0 0%
UFOV Proc.Spd	132/0 0%	34/32 94.1%	32/0 0%	47/6 12.8%
AGE	132/97 73.5%	34/0 0%	32/12 37.5%	47/0 0%
Young/Old	132/98 74.2%	34/0 0%	32/0 0%	47/18 38.3%
DPM pass/fail	132/0 0%	34/33 97.1%	32/0 0%	47/8 17.0%
UFOV pass/fail	132/0 0%	34/32 94.1%	32/0 0%	47/7 14.9%

categories. This hypothesis was not confirmed and no variables were identified which would predict the distribution of subjects into the four crashes/offenses categories.

AGE GROUP PREDICTIONS

Because some of the earlier results discussed here indicated that some of the UFOV test results showed a strong relationship to age, further analyses were conducted using discriminant analysis to see if this relationship continued to be indicated and if any variables, other than the ones already identified, contributed to the strength of the relationship.

Age Group Identification and Analysis

The subjects in the research were divided into two age groups: 20-55 (younger) and 65 and over (older). The database has 75 subjects in the younger group and 170 in the older group. Using the same variables as previously identified, analyses were conducted and the results are summarized in Table 45. (The results show the contribution of the UFOV tests, DPM performance, and offense data to the identification of age group.) The UFOV-Overall score, UFOV-Selective Attention, and UFOV-Divided Attention all correctly predict the age group of the subjects with statistical significance. Other variables of note are: DPM pass/fail and UFOV pass/fail which both correctly categorized 96 percent of the younger subjects; DPM-Search which correctly categorized 84.9 percent of the younger subjects; and general offense data (yes/no) which correctly categorized 85.3 percent of the older subjects. However, the predicting power of these four variables for placing subjects into the alternate groups was quite poor (range 11.2 to 36.7 percent correctly categorized) which indicates a high number

Table 45. Prediction of Age Group Populations

	Younger Subjects		Older Subjects			
Variable Name	Actual	Predicted	Actual	Predicted	Percent Correct	Signifi cant
DPM Overall	73	52 71.2%	166	76 45.8%	53.56	NO
DPM Search	73	62 84.9	166	61 36.7%	51.46	NO
DPM Speed	73	40 54.8%	166	102 61.4%	59.41	NO
DPM Direction Control	73	46 63.0%	166	96 57.8%	59.41	NO
UFOV Total	75	71 94.7%	170	134 78.8%	83.67	YES
UFOV Sel.Attn	75	73 97.3%	170	116 68.2%	77.14	YES
UFOV Div.Attn	75	69 92.0%	170	86 50.6%	63.27	YES
UFOV Proc.Spd	75	71 94.7%	170	28 16.5%	40.41	NO
Offenses (type)	75	30 40.0%	170	121 71.2%	61.63	NO
Offenses (yes/no)	75	21 28.0%	170	145 85.3%	67.76	NO
At-Fault Crash	75	29 38.7%	170	118 69.4%	60.00	NO
DPM pass/fail	75	72 96.0%	170	19 11.2%	37.14%	NO
UFOV pass/fail	75	72 96.0%	170	24 14.1%	39.18	NO

of incorrectly categorized subjects (i.e., too many false positive categorizations). The results of predictions based on UFOV are similar to the results from earlier sections of this report which also indicated the relationship of UFOV scores with the age of the subject.

Analysis Using Combinations of Variables

The three identified variables which indicate a relationship to the age of the subject are all UFOV scores. Because they are separate components of the overall UFOV score, the UFOV-Selective Attention and UFOV-Divided Attention scores can be combined with one another for analysis. However, neither of these scores can be combined with the UFOV-Overall score. Both variables entered the step-wise discriminant analysis procedure using UFOV-selective Attention and UFOV-Divided Attention and produced better results (statistically significant) than either of the variables produced individually. The results of the discriminant analysis procedure using the UFOV-Overall score were still better than the results obtained using the combination of the two component UFOV scores. This result was expected because the UFOV-Overall score is a direct combination of the three component UFOV scores (UFOV-Processing Speed is the third).

Discriminant analysis procedures conducted with the UFOV scores in combination with the DPM scores and driver history data indicated that none of the combination of variables predicted the age group of the subjects better than the UFOV scores on their own.

Conclusions Regarding Age Group Predictions

The only variables which were able to predict age group classifications with accuracy are the UFOV-Overall, UFOV-Selective Attention, and UFOV-Divided Attention scores. These results are similar to findings found in UFOV analysis section of this paper. The ability to predict the age group of subjects in not necessarily a good characteristic of this test if the UFOV test is being proffered as a surrogate exam for the vision test portion of driving examinations.

ANALYSIS OF PREDICTING UFOV PASS/FAIL

The analyses performed for this part of the report are somewhat of a reversal of the intent of the overall hypothesis. In this section the dependent variable will be the categorization of the subjects by whether they passed or failed the UFOV test. In much of the rest of the analyses in this report, the UFOV performance was used to predict performance in other areas. The process here performs a cross-check on some of the other analyses of the different measures.

UFOV Pass/Fail Criterion

The UFOV score of 40 was used in previous research (Owsley et al., 1991) as the pass/fail criterion, with scores above 40 considered failing and the scores below 40 considered as passing. Results from the section of this report focusing on UFOV performance confirmed the use of 40 as the pass/fail criterion. Of the 245 subjects in this research, 218 passed and 27 failed.

Predictions Using Single Variables

The applicable variables employed in the prior sections of this chapter were tested using discriminant analysis to determine the relationship to the UFOV pass/fail score. The results of these analyses are summarized in Table 46.

The results are similar to results obtained earlier in this report. The two age variables (chronological age and young/old age group) were significant predicting variables for the subjects in the UFOV pass/fail categories. The ability of either age variable to correctly categorize 88.9 percent of the subjects who failed the UFOV procedure is the reason why either variable is statistically significant, even though both of them correctly categorize about one-third of the subjects who passed the UFOV procedure.

The DPM-Overall, DPM-Search, and DPM-Directional Control scores, as well as DPM pass/fail, were also statistically significant in their prediction of UFOV pass/fail categorization. The DPM pass/fail data correctly categorizes 95.3 percent of the subjects who passed the UFOV procedure but correctly identifies only 6 of the 26 subjects who failed the UFOV test. The results from using the three identified DPM component scores show more balanced outcomes. The DPM-Overall and DPM-Direction Control scores correctly categorize 53.8 percent of the UFOV failing subjects and all three correctly categorizing more than 60 percent of the UFOV passing subjects.

Table 46. Predicting UFOV Pass/Fail Group Populations

	UFOV Pass		UFOV Fail			
Variable Name	Actual	Predicted	Actual	Predicted	Correct %	Signif-icance
DPM Overall	213	170 79.8%	26	14 53.8%	76.99%	YES
DPM Search	213	181 85.0%	26	11 42.3%	80.33%	YES
DPM Speed	213	111 52.1%	26	14 53.8%	52.30%	NO
DPM Direction Control	213	128 60.1%	26	14 53.8%	59.41%	YES
DPM pass/fail	213	203 95.3%	26	6 23.1%	87.45%	YES
Age	218	74 33.9%	27	24 88.9%	40.00%	YES
Young/Old	218	72 33.0%	27	24 88.9%	39.18%	YES
Offenses (type)	218	148 67.9%	27	9 33.3%	64.08%	NO
Offenses (yes/no)	218	148 67.9%	27	9 33.3%	64.08%	NO
At-Fault Crash	218	72 33.0%	27	18 66.7%	36.73%	NO

Comparing the results of discriminant analysis using the DPM-Search data with the DPM pass/fail data indicates that while there is a 10.8 percent decrease in the number of subjects correctly categorized as passing the UFOV procedure (from 203 to 181), there is also an 83.3 percent increase (from 6 to 11) in the correct categorization of subjects who failed the UFOV procedure. In general, the process using results from the DPM-Search would be more desirable than the results from the DPM pass/fail process because of more failing subjects being identified.

Analysis Using Combinations of Variables

The combinations of variables which were statistically significant in correctly predicting the group membership of the subjects in the UFOV pass/fail categories generally were DPM measures combined with age measures. The DPM-Overall score combined with age was a significant predictor as was DPM-Search combined with age. The combination of DPM pass/fail and age was a significant predictor. The DPM pass/fail and age group (young/old) combination was also a significant predictor. The significance of the age component would appear to be a carry over effect from the relationship of age and UFOV performance.

Conclusions Regarding UFOV Pass/Fail Predictions

The significant relationship between some components of DPM performance and UFOV performance is encouraging. Both of these measures are "real time" measurements so both procedures produce present time performance evaluations. Because there is significance in the relationship between DPM and UFOV performance measures, it would appear that there is some justification in using the results of UFOV testing as a preliminary screening device for evaluating driver performance. The UFOV screening would allow an observer to evaluate the performance of a subject in a controlled setting. This would minimize endangering the subject, the observer, and other users of the highway system by keeping a potentially poor driver off of the road until sufficient proficiency can be demonstrated.

The indication of age as a predictor of UFOV performance is cause for concern. The apparent strong relationship of UFOV performance with age would be difficult to overcome when trying to propose the UFOV test as a preliminary screening device for all drivers. As stated earlier, there is medical evidence that functions of the human body do deteriorate as we age. To assure the older population that the UFOV testing does not discriminate against older subjects (i.e., the test is not age biased), sufficient testing of younger subjects would need to be conducted to show that the procedure can identify younger drivers with problems similar to those identified in the older age groups. The research conducted here did show that the UFOV procedure correctly categorized the failing subject from the younger subject group. The fact that only one of the seventy-five younger subjects was categorized as failing the DPM procedure makes the results from the analysis unreliable, even though that person was correctly identified by the UFOV procedure. The process of using the UFOV procedure to identify potentially poor drivers would need to include a pre-screening process so that a sufficient number of subjects could be categorized as poor to reduce the number of persons that would have to be evaluated.

ANALYSIS OF DPM PASS/FAIL PERFORMANCE

In this section of the report, discriminant analysis will be used to predict the DPM pass/fail performance of the subjects. The pass/fail criterion was established at a score of 87 (out of 100), which represents the score at one standard deviation below the average score of all the subjects. This score was chosen because it relates to the UFOV pass/fail criterion of 40 which is approximately one standard deviation above the UFOV average score of all the subjects (higher UFOV scores indicating poorer performance).

Predictions Using Single Variables

Repeating the established procedure for predicting which subjects fall into which categories, there were several variables that showed significance for predicting the subjects who were categorized as passing or failing the DPM test. The results of the single variable analyses are summarized in Table 47.

Examining the UFOV-Overall and component scores indicates the UFOV-Overall score correctly categorized the highest number of subjects in the DPM failing category. The UFOV-Processing Speed score
correctly categorized the highest number of subjects in the DPM passing category. Since it is more important to identify poor performance (as it relates to the driving task), the UFOV-Overall score should be considered to be the best performer from the group of UFOV scores. Using age as a predicting variable for DPM passing and failing correctly identified the highest number of subjects failing the DPM test (15 of 16). However, the process correctly identified only 40.4 percent of the subjects

Table 47. Predicting DPM Pass/Fail Group Populations

	DPM Pass		DPM Fail			
Variable Name	Actual	Predicted	Actual	Predicted	% Correct	Significant
UFOV Total	223	173 77.6%	16	11 68.8%	76.99%	YES
UFOV Sel.Attn	223	158 70.9%	16	10 62.5%	70.29%	YES
UFOV Div.Attn	223	191 85.7%	16	8 50.0%	83.26%	YES
UFOV Proc.Spd	223	197 88.3%	16	5 31.3%	84.52%	YES
UFOV pass/fail	223	203 91.0%	16	6 37.5%	87.45%	YES
Age	223	90 40.4%	16	15 93.8%	43.93%	YES
Young/Old	223	72 32.3%	16	15 93.8%	36.40%	YES
Offenses (type)	223	156 70.0%	16	9 56.3%	69.04%	YES
Offenses (yes/no)	223	156 70.0%	16	9 56.3%	69.04%	YES
Crash (y/n)	223	151 67.7%	16	6 37.5%	65.69%	NO
At-Fault Crash	223	72 32.3%	16	10 62.5%	34.31%	NO

passing the DPM test. So while the variable is considered to be statistically significant, it is only because of the high number of subjects placed in the failing category. The results using age group (young/old) categories to predict DPM pass/fail are the same for the failing subjects (15 of 16) and is worse (32.3% vs. 40.4% correct) for the passing subjects.

The use of recorded offense data to predict which subjects passed and failed the DPM testing indicated that offense data is a significant predictor. This situation is true for the analysis using the three offense types (no offense, speed offense, and vehicle control offense) and for when the recorded offenses are considered without regard to offense type (offense present or not). The significance of this predicting variable is attributable to the identification of the failing subjects (9 of 16).

Crash involvement was not a significant predictor of DPM performance in either the crash/no crash form or the no crash/not-at-fault crash/at-fault crash form. The second form did identify 10 of 16 failing subjects but only identified 32.3 percent of the passing subjects. Being able to identify the subjects with at-fault crash involvement improves the ability to categorized failing subjects. However, the low number of subjects correctly categorized as passing the DPM procedure (72 out of 223) indicates that the penalty is severe (i.e., a high number of false positives) for correctly categorizing a large number of subjects who failed the DPM procedure. Using the discriminant analysis process with at-fault crash involvement as the independent variable to predict membership in the two DPM categories, 161 subjects are identified as failing but only 10 actually failed.

Analysis Using Combinations of Variables

Several combinations of the independent variables resulted in prediction models which were statistically significant. Step-wise discriminant analysis starting with **age, offenses, UFOV-Overall score, and crash involvement** as the independent variables resulted in **UFOV-Overall** and **offenses** as being significant in the process. Additionally, the following combinations of variables were also statistically significant in predicting the subjects in the DPM pass/fail categories:

1. UFOV-Selective Attention and offenses;
2. UFOV pass/fail and offenses; and
3. UFOV pass/fail, offenses, and age.

An interesting observation regarding this process pertains to the contribution of age to the process. In the original (independent) assessment of the variables, age data are identified as significant to the accuracy of the model. However, once the UFOV-Overall score (or the UFOV-Selective Attention score) enters the process, the significance attributed to age is reduced to a level below the minimum criterion to enter the process. This indicates that age is strongly correlated to UFOV performance. This is the same situation observed in previous chapters regarding analysis of UFOV scores. At this point it was decided to explore in more detail the contribution of age to this particular process (prediction of DPM pass/fail).

The Contribution of Age

The accounting for age was done by utilizing the previously defined age groups of younger (20-55 years of age) and older (over 65 years of age) subjects. Discriminant analyses were conducted on both of these groups using the same variables used in the analysis of the entire population: UFOV-Overall score, offenses, and age. Age is the chronological age of the subjects within the group and is included in the analysis to ascertain what affect, if any, age had on the predictive power of the models.

Analysis of the Younger Age Group

The range in ages for the younger group was from twenty-one to fifty-one years old, a span of 30 years. For the younger group only UFOV-Overall score was a significant predictor for the subjects in the DPM pass/fail categories. Neither offenses or age were significant enough (even when analyzed separately) to be included in the process. The population of the younger group is seventy-three with only one subject failing the DPM test. The discriminant analysis process correctly identified the one failing subject and seventy of the seventy-two passing subjects. The overall percentage of correctly classified cases was 97.26 percent. While this result is encouraging, the results should be interpreted with caution because of the small number of subjects in the DPM failing category. Further analysis using younger subjects would need to be undertaken to provide support (or lack of) for this result because only one subject failed the test.

Analysis of the Older Age Group

The range in age for the subjects in the older group was from sixty-five to eighty-nine years old, a span of twenty-four years. For the older group all three of the independent variables (age, UFOV-Overall, and offenses) were originally identified as significant. Age was the first variable to enter the step-wise process. Once age entered the process, the significance of the UFOV-Overall score decreased to below the level required to enter the process. Offenses were still identified as significant and entered the process on the next step. The significance of the UFOV-Overall score was again reduced by the inclusion of the offenses variable, although the reduction was minimal, compared to the reduction resulting from the inclusion of age in the process. The variables age and offenses correctly identified nine of the fifteen failing subjects and 113 of the 151 passing subjects. The percentage of cases correctly categorized in the older age group using age and offenses is 73.5 percent. The significance of the contribution of age to the process indicates there is a difference between the younger old and the older old.

It is apparent that age and UFOV performance are related, even within the older age group. Comparing the performance of the combination of age and offenses with the combination of UFOV-Overall score and offenses for correctly predicting the subjects in the DPM pass/fail categories indicates that the UFOV-Overall/offenses combination is a slightly better performer. Both combination correctly categorize nine of the fifteen failing subjects. The UFOV-Overall/offenses combination correctly categorizes 116 of the 151 passing subjects, compared to 113 of 151 for the age/offenses combination, an increase of three subjects.

The Contribution of Offense Type Within the Older Group

Because the offense data is in three groups (no offenses, speed offenses, and vehicle control offenses), further analysis was done to ascertain what the effects of the different offense types are as they relate to DPM performance. Two separate analyses were conducted with two sets of data.

The first analysis consisted of discriminant analysis using the UFOV-Overall score, age, and no offenses/vehicle control offenses (i.e., subjects with speed offenses were not included). In this subgroup of the older subjects there are 128 subjects who passed and 13 subjects who failed the DPM test. All of the variables used in this analysis are identified as significant. Age again is the first variable to enter the step-wise discriminant analysis process. The significance of the UFOV variable drops below the minimum level needed to enter the process when age is selected. Offenses enter the process on the second step. The UFOV score does not enter the process. The overall percentage of correctly categorized subjects is 73.1 percent, which is approximately equal to the 73.5 percent of the correctly categorized subjects when all of the offense data is used in the analysis.

Performing the discriminant analysis process using offense data containing the subjects with no offenses and speed offenses (i.e., no subjects with vehicle control offenses are in the sample) yields an interesting result. None of the three variables are now significantly related to the DPM performance score. This result confirms the finding in the chapter covering DPM performance and driving history that indicated the subjects with speed offenses performed as well as the subjects with no offenses and there was minimal age effect on the DPM performance of these subjects.

Conclusions Regarding DPM Pass/Fail Analysis

As previously stated, the pass/fail criterion of the DPM process was somewhat arbitrarily chosen to be one standard deviation below the average DPM score of all the subjects. In the sample of subjects used for this research effort, the UFOV-Overall score is the best single predictor of DPM pass/fail categorization. Offenses are also significantly related to the DPM pass/fail categorization of the entire sample. Unfortunately, age is also significantly related to the DPM pass/fail performance of this group of subjects.

When the sample is separated into younger and older subjects, the effects of age and offenses on the younger group become insignificant. The contribution of the UFOV-Overall score is still related significantly to the DPM pass/fail categorization of the younger group. In the older group, the effects of age, offenses, and UFOV performance are still significant, with age being the strongest individual contributor to the DPM pass/fail categorization.

The best model developed using discriminant analysis for DPM pass/fail categorization in the older group utilizes the UFOV-Overall and offense variables. The combination of age and offense generates a model that is slightly less effective.

Even though the model generated for the categorization of the DPM pass/fail subjects in the younger group indicates excellent performance, the fact is that only one of seventy-three younger subjects failed the DPM test. While the one failing subject was correctly identified, making any conclusions about the validity of using this process should be made with extreme caution.

While the results of the discriminant analysis process for the older subjects are encouraging, the effect of the age of the subjects on the performance scores makes it difficult to place a great deal of confidence in the outcomes. It is encouraging that the offense variable is not eliminated from the process by including either age or UFOV performance.

CONCLUSIONS: UFOV AND DPM PERFORMANCE

The primary focus of this section of the report was to evaluate the ability of the results of the UFOV and DPM testing procedures to identify the subjects with poor performance attributes, whether it was crash involvement or recorded offenses on their driving record. The age and age group (younger/older) of the subjects were also considered in the analysis.

The first analysis involved making a direct comparison between the pass/fail subjects on the UFOV test and the DPM test. This analysis showed that UFOV pass/fail correctly categorized 87.4 percent of the subjects, based on their DPM score. However, only six of the sixteen (37.5%) subjects who failed the DPM test were correctly identified. Lowering the pass/fail criterion for the UFOV test (i.e., more subjects "fail") did capture more of the subjects who failed the DPM test. However, the lower threshold also increases the number of subjects who passed the DPM test but are predicted as failing by the UFOV test. The number of incorrectly identified subjects more than offsets the gains in the number of subjects in the correct UFOV/-DPM failing category. Depending on the use of the data, justification for using a UFOV pass/fail criterion other than 40 will likely depend on the tolerance of errors in the proposed use (i.e., how many false positive identifications can be tolerated).

Discriminant analysis was also employed to evaluate the relationship between UFOV and DPM performance. Other measures such as offenses, crash history, and age were also used in the discriminant analysis process to determine which measures performed "best" in predicting the subjects passing and failing the DPM test. The combination of measures which identified the most failing subjects was the combination of **UFOV pass/fail, offenses,** and **age**. This combination correctly categorized nine of the sixteen (56.25%) of the DPM failing subjects and 182 of the 223 (81.6%) of the DPM passing subjects. The relationship between the direct comparison and discriminant analysis is presented in Table 48. While the overall percentage correct is higher for the direct comparison method, the results from the discriminant analysis indicate that more of the <u>failing</u> subjects are correctly selected using discriminant analysis.

Table 48. Predicting DPM Pass/Fail Categorization Using Direct Comparison and Discriminant Analysis

Method	Total Pass	Predicted Pass	Total Fail	Predicted Fail	Overall Percent Correct
Direct Comparison	223	203 91.0%	16	6 37.5%	87.44%
Discriminant Analysis	223	182 81.6%	16	9 56.3%	79.92%

Since the objective of vision screening and driver evaluation is to identify potentially hazardous drivers, the measures identified as important through discriminant analysis yield better results than the results from direct comparison. The increase in correctly predicted failing subjects using the discriminant analysis model is approximately 19 percent with a corresponding decrease in correctly predicted passing subjects of approximately 9.5 percent compared to the direct comparison process.

HYPOTHESIS EVALUATION

The comparison of UFOV and DPM performance was conducted to determine the strength of the relationship between the two measures. Both measures are "present" measures in that they evaluate the performance of a subject in the present time. Previous research indicated that UFOV performance could be related to driving history, particularly crash involvement (Owsley et al., 1991). Results from the section of this report pertaining to DPM performance and driving history indicated that the two measures are related (i.e., poor driving history is related to poor DPM performance). Based upon the relationship of the two measures to driving history, it was believed there would be a significant relationship between UFOV and DPM performance.

Restating the hypothesis for this part of the research:

There is a correlation between UFOV performance and driving performance as determined using the DPM performance criteria.

Based upon the results of the analyses, a positive relationship <u>can</u> be shown to exist between the two measures. Therefore, it can be stated that the hypothesis is <u>true</u>. The process of utilizing UFOV performance as a predictor of driving performance is not without problems, however.

One of the results which came from the section of this report which covered the analysis of UFOV performance and driving history was that <u>age</u> was a significant factor in UFOV performance. When the sample of subjects was divided between younger and older subjects and DPM analysis conducted, the contribution from age disappeared for the younger subjects but not for the older subjects. Therefore, the contribution attributable to age carries through the process via the use of the UFOV test. This is another reason for including measures, such as offense data, along with UFOV performance in the screening process. This will help to reduce the contribution of age to the process.

SUMMARY, CONCLUSIONS, AND DISCUSSION

UFOV TESTING AND DRIVER HISTORY EVALUATION

The use of the UFOV testing procedure was an important part of this research. Therefore, it was necessary to critically re-examine the process used in earlier UFOV research efforts (Ball et al. 1993) and their results (Owsley et al. 1991) which had indicated a relatively strong relationship between UFOV performance and crash involvement.

The procedure used for the UFOV evaluation closely followed the guidelines received with the testing equipment which was acquired from the manufacturer. All of the subjects participated in the UFOV testing, which consisted of three sections: **Processing Speed, Divided Attention,** and **Selective Attention**. A few subjects expressed displeasure with the testing, usually when they had difficulty with glare from the distractors displayed in the third section (Selective Attention) of the test.

The same criteria as utilized in the previous UFOV research, **sensitivity** and **specificity**, were used in this research. Sensitivity was defined as the probability that a subject's UFOV-Overall score is above 40, given that they have been crash-involved. Specificity was defined as the probability that a subject's UFOV-Overall score is below 40, given that they are not crash-involved. The criterion of 40 as the pass/fail UFOV-Overall score was established in previous research efforts (Owsley et al. 1991) through a process of manipulation of the pass/fail point until the best cell populations were attained. For the subjects in the current research effort, the UFOV-Overall score of 40 is one standard deviation above the mean score of 25.5. Additionally, using the

UFOV-Overall pass/fail criterion of 40 in analyses of these data produced results which correctly categorized the data at a high percentage (i.e., produced the best cell populations).

The results from the UFOV analysis conducted for this research were not encouraging as they related to typical highway safety analysis measures of crash involvement and offenses. The results from two previous research efforts and results from this research are summarized in Table 49 (a repeat of Table 5). The sensitivity scores from this study are strikingly different (lower) from the previous studies. The probable reason for the large difference in performance is due almost entirely to the differences in the subjects in the sample for this project as compared to the subjects in the samples used in previous UFOV work. The subjects from the earlier UFOV research efforts were much more likely to have been crash-involved. The process for selecting the subjects for this study was done using a stratified random sample with the stratification being age group. The age group stratifications were the only restrictions on the construction of the sample and the age groups were defined as age 20-55 and 65 and older. Within the age groups, sampling was purely random.

Table 49. Results From UFOV Research Efforts

Study Cited	Sensitivity	Specificity
Ball/Owsley (1993)	0.89 (142/160)	0.81 (109/134)
Ball (1995)	0.94 (n/a)	0.64 (n/a)
Michigan State (1994)	0.11 (9/81)	0.89 (146/164)
Random Sampling (MSU)	0.33 (27/81)	0.67 (110/164)

The process for selecting the subjects for the previous UFOV research efforts (Ball and Owsley, 1991) was done by identifying the characteristics of the design matrix, identifying the subjects who fit into those classifications, and recruiting them to participate. There is some randomness involved in building the sample for the previous UFOV research, it is much less random than the process used in this research effort.

Additional analyses were conducted using hybrid samples which were constructed to "look like" the samples used in previous UFOV research by Ball and Owsley (1991). There were two samples constructed. The first sample consisted of 67 percent crash-involved subjects and 33 percent non-crash-involved subjects. The second sample consisted of 67 percent at-fault crash-involved and 33 percent non-crash-involved. There was not any improvement in the sensitivity scores and the specificity scores increased slightly. The summary of the analyses conducted with these samples are shown in Tables 9, 10, 11, and 12 in the chapter on UFOV analysis. In short, the results here are significantly worse than those previously obtained in other research efforts.

The variable that contributed the most to the prediction of UFOV performance was chronological age. This contribution from age to the UFOV performance scores of the subjects will make it difficult to support UFOV testing as an age-blind procedure. Additionally, some subjects who performed poorly on the UFOV testing related that they were aware of some visual degradation and often mentioned that they had modified their driving behavior to compensate (e.g., avoided driving at night).

After analyses of the UFOV and driver history data, the following conclusions can be made:

1. UFOV testing related to driving history is somewhat effective for subjects age 65 and older and not effective for subjects under age 55;

2. persons over the age of 65 with "poor" UFOV performance are more likely to be cited for vehicle control type offenses;

3. persons over the age of 65 with "poor" UFOV performance are more likely to be determined to be at-fault when involved in a crash; and

4. persons over the age of 65 with citations for speed violations are more likely to have "good" UFOV performance than other subjects in the same age group.

In general, because of the significant relationship of age to UFOV performance, widespread use of UFOV testing to assess driving capability is not recommended. If a separate UFOV criterion can be developed for younger drivers, perhaps the UFOV testing could be more appropriate for general testing (i.e., less age biased).

DPM AND DRIVER HISTORY EVALUATION

The Driver Performance Measurement process was developed for the evaluation of driving behaviors, both good and bad, of the subjects being observed. This part of the research effort was focused on evaluating the relationship between DPM performance and the driving history of the participating subjects. The reasoning behind this effort was to establish the relationship of a widely accepted driver evaluation process (driving history) with DPM performance, which is a present time evaluation (i.e., comparing past performance to present performance).

To facilitate this comparison, the DPM data collected from the subjects on the driving route were analyzed and compared to crash involvement and offense history from the subjects' driving records. Additional data such as age, age group (younger/older), at-fault crash involvement, and general offense type (no offense, vehicle control offense, and speed offense) were also included in the analyses.

The DPM driving route consisted of nine different types of locations which were primarily intersections of different geometric configurations in both rural and urban locations. Additionally, the performance of the subjects on horizontal curves in rural locations was also observed. Subjects were observed and data were collected for each subject at each location.

The assessment of driving history and DPM performance indicated that there is a positive relationship between the two measures. The subjects with vehicle control offenses on their driving record were generally the subjects with poorer DPM performance scores. An interesting finding relating offenses and DPM performance was the performance of subjects with speed offenses on their record compared to the subjects with no offenses and also to those subjects with vehicle control offenses. As the age of the subjects increased, the DPM performance scores for subjects in the no offenses and vehicle control offenses categories declined (i.e., got worse). This was not the pattern for the subjects with speed offenses. The scores for this group of subjects did not decrease as age increased (see Table 27, page 96).

The age effects on DPM performance were only significant for the no offenses group of subjects, which is attributable primarily to the size of the sample in this category. The age effects for the subjects in the vehicle control offenses group were more pronounced (i.e., larger decrease with increasing age) but not statistically significant, again attributable to the size of the sample of subjects in this category.

Using a combination consisting of the complexity of the site, the number of tasks required at each type of location, and engineering judgement, each type of site was assessed as to its level of difficulty. Not surprisingly, the urban sites were determined to be the more difficult locations. The most difficult site type was the mid-block (non-signalized) left-turn from a 5-lane arterial street. Each subject was required to find these intersections by street name (there were three such locations). At the urban locations, there was a significant difference in the performance of subjects between the different age groups, with the older age groups performing more poorly. The performance scores from the different age groups at the different sites are summarized in Table 27 (page 96).

The results of the analyses of DPM performance with the driving history of the subjects leads to the following conclusions:

1. The relationship between general crash involvement and DPM performance does not establish any trend;

2. The relationship between **no-crash, no-at-fault,** and **at-fault** crash involvement and DPM performance shows that **at-fault** subjects have generally lower performance scores, although not statistically significant;

3. The relationship between recorded offenses and DPM performance indicates that the subjects with offenses have generally lower DPM performance scores, although not statistically significant;

4. The relationship between offense types and DPM performance indicates that subjects with **vehicle control offenses** have lower DPM performance scores than subjects with **speed offenses** or **no offenses** and the differences are statistically significant;

5. There are age effects--older subjects have generally lower DPM performance scores. However, these differences were significant only within the **no offenses** category; and

6. Subjects with **speed offenses** had DPM performance scores as good as and sometimes better than the subjects with **no offenses**. Additionally, increasing age did not appear to affect the DPM performance of the subjects with speed offenses.

The analyses of DPM performance does indicate that the subjects with potentially the worst type of error on their driving record, vehicle control offenses, can be identified using the DPM procedure. This finding supports the findings of the developers of the DPM process (Forbes et al., 1973) that DPM is useful in identifying driving behaviors determined to be unsafe (or to increase hazard potential).

UFOV AND DPM ANALYSES

For the comparison of subjects' UFOV performance with their driving performance as evaluated using DPM techniques, it was expected that there would be a positively correlated, statistically significant relationship established. The results indicate that such a relationship exists. The UFOV testing procedure is a highly visual (i.e., relies on visual detection of objects) process, as is driving. The vast majority of data used for decision making by the operator of an automobile is obtained through visual processes. Therefore, a relationship between UFOV and DPM performance makes intuitive sense and the evaluation measures provide statistical support for the relationship.

The evaluation procedures included direct comparison between UFOV and DPM performance (see Table 36) and discriminant analyses. Additional data such as age, crash involvement, and offenses were included in the evaluation process. The analyses concerned with predicting crash involvement using the collected data showed that only offense data were significant in predicting crash involvement (see Table 38). While the UFOV-Processing Speed data identified over 90 percent (73 of 81) of the crash-involved subjects, it misidentified 140 of the 164 non-crash-involved subjects. The prediction of crash involvement using DPM pass/fail data identified over 92 percent (151 of 164) of the non-crash-involved subjects. However, only nine of the eighty-one (11.1%) of the crash-involved subjects were identified using the DPM pass/fail data. Individually, none of the UFOV or DPM scores was a significant predictor of crash involvement.

Using the step-wise process of discriminant analysis to ascertain if there was a combination of variables that would predict general crash involvement indicated that offense data were the only significant (statistically) predictors. Categorizing the subjects as at-fault, not-at-fault, and non-crash-involved and using discriminant analysis to predict membership in the three categories again indicated only offense data as being significant in predicting for this stratification of crash involvement. Therefore, UFOV and DPM data were not reliable predictors of crash involvement.

Since offense data were the only significant predictors of crash involvement, further analyses were conducted to determine if UFOV and/or DPM performance measures could be related significantly to the presence of recorded offenses on a subject's driving record. The reasoning for pursuing this relationship was to see if a chain could be established linking UFOV and/or DPM performance to recorded offenses which are related to crash involvement. The analyses of the data indicates that none of the UFOV test results, DPM performance measures, or age data is significantly related to the occurrence of recorded offenses. Therefore, there was no relationship established linking UFOV, DPM, or age data with crash involvement through recorded offenses from the driving history of the subjects.

Notwithstanding the results immediately above, the DPM process is still useful for identifying potentially dangerous driving behaviors. Further analyses of data were conducted to determine the relationship between DPM performance and the other collected data.

The comparison of UFOV and DPM performance indicated there is a positive relationship between the two measures. Employing discriminant analysis using the UFOV-Overall performance score, recorded driving offenses, and chronological age to predict DPM performance correctly identified approximately 80 percent (79.9%) of the passing and failing drivers (DPM criterion). Only sixteen of the 239 (6.7%) subjects who completed the driving portion of the test were classified by DPM measures as failing. The selection process using the three aforementioned measures identified nine of the sixteen (56.3%) subjects. Given that 6.7 percent of the subjects in the sample for this research were classified as failing, a stratified random selection process which put 6.7 percent of the subjects in the failing group and the remainder into the passing group would "capture," on average, only one failing subject. Therefore, this process for identifying potentially poor drivers, as determined using the DPM procedure, is much improved over a random selection process.

The contribution from age to the selection process is cause for some concern, especially if the UFOV test is to be proffered as an unbiased procedure. When the sample was split into younger and older groups and analyzed, the contribution from age disappeared from the younger group but not from the older group. The DPM pass/fail results from the younger group analyses were encouraging (97.3% correct) but should be interpreted with caution due to the size of the sample and the number of failing subjects (one).

Even though the UFOV test appears to be age related, the human body functions do deteriorate as age increases (Kart et al., 1992). One objective of transportation engineers is to find ways to make the highways safer. Crash history indicates that older drivers are over-represented in several types of collisions. In order to make the highways safer, the poor drivers, old or not, need to be identified. The UFOV test in conjunction with driving history and age appears to be a process which can identify potentially poor drivers, as determined from the DPM performance scores. Short of a comprehensive road test, the procedure using the three measures offers an identification process which uses presently available information and technology. The practicality of its use should be pursued.

The following general conclusions can be made regarding UFOV and DPM performance:

1. There was no relationship established between UFOV and/or DPM performance and predicting crash involvement;

2. UFOV performance can be used as a predictor of driving performance as evaluated using the DPM procedure;

3. Individually, age, UFOV performance, and offense data are significant predictors of DPM driving performance. Combinations of these data correctly categorize approximately 80 percent of the subjects from this research;

4. UFOV performance was an excellent predictor of DPM driving performance in the younger age group. However, the results should be viewed with caution due to the small number of failing subjects; and

5. Within the older group, chronological age was the most significant predictor of DPM driving performance which is indicative of the differences between the younger-old and the older-old.

UTILITY OF THE FINDINGS

The practicality of using the UFOV and/or DPM processes as a primary screening procedure for drivers is low. The UFOV testing process can take from twelve to thirty minutes to conduct, which makes it impractical from a time consumption aspect. In Michigan, for example, the vision screening procedure can be conducted in approximately one minute, and replacing the Michigan vision screening procedure with the UFOV testing procedure would substantially increase the time required for the vision testing (1200 to 3000 percent!).

The research here showed that there is a good relationship between assessed DPM performance and driving history (offenses). Using the DPM process to identify those drivers with an increased propensity for higher risk driving behaviors would be reasonable and practical from an accuracy perspective. For use as a primary screening procedure however, the amount of time and costs involved with testing makes DPM impractical. The most reasonable and practical use of the UFOV and DPM processes would be as a secondary procedure to assess the capabilities of drivers after they have been identified as potentially hazardous. The primary identification can be accomplished through assessment of the driving record, from a doctor's recommendation, by a family member, or some other means. The UFOV and DPM processes could then be utilized in the following manner:

1. The subject is given the UFOV test to assess their visual and mental processing status.

2. The subject then takes a road test to have their driving ability assessed for higher risk behaviors.

3. The subject is then briefed on what is and is not good about their driving behaviors as well as what the UFOV testing has indicated potential problems there may be for them. The subject is then given suggestions to improve their driving performance by changing some aspects of their behavior (e.g., increase the use of mirrors) or driving situations to try to avoid.

4. The subject would be scheduled for a retest (UFOV and DPM) at a prescribed time in the future (e.g., six months) and their performance analyzed for improvements.

The earlier UFOV testing results indicated that the process is capable of identifying subjects with a higher propensity to have been involved in crashes (Ball et al, 1993). However, the research conducted here does not support those results. Base on these disparate results, using the UFOV procedure alone may not be a fair evaluation of a person's driving ability. The UFOV procedure would fail many "safe" drivers, some of whom have recognized that they have visual limitations (or problems in high stress areas) and adjusted their driving behavior to compensate. The definition of a "safe" driver in this context would be those who have a "clean" driving history (i.e., no crashes, no violations).

Assuming the UFOV procedure can identify potentially "poor" drivers (which was not supported by this research), using the UFOV testing in conjunction with driving analysis using DPM procedures would allow a person who performs poorly on the UFOV procedure to demonstrate on the DPM driving evaluation that they have identified (consciously or not) their deficit(s) and have adjusted their driving behavior. While there is not a "standard" DPM driving route, there is an established procedure for identifying the parts of the DPM sequence-building process. This process would allow a person properly trained in DPM techniques to construct a route from a series of sequences and therefore have a route that any other properly trained person would quickly understand and be able to use to assess driving performance.

Once a person is identified as being a potential problem driver, the UFOV and DPM assessments could be a way to identify the behaviors (habits) of persons which pose an increased risk in the driving population and also identifying potential solutions for addressing the problem area(s). This process does not discriminate by age from an agency perspective because the primary identification is through driving records, doctor recommendations, or family requests. The procedure also requires the same performance from all subjects. If their UFOV performance score is above a predetermined level (lower UFOV scores are better), they would then be required to be tested using the DPM driving process. Subjects who score below the predetermined level on the UFOV test would not necessarily be required to take a road test (as a means to lower costs). Any poor driving behaviors identified could be addressed with the subject and solutions presented. If no particular bad driving behaviors are subsequently identified using the DPM process, the subject's UFOV performance could still be analyzed and potential problems identified by the UFOV process could still be addressed. An educated driver should be a better driver, which would make the highways a safer place for all users.

SUGGESTIONS FOR ADDITIONAL RESEARCH

The problem areas of this research also provide some impetus for further research efforts. As mentioned, comparing UFOV and DPM performance with driving history compares current measures (UFOV, DPM) with past performance (driving history). There is no control for exposure (i.e., how much driving someone does) or allowance for medical changes (e.g., cataract surgery).

One method to determine if UFOV and/or DPM performance predicts driving performance is to conduct a longitudinal study to track the performance of subjects over time. Subjects could be asked to keep a simple log pertaining to driving characteristics (e.g., time-of-day, distance, weather) and also a medical log (i.e., medications, surgeries). Using the subject logs and driving records, the study would be used to analyze the effectiveness of UFOV and/or DPM for predicting crash-involvement or other specified driving performance (e.g., violations). This process would use a current evaluation procedure to predict future performance and track that performance.

GLOSSARY

ANOVA — Analysis of Variance

AMD — Age-Related Macular Degeneration. A disease that affects the central vision.

Discriminant Analysis — Procedure utilized in the analysis of combinations of dichotomous (e.g., yes/no, 1/0) and continuous data types.

DMV — Department of Motor Vehicles.

DPM — Driver Performance Measurement. The process used in the assessment of the subjects' driving behaviors.

Induced Exposure — Method used to determine the relative frequency of a defined group's crash involvement.

MDOS — Michigan Department of State.

NCHRP — National Cooperative Highway Research Program.

SPSS — The Statistical Package for the Social Sciences.

TRB — Transportation Research Board.

UFOV — Useful Field of View. The name given to the vision/mental processing test. This term also describes the visual field as determined by the UFOV test.

APPENDIX A

APPENDIX A

Data from the entire sample:

LICTYPE

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
Operator	1	3725	92.5	92.5	92.5
Chauffeur	2	110	2.7	2.7	95.2
Operator w/cycle end.	5	158	3.9	3.9	99.1
Chauffeur w/cycle end.	6	36	.9	.9	100.0
	Total	4029	100.0	100.0	

Valid cases 4029 Missing cases 0

- -

RESTRICT

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
	0	1861	46.2	46.2	46.2
Corrective Lens	1	2166	53.8	53.8	100.0
Corr Lens/R.S. Mirror	3	2	.0	.0	100.0
	Total	4029	100.0	100.0	

Valid cases 4029 Missing cases 0

PROBAT

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
		3973	98.6	98.6	98.6
	P	56	1.4	1.4	100.0
	Total	4029	100.0	100.0	

Valid cases 4029 Missing cases 0

MF

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
Female	F	2105	52.2	52.2	52.2
Male	M	1924	47.8	47.8	100.0
	Total	4029	100.0	100.0	

Valid cases 4029 Missing cases 0

CONVICTIONS

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
		3	.1	.1	.1
	0	2590	64.3	64.3	64.4
	1	771	19.1	19.1	83.5
	2	321	8.0	8.0	91.5
	3	138	3.4	3.4	94.9
	4	81	2.0	2.0	96.9
	5	38	.9	.9	97.8
	6	20	.5	.5	98.3
	7	21	.5	.5	98.9
	8	16	.4	.4	99.3
	9	7	.2	.2	99.4
	10	6	.1	.1	99.6
	11	3	.1	.1	99.7
	12	6	.1	.1	99.8
	13	2	.0	.0	99.9
	14	1	.0	.0	99.9
	15	2	.0	.0	99.9
	16	2	.0	.0	100.0
	22	1	.0	.0	100.0
	Total	4029	100.0	100.0	

Valid cases 4029 Missing cases 0

POINTS

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
		3	.1	.1	.1
	0	2628	65.2	65.2	65.3
	1	59	1.5	1.5	66.8
	2	494	12.3	12.3	79.0
	3	201	5.0	5.0	84.0
	4	194	4.8	4.8	88.8
	5	90	2.2	2.2	91.1
	6	102	2.5	2.5	93.6
	7	40	1.0	1.0	94.6
	8	48	1.2	1.2	95.8
	9	21	.5	.5	96.3
	10	32	.8	.8	97.1
	11	27	.7	.7	97.8
	12	14	.3	.3	98.1
	13	13	.3	.3	98.4
	14	13	.3	.3	98.8
	15	9	.2	.2	99.0
	16	4	.1	.1	99.1
	17	4	.1	.1	99.2
	18	8	.2	.2	99.4
	19	2	.0	.0	99.4
	20	1	.0	.0	99.5
	21	3	.1	.1	99.5
	22	3	.1	.1	99.6
	23	5	.1	.1	99.7
	24	1	.0	.0	99.8
	25	1	.0	.0	99.8
	26	3	.1	.1	99.9
	28	3	.1	.1	99.9
	33	1	.0	.0	100.0
	36	1	.0	.0	100.0
	51	1	.0	.0	100.0
		-------	-------	-------	
	Total	4029	100.0	100.0	

Valid cases 4029 Missing cases 0

OFFENSE1

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
Codes					
		2593	64.4	64.4	64.4
	05	4	.1	.1	64.5
	07	8	.2	.2	64.7
	088	1	.0	.0	64.7
	105	1	.0	.0	64.7
	11	7	.2	.2	64.9
	110	1	.0	.0	64.9
	111	2	.0	.0	65.0
	115	1	.0	.0	65.0
	116	4	.1	.1	65.1
	118	9	.2	.2	65.3
	119	2	.0	.0	65.4
	123	2	.0	.0	65.4
	125	1	.0	.0	65.4
	128	1	.0	.0	65.5
	130	1	.0	.0	65.5
	137	1	.0	.0	65.5
	144	2	.0	.0	65.5
	145	1	.0	.0	65.6
	148	1	.0	.0	65.6
	15	1	.0	.0	65.6
	151	1	.0	.0	65.6
	155	3	.1	.1	65.7
	16	92	2.3	2.3	68.0
	165	1	.0	.0	68.0
	17	2	.0	.0	68.1
	171	1	.0	.0	68.1
	179	1	.0	.0	68.1
	18	468	11.6	11.6	79.7
	184	2	.0	.0	79.8
	188	2	.0	.0	79.8
	19	106	2.6	2.6	82.5
	196	2	.0	.0	82.5
	215	1	.0	.0	82.6
	218	1	.0	.0	82.6
	219	1	.0	.0	82.6
	22	12	.3	.3	82.9
	223	1	.0	.0	82.9
	229	1	.0	.0	82.9
	23	48	1.2	1.2	84.1
	25	14	.3	.3	84.5
	27	6	.1	.1	84.6
	270	1	.0	.0	84.7
	29	3	.1	.1	84.7
	30	132	3.3	3.3	88.0
	318	3	.1	.1	88.1
	378	1	.0	.0	88.1
	39	3	.1	.1	88.2
	40	4	.1	.1	88.3
	430	1	.0	.0	88.3
	44	27	.7	.7	89.0
	45	33	.8	.8	89.8
	46	6	.1	.1	89.9
	47	31	.8	.8	90.7
	471	1	.0	.0	90.7
	477	1	.0	.0	90.8

OFFENSE1	484	1	.0	.0	90.8
	51	3	.1	.1	90.9
	512	1	.0	.0	90.9
	516	1	.0	.0	90.9
	518	2	.0	.0	91.0
	52	1	.0	.0	91.0
	523	1	.0	.0	91.0
	530	1	.0	.0	91.0
	55	100	2.5	2.5	93.5
	555	1	.0	.0	93.5
	571	2	.0	.0	93.6
	630	1	.0	.0	93.6
	65	1	.0	.0	93.6
	66	4	.1	.1	93.7
	70	11	.3	.3	94.0
	71	13	.3	.3	94.3
	717	1	.0	.0	94.4
	718	2	.0	.0	94.4
	719	2	.0	.0	94.5
	730	1	.0	.0	94.5
	74	10	.2	.2	94.7
	741	1	.0	.0	94.8
	75	2	.0	.0	94.8
	750	1	.0	.0	94.8
	770	1	.0	.0	94.9
	774	1	.0	.0	94.9
	775	1	.0	.0	94.9
	78	1	.0	.0	94.9
	81	1	.0	.0	95.0
	818	2	.0	.0	95.0
	819	1	.0	.0	95.0
	84	81	2.0	2.0	97.0
	87	1	.0	.0	97.1
	879	1	.0	.0	97.1
	88	60	1.5	1.5	98.6
	884	1	.0	.0	98.6
	89	13	.3	.3	98.9
	90	1	.0	.0	99.0
	923	1	.0	.0	99.0
	930	1	.0	.0	99.0
	941	1	.0	.0	99.0
	96	39	1.0	1.0	100.0
		-------	-------	-------	
	Total	4029	100.0	100.0	

Valid cases 4029 Missing cases 0

TOTALACC

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
	0	2723	67.6	67.6	67.6
	1	891	22.1	22.1	89.8
	2	293	7.3	7.3	97.0
	3	86	2.1	2.1	99.2
	4	20	.5	.5	99.7
	5	10	.2	.2	99.9
	6	2	.0	.0	100.0
	7	1	.0	.0	100.0
	.	3	.1	Missing	
	Total	4029	100.0	100.0	

Valid cases 4026 Missing cases 3

Data from the participating subjects:

LICTYPE

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
Operator	1	205	83.7	87.6	87.6
Chauffeur	2	15	6.1	6.4	94.0
Operator w/cycle end.	5	12	4.9	5.1	99.1
Chauffeur w/cycle end.	6	2	.8	.9	100.0
	.	11	4.5	Missing	
	Total	245	100.0	100.0	

Valid cases 234 Missing cases 11

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RESTRICT

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
	0	104	42.4	44.4	44.4
Corrective Lens	1	130	53.1	55.6	100.0
	.	11	4.5	Missing	
	Total	245	100.0	100.0	

Valid cases 234 Missing cases 11

PROBAT

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
		242	98.8	98.8	98.8
	P	3	1.2	1.2	100.0
	Total	245	100.0	100.0	

Valid cases 245 Missing cases 0

SEX Subject gender

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
male	1	126	51.4	51.4	51.4
female	2	119	48.6	48.6	100.0
	Total	245	100.0	100.0	

Valid cases 245 Missing cases 0

- -

CONVICTIONS

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
		11	4.5	4.5	4.5
	0	147	60.0	60.0	64.5
	1	44	18.0	18.0	82.4
	2	23	9.4	9.4	91.8
	3	17	6.9	6.9	98.8
	5	1	.4	.4	99.2
	6	2	.8	.8	100.0
	Total	245	100.0	100.0	

Valid cases 245 Missing cases 0

POINTS

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
		11	4.5	4.5	4.5
	0	149	60.8	60.8	65.3
	1	4	1.6	1.6	66.9
	2	26	10.6	10.6	77.6
	3	12	4.9	4.9	82.4
	4	15	6.1	6.1	88.6
	5	10	4.1	4.1	92.7
	6	12	4.9	4.9	97.6
	7	3	1.2	1.2	98.8
	9	1	.4	.4	99.2
	13	1	.4	.4	99.6
	15	1	.4	.4	100.0
		-------	-------	-------	
	Total	245	100.0	100.0	

Valid cases 245 Missing cases 0

OFFENSE1

Value Label Codes	Value	Frequency	Percent	Valid Percent	Cum Percent
		158	64.5	64.5	64.5
	05	1	.4	.4	64.9
	118	1	.4	.4	65.3
	16	4	1.6	1.6	66.9
	18	33	13.5	13.5	80.4
	19	9	3.7	3.7	84.1
	23	1	.4	.4	84.5
	25	1	.4	.4	84.9
	27	1	.4	.4	85.3
	30	7	2.9	2.9	88.2
	318	1	.4	.4	88.6
	39	1	.4	.4	89.0
	44	1	.4	.4	89.4
	45	3	1.2	1.2	90.6
	46	3	1.2	1.2	91.8
	47	1	.4	.4	92.2
	55	6	2.4	2.4	94.7
	65	1	.4	.4	95.1
	74	1	.4	.4	95.5
	84	4	1.6	1.6	97.1
	88	4	1.6	1.6	98.8
	89	2	.8	.8	99.6
	96	1	.4	.4	100.0
	Total	245	100.0	100.0	

Valid cases 245 Missing cases 0

TOTALACC

Value Label	Value	Frequency	Valid Percent	Cum Percent	Percent
	0	153	62.4	65.4	65.4
	1	51	20.8	21.8	87.2
	2	23	9.4	9.8	97.0
	3	6	2.4	2.6	99.6
	4	1	.4	.4	100.0
	.	11	4.5	Missing	
	Total	245	100.0	100.0	

Valid cases 234 Missing cases 11

* * * C E L L M E A N S * * *

TOTALSCO Total score
by ATFAULT
NEWAGEGP

Total Population

25.59
(243)

ATFAULT

0	1	2
23.46	25.71	26.06
(39)	(42)	(162)

NEWAGEGP

1	2	3	4	5	6
14.63	26.56	28.33	37.08	40.58	40.00
(75)	(61)	(60)	(30)	(13)	(4)

ATFAULT \ NEWAGEGP	1	2	3	4	5	6
0	12.88	24.83	33.33	33.33	40.00	35.00
	(13)	(15)	(6)	(3)	(1)	(1)
1	14.22	25.00	25.68	40.36	54.17	.00
	(16)	(5)	(11)	(7)	(3)	(0)
2	15.27	27.38	28.31	36.50	36.11	41.67
	(46)	(41)	(43)	(20)	(9)	(3)

* * * A N A L Y S I S   O F   V A R I A N C E * * *

TOTALSCO Total score
by ATFAULT
NEWAGEGP

HIERARCHICAL sums of squares
Covariates entered FIRST

Source of Variation	Sum of Squares	DF	Mean Square	F	Sig of F
Main Effects	17270.567	7	2467.224	12.468	.00
ATFAULT	213.852	2	106.926	.540	.583
NEWAGEGP	17056.715	5	3411.343	17.240	.00
2-Way Interactions	1219.253	9	135.473	.685	.723
ATFAULT NEWAGEGP	1219.253	9	135.473	.685	.723
Explained	18489.820	16	1155.614	5.840	.000
Residual	44720.365	226	197.878		
Total	63210.185	242	261.199		

245 cases were processed.
2 cases (.8 pct) were missing.

* * M U L T I P L E   C L A S S I F I C A T I O N   A N A L Y S I S * *

TOTALSCO Total score
by ATFAULT
NEWAGEGP

Grand Mean = 25.59

Variable + Category	N	Unadjusted Dev'n	Unadjusted Eta	Adjusted for Independents Dev'n	Adjusted for Independents Beta
ATFAULT					
0 not at fault	39	-2.12		-.94	
1 at fault	42	.13		.50	
2 no crash	162	.48		.10	
			.06		.03
NEWAGEGP					
1 20-55	75	-10.95		-10.96	
2 65-69	61	.97		1.10	
3 70-74	60	2.75		2.68	
4 75-79	30	11.50		11.41	
5 80-84	13	14.99		14.88	
6 85+	4	14.41		14.58	
			.52		.52

Multiple R Squared	.273
Multiple R	.523

* * * C E L L   M E A N S * * *

SELATTEN Selective attention
by ATFAULT
NEWAGEGP

Total Population

19.92
(243)

ATFAULT

0	1	2
19.23	19.94	20.07
(39)	(42)	(162)

NEWAGEGP

1	2	3	4	5	6
12.37	22.20	22.08	25.67	26.73	28.75
(75)	(61)	(60)	(30)	(13)	(4)

ATFAULT	NEWAGEGP 1	2	3	4	5	6
0	12.88	21.50	20.00	28.33	25.00	30.00
	(13)	(15)	(6)	(3)	(1)	(1)
1	12.03	24.00	21.59	29.29	27.50	.00
	(16)	(5)	(11)	(7)	(3)	(0)
2	12.34	22.24	22.50	24.00	26.67	28.33
	(46)	(41)	(43)	(20)	(9)	(3)

* * * A N A L Y S I S   O F   V A R I A N C E * * *

SELATTEN Selective attention
by ATFAULT
NEWAGEGP

HIERARCHICAL sums of squares
Covariates entered FIRST

Source of Variation	Sum of Squares	DF	Mean Square	F	Sig of F
Main Effects	6804.159	7	972.023	34.682	.000
ATFAULT	22.385	2	11.193	.399	.671
NEWAGEGP	6781.774	5	1356.355	48.395	.000
2-Way Interactions	220.291	9	24.477	.873	.550
ATFAULT NEWAGEGP	220.291	9	24.477	.873	.550
Explained	7024.450	16	439.028	15.665	.000
Residual	6334.070	226	28.027		
Total	13358.521	242	55.200		

245 cases were processed.
2 cases (.8 pct) were missing.

* * M U L T I P L E   C L A S S I F I C A T I O N   A N A L Y S I S * *

SELATTEN Selective attention
by ATFAULT
NEWAGEGP

Grand Mean = 19.92

Variable + Category	N	Unadjusted Dev'n	Unadjusted Eta	Adjusted for Independents Dev'n	Adjusted for Independents Beta
ATFAULT					
0 not at fault	39	-.68		-.24	
1 at fault	42	.02		.63	
2 no crash	162	.16		-.11	
			.04		.04
NEWAGEGP					
1 20-55	75	-7.55		-7.58	
2 65-69	61	2.29		2.37	
3 70-74	60	2.17		2.15	
4 75-79	30	5.75		5.70	
5 80-84	13	6.82		6.76	
6 85+	4	8.83		8.97	
			.71		.71

Multiple R Squared	.509
Multiple R	.714

* * * C E L L   M E A N S * * *

DIVATTEN Divided attention
by ATFAULT
NEWAGEGP

Total Population

3.80
(243)

ATFAULT

0	1	2
2.69	4.23	3.95
(39)	(42)	(162)

NEWAGEGP

1	2	3	4	5	6
1.07	3.03	4.08	7.92	10.38	10.00
(75)	(61)	(60)	(30)	(13)	(4)

ATFAULT	NEWAGEGP 1	2	3	4	5	6
0	.00	1.67	7.50	5.00	15.00	5.00
	(13)	(15)	(6)	(3)	(1)	(1)
1	.31	1.00	4.09	11.07	15.00	.00
	(16)	(5)	(11)	(7)	(3)	(0)
2	1.63	3.78	3.60	7.25	8.33	11.67
	(46)	(41)	(43)	(20)	(9)	(3)

* * * A N A L Y S I S O F V A R I A N C E * * *

DIVATTEN Divided attention
by ATFAULT
NEWAGEGP
HIERARCHICAL sums of squares
Covariates entered FIRST

Source of Variation	Sum of Squares	DF	Mean Square	F	Sig of F
Main Effects	1846.189	7	263.741	6.929	.000
ATFAULT	59.153	2	29.576	.777	.461
NEWAGEGP	1787.036	5	357.407	9.390	.000
2-Way Interactions	431.146	9	47.905	1.259	.261
ATFAULT NEWAGEGP	431.146	9	47.905	1.259	.261
Explained	2277.335	16	142.333	3.740	.000
Residual	8601.832	226	38.061		
Total	10879.167	242	44.955		

245 cases were processed.
2 cases (.8 pct) were missing.

* * M U L T I P L E C L A S S I F I C A T I O N A N A L Y S I S * *

DIVATTEN Divided attention
by ATFAULT
NEWAGEGP

Grand Mean = 3.80

Variable + Category	N	Unadjusted Dev'n	Unadjusted Eta	Adjusted for Independents Dev'n	Adjusted for Independents Beta
ATFAULT					
0 not at fault	39	-1.10		-.61	
1 at fault	42	.43		.35	
2 no crash	162	.15		.06	
			.07		.04
NEWAGEGP					
1 20-55	75	-2.73		-2.73	
2 65-69	61	-.76		-.68	
3 70-74	60	.29		.24	
4 75-79	30	4.12		4.06	
5 80-84	13	6.59		6.52	
6 85+	4	6.20		6.31	
			.41		.41

Multiple R Squared	.170
Multiple R	.412

* * * C E L L   M E A N S * * *

PROCSPED Processing speed
by ATFAULT
NEWAGEGP

Total Population

1.87
(243)

ATFAULT

0	1	2
1.54	1.55	2.04
(39)	(42)	(162)

NEWAGEGP

1	2	3	4	5	6
1.20	1.31	2.17	3.50	3.46	1.25
(75)	(61)	(60)	(30)	(13)	(4)

ATFAULT \ NEWAGEGP	1	2	3	4	5	6
0	.00	1.67	5.83	.00	.00	.00
	(13)	(15)	(6)	(3)	(1)	(1)
1	1.88	.00	.00	.00	11.67	.00
	(16)	(5)	(11)	(7)	(3)	(0)
2	1.30	1.34	2.21	5.25	1.11	1.67
	(46)	(41)	(43)	(20)	(9)	(3)

* * * A N A L Y S I S   O F   V A R I A N C E * * *

PROCSPED Processing speed
by ATFAULT
NEWAGEGP
HIERARCHICAL sums of squares
Covariates entered FIRST

Source of Variation	Sum of Squares	DF	Mean Square	F	Sig of F
Main Effects	184.933	7	26.419	.758	.624
ATFAULT	13.170	2	6.585	.189	.828
NEWAGEGP	171.762	5	34.352	.985	.428
2-Way Interactions	606.149	9	67.350	1.931	.049
ATFAULT NEWAGEGP	606.149	9	67.350	1.931	.049
Explained	791.081	16	49.443	1.418	.135
Residual	7881.964	226	34.876		
Total	8673.045	242	35.839		

245 cases were processed.
2 cases (.8 pct) were missing.

* * M U L T I P L E   C L A S S I F I C A T I O N   A N A L Y S I S * *

PROCSPED Processing speed
by ATFAULT
NEWAGEGP

Grand Mean = 1.87

Variable + Category	N	Unadjusted Dev'n	Unadjusted Eta	Adjusted for Independents Dev'n	Adjusted for Independents Beta
ATFAULT					
0 not at fault	39	-.33		-.08	
1 at fault	42	-.32		-.47	
2 no crash	162	.16		.14	
			.04		.04
NEWAGEGP					
1 20-55	75	-.67		-.64	
2 65-69	61	-.56		-.60	
3 70-74	60	.29		.29	
4 75-79	30	1.63		1.65	
5 80-84	13	1.59		1.61	
6 85+	4	-.62		-.71	
			.14		.14
Multiple R Squared					.021
Multiple R					.146

The information first presented here pertains to the entire sample pool.

- Chi-Square Test

GENDER

	Category	Cases Observed	Expected	Residual
Male	1	1924	1958.09	-34.09
Female	2	2105	2070.91	34.09
	Total	4029		

Chi-Square	D.F.	Significance
1.1549	1	.2825

- - - - - Chi-Square Test

CRSHRATE

Category	Cases Observed	Expected	Residual
.00	2726	2626.91	99.09
1.00	1303	1402.09	-99.09
Total	4029		

Chi-Square	D.F.	Significance
10.7412	1	.0010

- - - - - Chi-Square Test

OFFENSE

Category	Cases Observed	Expected	Residual
.00	2593	2530.21	62.79
1.00	1436	1498.79	-62.79
Total	4029		

Chi-Square	D.F.	Significance
4.1885	1	.0407

Number of valid observations (listwise) = 4029.00

Variable	Mean	Std Dev	Minimum	Maximum	Valid N	Label
CRSHRATE	.32	.47	.00	1.00	4029	

The information after this point pertains to the participating subjects.

- - - - - Chi-Square Test, Younger subjects

SEX Subject sex

	Category	Cases Observed	Expected	Residual
male	1	126	119.07	6.93
female	2	119	125.93	-6.93
	Total	245		

Chi-Square	D.F.	Significance
.7847	1	.3757

- - - - - Chi-Square Test

CRSHRATE

Category	Cases Observed	Expected	Residual
.00	46	48.90	-2.90
1.00	29	26.10	2.90
Total	75		

Chi-Square	D.F.	Significance
.4942	1	.4821

- - - - - Chi-Square Test, Older subjects

CRSHRATE

Category	Cases Observed	Expected	Residual
.00	117	110.84	6.16
1.00	53	59.16	-6.16
Total	170		

Chi-Square	D.F.	Significance
.9838	1	.3213

- - - - - Chi-Square Test, Younger subjects

VIOLRATE

Category	Cases Observed	Expected	Residual
.00	40	47.10	-7.10
1.00	35	27.90	7.10
	--		
Total	75		

Chi-Square	D.F.	Significance
2.8771	1	.0898

- - - - - Chi-Square Test, Older subjects

VIOLRATE

Category	Cases Observed	Expected	Residual
.00	118	106.76	11.24
1.00	52	63.24	-11.24

Total	170		

Chi-Square	D.F.	Significance
3.1811	1	.0745

* * * C E L L   M E A N S * * *

PROCSPED Processing speed
by OFFENSE
NEWAGEGP

Total Population

Mean	1.87
N	(243)

OFFENSE

	0	1	2
Mean	1.83	.98	3.33
N	(164)	(46)	(33)

NEWAGEGP

	1	2	3	4	5	6
Mean	1.20	1.31	2.17	3.50	3.46	1.25
N	(75)	(61)	(60)	(30)	(13)	(4)

OFFENSE \ NEWAGEGP	1	2	3	4	5	6
0	1.44	1.51	2.05	3.42	1.00	1.67
	(45)	(43)	(44)	(19)	(10)	(3)
1	1.19	.00	1.43	2.00	.00	.00
	(21)	(12)	(7)	(5)	(0)	(1)
2	.00	2.50	3.33	5.00	11.67	.00
	(9)	(6)	(9)	(6)	(3)	(0)

* * * A N A L Y S I S   O F   V A R I A N C E * * *

PROCSPED Processing speed
by OFFENSE
NEWAGEGP

HIERARCHICAL sums of squares
Covariates entered FIRST

Source of Variation	Sum of Squares	DF	Mean Square	F	Sig of F
Main Effects	243.813	7	34.830	.970	.454
OFFENSE	107.514	2	53.757	1.498	.226
NEWAGEGP	136.299	5	27.260	.759	.580
2-Way Interactions	281.051	8	35.131	.979	.453
OFFENSE NEWAGEGP	281.051	8	35.131	.979	.453
Explained	524.864	15	34.991	.975	.483
Residual	8148.182	227	35.895		
Total	8673.045	242	35.839		

245 cases were processed.
2 cases (.8 pct) were missing.

* * * C E L L   M E A N S * * *

DIVATTEN Divided attention
by OFFENSE
NEWAGEGP

Total Population

3.80
(243)

OFFENSE

0	1	2
3.86	2.17	5.76
(164)	(46)	(33)

NEWAGEGP

1	2	3	4	5	6
1.07	3.03	4.08	7.92	10.38	10.00
(75)	(61)	(60)	(30)	(13)	(4)

OFFENSE \ NEWAGEGP	1	2	3	4	5	6
0	1.67	3.26	3.30	7.76	9.00	11.67
	(45)	(43)	(44)	(19)	(10)	(3)
1	.24	2.50	5.00	5.00	.00	5.00
	(21)	(12)	(7)	(5)	(0)	(1)
2	.00	2.50	7.22	10.83	15.00	.00
	(9)	(6)	(9)	(6)	(3)	(0)

* * * A N A L Y S I S   O F   V A R I A N C E * * *

DIVATTEN Divided attention
by OFFENSE
NEWAGEGP

HIERARCHICAL sums of squares
Covariates entered FIRST

Source of Variation	Sum of Squares	DF	Mean Square	F	Sig of F
Main Effects	1926.454	7	275.208	7.204	.000
OFFENSE	248.615	2	124.307	3.254	.040
NEWAGEGP	1677.840	5	335.568	8.784	.000
2-Way Interactions	280.818	8	35.102	.919	.502
OFFENSE NEWAGEGP	280.818	8	35.102	.919	.502
Explained	2207.272	15	147.151	3.852	.000
Residual	8671.894	227	38.202		
Total	10879.167	242	44.955		

245 cases were processed.
2 cases (.8 pct) were missing.

* * * C E L L   M E A N S * * *

SELATTEN Selective attention
by OFFENSE
NEWAGEGP

Total Population

19.92
(243)

OFFENSE

0	1	2
20.11	17.71	22.05
(164)	(46)	(33)

NEWAGEGP

1	2	3	4	5	6
12.37	22.20	22.08	25.67	26.73	28.75
(75)	(61)	(60)	(30)	(13)	(4)

OFFENSE	NEWAGEGP 1	2	3	4	5	6
0	12.89	22.62	21.53	23.95	25.75	28.33
	(45)	(43)	(44)	(19)	(10)	(3)
1	10.60	20.38	25.36	28.00	.00	30.00
	(21)	(12)	(7)	(5)	(0)	(1)
2	13.89	22.92	22.22	29.17	30.00	.00
	(9)	(6)	(9)	(6)	(3)	(0)

* * * A N A L Y S I S   O F   V A R I A N C E * * *

SELATTEN Selective attention
by OFFENSE
NEWAGEGP

HIERARCHICAL sums of squares
Covariates entered FIRST

Source of Variation	Sum of Squares	DF	Mean Square	F	Sig of F
Main Effects	6877.901	7	982.557	36.349	.000
OFFENSE	380.168	2	190.084	7.032	.001
NEWAGEGP	6497.733	5	1299.547	48.076	.000
2-Way Interactions	344.603	8	43.075	1.594	.128
OFFENSE NEWAGEGP	344.603	8	43.075	1.594	.128
Explained	7222.504	15	481.500	17.813	.000
Residual	6136.016	227	27.031		
Total	13358.521	242	55.200		

245 cases were processed.
2 cases (.8 pct) were missing.

* * * C E L L   M E A N S * * *

TOTALSCO Total score
by OFFENSE
NEWAGEGP

Total Population

25.59
(243)

OFFENSE

0	1	2
25.79	20.87	31.14
(164)	(46)	(33)

NEWAGEGP

1	2	3	4	5	6
14.63	26.56	28.33	37.08	40.58	40.00
(75)	(61)	(60)	(30)	(13)	(4)

OFFENSE \ NEWAGEGP	1	2	3	4	5	6
0	16.00	27.38	26.88	35.13	35.75	41.67
	(45)	(43)	(44)	(19)	(10)	(3)
1	12.02	22.92	31.79	35.00	.00	35.00
	(21)	(12)	(7)	(5)	(0)	(1)
2	13.89	27.92	32.78	45.00	56.67	.00
	(9)	(6)	(9)	(6)	(3)	(0)

* * * A N A L Y S I S   O F   V A R I A N C E * * *

TOTALSCO Total score
by OFFENSE
NEWAGEGP

HIERARCHICAL sums of squares
Covariates entered FIRST

Source of Variation	Sum of Squares	DF	Mean Square	F	Sig of F
Main Effects	18005.669	7	2572.238	13.366	.00
OFFENSE	2046.880	2	1023.440	5.318	.006
NEWAGEGP	15958.788	5	3191.758	16.585	.00
2-Way Interactions	1519.420	8	189.928	.987	.447
OFFENSE NEWAGEGP	1519.420	8	189.928	.987	.447
Explained	19525.089	15	1301.673	6.764	.00
Residual	43685.097	227	192.445		
Total	63210.185	242	261.199		

245 cases were processed.
2 cases (.8 pct) were missing.

* * * C E L L   M E A N S * * *

TOTALSCO Total score
by OFFENSE
NEWAGEGP

Total Population

25.59
(243)

OFFENSE

0	1	2
25.79	20.87	31.14
(164)	(46)	(33)

NEWAGEGP

1	2	3	4	5	6
14.63	26.56	28.33	37.08	40.58	40.00
(75)	(61)	(60)	(30)	(13)	(4)

OFFENSE \ NEWAGEGP	1	2	3	4	5	6
0	16.00	27.38	26.88	35.13	35.75	41.67
	(45)	(43)	(44)	(19)	(10)	(3)
1	12.02	22.92	31.79	35.00	.00	35.00
	(21)	(12)	(7)	(5)	(0)	(1)
2	13.89	27.92	32.78	45.00	56.67	.00
	(9)	(6)	(9)	(6)	(3)	(0)

* * * A N A L Y S I S   O F   V A R I A N C E * * *

TOTALSCO Total score
by OFFENSE
NEWAGEGP

HIERARCHICAL sums of squares
Covariates entered FIRST

Source of Variation	Sum of Squares	DF	Mean Square	F	Sig of F
Main Effects	18005.669	7	2572.238	13.366	.00
OFFENSE	2046.880	2	1023.440	5.318	.006
NEWAGEGP	15958.788	5	3191.758	16.585	.00
2-Way Interactions	1519.420	8	189.928	.987	.447
OFFENSE NEWAGEGP	1519.420	8	189.928	.987	.447
Explained	19525.089	15	1301.673	6.764	.00
Residual	43685.097	227	192.445		
Total	63210.185	242	261.199		

245 cases were processed.
2 cases (.8 pct) were missing.

* * M U L T I P L E   C L A S S I F I C A T I O N   A N A L Y S I S * *

TOTALSCO Total score
by OFFENSE
NEWAGEGP

Grand Mean = 25.59

Variable + Category	N	Unadjusted Dev'n	Unadjusted Eta	Adjusted for Independents Dev'n	Adjusted for Independents Beta
OFFENSE					
0 no offenses	164	.21		-.28	
1 speed offense	46	-4.72		-2.06	
2 veh ctrl offense	33	5.55		4.24	
			.18		.11
NEWAGEGP					
1 20-55	75	-10.95		-10.72	
2 65-69	61	.97		1.15	
3 70-74	60	2.75		2.55	
4 75-79	30	11.50		11.17	
5 80-84	13	14.99		14.22	
6 85+	4	14.41		15.14	
			.52		.51

Multiple R Squared .285
Multiple R .534

APPENDIX B

APPENDIX B

Younger Male Subjects

Number of valid observations (listwise) = 25.00

Variable	Mean	Std Dev	Minimum	Maximum	Valid N	Label
DRCALDPM	80.76	10.47	50	96	25	% Dir.Ctl Score
SPDALDPM	72.96	11.70	47	94	25	% Speed Score
SRHALDPM	98.52	1.48	94	100	25	% Search Score-Whole
OVRALDPM	96.56	2.86	88	100	25	% Overall DPM score

Younger Female Subjects.

Number of valid observations (listwise) = 48.00

Variable	Mean	Std Dev	Minimum	Maximum	Valid N	Label
DRCALDPM	79.98	10.05	61	97	48	% Dir.Ctl Score
SPDALDPM	74.69	8.16	56	88	48	% Speed Score
SRHALDPM	98.40	2.19	90	100	48	% Search Score
OVRALDPM	95.75	3.50	83	100	48	% Overall DPM score

* * * C E L L   M E A N S * * *

OVRALDPM % Overall DPM score
by ATFAULT
NEWAGEGP

Total Population

94.09
(237)

ATFAULT

0	1	2
95.67	92.62	94.06
(39)	(39)	(159)

NEWAGEGP

1	2	3	4	5	6
96.03	94.97	94.54	90.89	84.31	92.33
(73)	(61)	(59)	(28)	(13)	(3)

ATFAULT \ NEWAGEGP	1	2	3	4	5	6
0	97.31	95.53	94.33	93.67	94.00	92.00
	(13)	(15)	(6)	(3)	(1)	(1)
1	95.21	95.20	93.36	87.83	83.00	.00
	(14)	(5)	(11)	(6)	(3)	(0)
2	95.91	94.73	94.88	91.42	83.67	92.50
	(46)	(41)	(42)	(19)	(9)	(2)

* * * A N A L Y S I S   O F   V A R I A N C E * * *

OVRALDPM % Overall DPM score
by ATFAULT
NEWAGEGP
HIERARCHICAL sums of squares
Covariates entered FIRST

Source of Variation	Sum of Squares	DF	Mean Square	F	Sig of F
Main Effects	1973.794	7	281.971	6.661	.000
ATFAULT	181.871	2	90.935	2.148	.119
NEWAGEGP	1791.923	5	358.385	8.467	.000
2-Way Interactions	145.070	9	16.119	.381	.944
ATFAULT NEWAGEGP	145.070	9	16.119	.381	.944
Explained	2118.863	16	132.429	3.129	.000
Residual	9312.276	220	42.329		
Total	11431.139	236	48.437		

245 cases were processed.
8 cases (3.3 pct) were missing.

* * M U L T I P L E   C L A S S I F I C A T I O N   A N A L Y S I S * *

OVRALDPM % Overall DPM score
by ATFAULT
NEWAGEGP

Grand Mean = 94.09

Variable + Category	N	Unadjusted Dev'n	Unadjusted Eta	Adjusted for Independents Dev'n	Adjusted for Independents Beta
ATFAULT					
0 not at fault	39	1.58		1.11	
1 at fault	39	-1.47		-1.21	
2 no crash	159	-.03		.02	
			.13		.10
NEWAGEGP					
1 20-55	73	1.94		1.96	
2 65-69	61	.88		.69	
3 70-74	59	.45		.55	
4 75-79	28	-3.20		-3.07	
5 80-84	13	-9.78		-9.60	
6 85+	3	-1.76		-2.14	
			.40		.40
Multiple R Squared					.173
Multiple R					.416

* * * C E L L   M E A N S * * *

SRHALDPM % Search Score-Whole Route
by ATFAULT
NEWAGEGP

Total Population

97.39
(237)

ATFAULT

0	1	2
98.15	95.51	97.66
(39)	(39)	(159)

NEWAGEGP

1	2	3	4	5	6
98.44	98.11	97.85	95.64	89.92	96.67
(73)	(61)	(59)	(28)	(13)	(3)

ATFAULT \ NEWAGEGP	1	2	3	4	5	6
0	99.00	98.07	97.33	97.33	97.00	97.00
	(13)	(15)	(6)	(3)	(1)	(1)
1	97.79	95.80	97.55	90.17	87.67	.00
	(14)	(5)	(11)	(6)	(3)	(0)
2	98.48	98.41	98.00	97.11	89.89	96.50
	(46)	(41)	(42)	(19)	(9)	(2)

* * * A N A L Y S I S   O F   V A R I A N C E * * *

SRHALDPM % Search Score-Whole Route
by ATFAULT
NEWAGEGP
HIERARCHICAL sums of squares
Covariates entered FIRST

Source of Variation	Sum of Squares	DF	Mean Square	F	Sig of F
Main Effects	1064.284	7	152.041	9.330	.000
ATFAULT	171.806	2	85.903	5.272	.006
NEWAGEGP	892.478	5	178.496	10.954	.000
2-Way Interactions	211.078	9	23.453	1.439	.173
ATFAULT NEWAGEGP	211.078	9	23.453	1.439	.173
Explained	1275.361	16	79.710	4.892	.000
Residual	3584.926	220	16.295		
Total	4860.287	236	20.594		

245 cases were processed.
8 cases (3.3 pct) were missing.

* * M U L T I P L E   C L A S S I F I C A T I O N   A N A L Y S I S * *

SRHALDPM % Search Score-Whole Route
by ATFAULT
NEWAGEGP

Grand Mean = 97.39

Variable + Category	N	Unadjusted Dev'n	Unadjusted Eta	Adjusted for Independents Dev'n	Adjusted for Independents Beta
ATFAULT					
0 not at fault	39	.77		.45	
1 at fault	39	-1.88		-1.67	
2 no crash	159	.27		.30	
			.19		.16
NEWAGEGP					
1 20-55	73	1.05		1.10	
2 65-69	61	.73		.55	
3 70-74	59	.46		.51	
4 75-79	28	-1.75		-1.64	
5 80-84	13	-7.47		-7.32	
6 85+	3	-.72		-1.07	
			.44		.43
Multiple R Squared					.219
Multiple R					.468

* * * C E L L   M E A N S * * *

SPDALDPM % Speed Score-Whole Route
by ATFAULT
NEWAGEGP

Total Population

76.59
(237)

ATFAULT

0	1	2
75.77	79.05	76.19
(39)	(39)	(159)

NEWAGEGP

1	2	3	4	5	6
74.10	76.93	79.03	76.71	78.23	74.00
(73)	(61)	(59)	(28)	(13)	(3)

ATFAULT \ NEWAGEGP	1	2	3	4	5	6
0	75.15	74.47	80.33	76.33	75.00	75.00
	(13)	(15)	(6)	(3)	(1)	(1)
1	76.86	79.40	80.91	77.83	84.33	.00
	(14)	(5)	(11)	(6)	(3)	(0)
2	72.96	77.54	78.36	76.42	76.56	73.50
	(46)	(41)	(42)	(19)	(9)	(2)

* * * A N A L Y S I S   O F   V A R I A N C E * * *

SPDALDPM % Speed Score-Whole Route
by ATFAULT
NEWAGEGP
HIERARCHICAL sums of squares
Covariates entered FIRST

Source of Variation	Sum of Squares	DF	Mean Square	F	Sig of F
Main Effects	1162.305	7	166.044	2.550	.015
ATFAULT	288.139	2	144.070	2.212	.112
NEWAGEGP	874.166	5	174.833	2.685	.022
2-Way Interactions	251.140	9	27.904	.429	.919
ATFAULT NEWAGEGP	251.140	9	27.904	.429	.919
Explained	1413.446	16	88.340	1.357	.165
Residual	14325.854	220	65.118		
Total	15739.300	236	66.692		

245 cases were processed.
8 cases (3.3 pct) were missing.

* * M U L T I P L E   C L A S S I F I C A T I O N   A N A L Y S I S * *

SPDALDPM % Speed Score-Whole Route
by ATFAULT
NEWAGEGP

Grand Mean = 76.59

Variable + Category	N	Unadjusted Dev'n	Unadjusted Eta	Adjusted for Independents Dev'n	Adjusted for Independents Beta
ATFAULT					
0 not at fault	39	-.82		-.54	
1 at fault	39	2.46		2.53	
2 no crash	159	-.40		-.49	
			.14		.14
NEWAGEGP					
1 20-55	73	-2.49		-2.58	
2 65-69	61	.34		.60	
3 70-74	59	2.44		2.37	
4 75-79	28	.12		-.03	
5 80-84	13	1.64		1.44	
6 85+	3	-2.59		-2.08	
			.24		.24
Multiple R Squared					.074
Multiple R					.272

*** CELL MEANS ***

DRCALDPM % Dir.Ctl Score-Whole Route
by ATFAULT
NEWAGEGP

Total Population

76.31
(237)

ATFAULT

0	1	2
74.13	76.38	76.83
(39)	(39)	(159)

NEWAGEGP

1	2	3	4	5	6
80.25	75.84	77.90	69.68	64.69	71.33
(73)	(61)	(59)	(28)	(13)	(3)

ATFAULT	NEWAGEGP 1	2	3	4	5	6
0	80.92	72.67	70.67	67.33	70.00	53.00
	(13)	(15)	(6)	(3)	(1)	(1)
1	80.64	75.00	77.55	72.50	62.33	.00
	(14)	(5)	(11)	(6)	(3)	(0)
2	79.93	77.10	79.02	69.16	64.89	80.50
	(46)	(41)	(42)	(19)	(9)	(2)

* * * A N A L Y S I S   O F   V A R I A N C E * * *

DRCALDPM % Dir.Ctl Score-Whole Route
by ATFAULT
NEWAGEGP
HIERARCHICAL sums of squares
Covariates entered FIRST

Source of Variation	Sum of Squares	DF	Mean Square	F	Sig of F
Main Effects	4687.991	7	669.713	6.035	.000
ATFAULT	228.890	2	114.445	1.031	.358
NEWAGEGP	4459.102	5	891.820	8.037	.000
2-Way Interactions	885.233	9	98.359	.886	.538
ATFAULT NEWAGEGP	885.233	9	98.359	.886	.538
Explained	5573.224	16	348.327	3.139	.000
Residual	24413.670	220	110.971		
Total	29986.895	236	127.063		

245 cases were processed.
8 cases (3.3 pct) were missing.

* * M U L T I P L E   C L A S S I F I C A T I O N   A N A L Y S I S * *

DRCALDPM % Dir.Ctl Score-Whole Route
by ATFAULT
NEWAGEGP

Grand Mean = 76.31

Variable + Category	N	Unadjusted Dev'n	Unadjusted Eta	Adjusted for Independents Dev'n	Adjusted for Independents Beta
ATFAULT					
0 not at fault	39	-2.18		-2.69	
1 at fault	39	.07		.24	
2 no crash	159	.52		.60	
			.09		.11
NEWAGEGP					
1 20-55	73	3.93		3.99	
2 65-69	61	-.48		-.24	
3 70-74	59	1.59		1.39	
4 75-79	28	-6.63		-6.80	
5 80-84	13	-11.62		-11.88	
6 85+	3	-4.98		-4.48	
			.38		.39
Multiple R Squared					.156
Multiple R					.395

The first run (A-K) is for **atfault = 0**, not-at-fault crash involved

- - - - - O N E W A Y - - - - -

Variable ASITESCR "A" site performance
By Variable NEWAGEGP

Analysis of Variance

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	5	175.5572	35.1114	1.7514	.1504
Within Groups	33	661.5774	20.0478		
Total	38	837.1345			

- - - - - O N E W A Y - - - - -

Variable ASITESCR "A" site performance
By Variable NEWAGEGP

Multiple Range Tests: Tukey-B test with significance level .050

The difference between two means is significant if
MEAN(J)-MEAN(I) >= 3.1661 * **RANGE** * **SQRT**(1/N(I) + 1/N(J))
with the following value(s) for RANGE:

Step	2	3	4	5	6
RANGE	3.58	3.87	4.05	4.18	4.28

- **No two groups are significantly different at the** .050 **level**

- - - - - O N E W A Y - - - - -

```
     Variable  BSITESCR   "B" site performance
  By Variable  NEWAGEGP
```

Analysis of Variance

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	5	143.8390	28.7678	4.1024	.0052
Within Groups	33	231.4103	7.0124		
Total	38	375.2493			

- - - - - O N E W A Y - - - - -

```
     Variable  BSITESCR   "B" site performance
  By Variable  NEWAGEGP

Multiple Range Tests:  Tukey-B test with significance level .050

The difference between two means is significant if
  MEAN(J)-MEAN(I)  >= 1.8725 * RANGE * SQRT(1/N(I) + 1/N(J))
  with the following value(s) for RANGE:

 Step       2      3      4      5      6
 RANGE    3.58   3.87   4.05   4.18   4.28

    (*) Indicates significant differences which are shown in the lower
        triangle

                           G G G G G G
                           r r r r r r
                           p p p p p p

                           4 6 3 1 2 5
     Mean        NEWAGEGP

    93.0556      Grp 4
    95.0000      Grp 6
    98.6111      Grp 3     *
    99.6154      Grp 1     *
   100.0000      Grp 2     *
   100.0000      Grp 5
```

- - - - - O N E W A Y - - - - -

Variable CSITESCR "C" site performance
By Variable NEWAGEGP

Analysis of Variance

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	5	1064.0182	212.8036	.6303	.6779
Within Groups	32	10803.7861	337.6183		
Total	37	11867.8043			

- - - - - O N E W A Y - - - - -

Variable CSITESCR "C" site performance
By Variable NEWAGEGP

Multiple Range Tests: Tukey-B test with significance level .050

The difference between two means is significant if
MEAN(J)-MEAN(I) >= 12.9927 * RANGE * SQRT(1/N(I) + 1/N(J))
with the following value(s) for RANGE:

Step	2	3	4	5	6
RANGE	3.58	3.88	4.06	4.18	4.28

- No two groups are significantly different at the .050 level

- - - - - O N E W A Y - - - - -

Variable DSITESCR "D" site performance
By Variable NEWAGEGP

Analysis of Variance

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	5	220.2948	44.0590	.4347	.8210
Within Groups	32	3243.3331	101.3542		
Total	37	3463.6279			

- - - - - O N E W A Y - - - - -

Variable DSITESCR "D" site performance
By Variable NEWAGEGP

Multiple Range Tests: Tukey-B test with significance level .050

The difference between two means is significant if
MEAN(J)-MEAN(I) >= 7.1188 * RANGE * SQRT(1/N(I) + 1/N(J))
with the following value(s) for RANGE:

Step	2	3	4	5	6
RANGE	3.58	3.88	4.06	4.18	4.28

- No two groups are significantly different at the .050 level

- - - - - O N E W A Y - - - - -

Variable FSITESCR "F" site performance
By Variable NEWAGEGP

Analysis of Variance

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	5	39.0625	7.8125	.6000	.7002
Within Groups	30	390.6250	13.0208		
Total	35	429.6875			

- - - - - O N E W A Y - - - - -

Variable FSITESCR "F" site performance
By Variable NEWAGEGP

Multiple Range Tests: Tukey-B test with significance level .050

The difference between two means is significant if
MEAN(J)-MEAN(I) >= 2.5516 * RANGE * SQRT(1/N(I) + 1/N(J))
with the following value(s) for RANGE:

Step	2	3	4	5	6
RANGE	3.60	3.89	4.07	4.20	4.30

- No two groups are significantly different at the .050 level

- - - - - O N E W A Y - - - - -

Variable GSITESCR "G" site performance
By Variable NEWAGEGP

Analysis of Variance

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	5	3.2018	.6404	.4640	.8001
Within Groups	32	44.1667	1.3802		
Total	37	47.3684			

- - - - - O N E W A Y - - - - -

Variable GSITESCR "G" site performance
By Variable NEWAGEGP

Multiple Range Tests: Tukey-B test with significance level .050

The difference between two means is significant if
MEAN(J)-MEAN(I) >= .8307 * RANGE * SQRT(1/N(I) + 1/N(J))
with the following value(s) for RANGE:

Step	2	3	4	5	6
RANGE	3.58	3.88	4.06	4.18	4.28

- No two groups are significantly different at the .050 level

- - - - - O N E W A Y - - - - -

Variable ISITESCR "I" site performance
By Variable NEWAGEGP

Analysis of Variance

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	5	9348.2458	1869.6492	2.2557	.0726
Within Groups	32	26523.0769	828.8462		
Total	37	35871.3227			

- - - - - O N E W A Y - - - - -

Variable ISITESCR "I" site performance
By Variable NEWAGEGP

Multiple Range Tests: Tukey-B test with significance level .050

The difference between two means is significant if
MEAN(J)-MEAN(I) >= 20.3574 * RANGE * SQRT(1/N(I) + 1/N(J))
with the following value(s) for RANGE:

Step	2	3	4	5	6
RANGE	3.58	3.88	4.06	4.18	4.28

- No two groups are significantly different at the .050 level

- - - - - O N E W A Y - - - - -

```
     Variable  JSITESCR   "J" site performance
  By Variable  NEWAGEGP
```

Analysis of Variance

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	5	692.9825	138.5965	2.1947	.0793
Within Groups	32	2020.8333	63.1510		
Total	37	2713.8158			

- - - - - O N E W A Y - - - - -

```
     Variable  JSITESCR   "J" site performance
  By Variable  NEWAGEGP
```

Multiple Range Tests: Tukey-B test with significance level .050

```
The difference between two means is significant if
  MEAN(J)-MEAN(I)  >= 5.6192 * RANGE * SQRT(1/N(I) + 1/N(J))
  with the following value(s) for RANGE:
```

Step	2	3	4	5	6
RANGE	3.58	3.88	4.06	4.18	4.28

(*) Indicates significant differences which are shown in the lower triangle

Mean	NEWAGEGP	Grp 6	Grp 4	Grp 3	Grp 2	Grp 1	Grp 5
75.0000	Grp 6						
91.6667	Grp 4						
95.8333	Grp 3						
96.6667	Grp 2						
100.0000	Grp 1	*					
100.0000	Grp 5						

- - - - - O N E W A Y - - - - -

Variable KSITESCR "K" site performance
By Variable NEWAGEGP

Analysis of Variance

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	5	21.9587	4.3917	.3078	.9047
Within Groups	33	470.8077	14.2669		
Total	38	492.7664			

- - - - - O N E W A Y - - - - -

Variable KSITESCR "K" site performance
By Variable NEWAGEGP

Multiple Range Tests: Tukey-B test with significance level .050

The difference between two means is significant if
MEAN(J)-MEAN(I) >= 2.6709 * RANGE * SQRT(1/N(I) + 1/N(J))
with the following value(s) for RANGE:

Step	2	3	4	5	6
RANGE	3.58	3.87	4.05	4.18	4.28

- No two groups are significantly different at the .050 level

This run (A-K) is for **atfault = 1**, at fault crash involved.

- - - - - O N E W A Y - - - - -

Variable ASITESCR "A" site performance
By Variable NEWAGEGP

Analysis of Variance

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	4	657.4135	164.3534	2.2461	.0853
Within Groups	33	2414.7177	73.1733		
Total	37	3072.1312			

- - - - - O N E W A Y - - - - -

Variable ASITESCR "A" site performance
By Variable NEWAGEGP

Multiple Range Tests: Tukey-B test with significance level .050

The difference between two means is significant if
MEAN(J)-MEAN(I) >= 6.0487 * RANGE * SQRT(1/N(I) + 1/N(J))
with the following value(s) for RANGE:

Step	2	3	4	5
RANGE	3.48	3.77	3.95	4.08

- No two groups are significantly different at the .050 level

- - - - - O N E W A Y - - - - -

Variable BSITESCR "B" site performance
By Variable NEWAGEGP

Analysis of Variance

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	4	733.1978	183.2995	2.9879	.0328
Within Groups	33	2024.4627	61.3474		
Total	37	2757.6605			

- - - - - O N E W A Y - - - - -

Variable BSITESCR "B" site performance
By Variable NEWAGEGP

Multiple Range Tests: Tukey-B test with significance level .050

The difference between two means is significant if
MEAN(J)-MEAN(I) >= 5.5384 * RANGE * SQRT(1/N(I) + 1/N(J))
with the following value(s) for RANGE:

Step	2	3	4	5
RANGE	3.48	3.77	3.95	4.08

(*) Indicates significant differences which are shown in the lower triangle

Mean	NEWAGEGP	Grp 5	Grp 4	Grp 3	Grp 2	Grp 1
79.0761	Grp 5					
93.4722	Grp 4					
95.6818	Grp 3	*				
97.5000	Grp 2	*				
98.8095	Grp 1	*				

- - - - - O N E W A Y - - - - -

Variable CSITESCR "C" site performance
By Variable NEWAGEGP

Analysis of Variance

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	4	90.3719	22.5930	.2755	.8917
Within Groups	34	2788.2339	82.0069		
Total	38	2878.6058			

- - - - - O N E W A Y - - - - -

Variable CSITESCR "C" site performance
By Variable NEWAGEGP

Multiple Range Tests: Tukey-B test with significance level .050

The difference between two means is significant if
MEAN(J)-MEAN(I) >= 6.4034 * RANGE * SQRT(1/N(I) + 1/N(J))
with the following value(s) for RANGE:

Step	2	3	4	5
RANGE	3.47	3.76	3.94	4.07

- No two groups are significantly different at the .050 level

- - - - - O N E W A Y - - - - -

Variable DSITESCR "D" site performance
By Variable NEWAGEGP

Analysis of Variance

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	4	288.8682	72.2170	.5846	.6761
Within Groups	32	3953.1767	123.5368		
Total	36	4242.0449			

- - - - - O N E W A Y - - - - -

Variable DSITESCR "D" site performance
By Variable NEWAGEGP

Multiple Range Tests: Tukey-B test with significance level .050

The difference between two means is significant if
MEAN(J)-MEAN(I) >= 7.8593 * RANGE * SQRT(1/N(I) + 1/N(J))
with the following value(s) for RANGE:

Step	2	3	4	5
RANGE	3.48	3.78	3.96	4.08

- No two groups are significantly different at the .050 level

- - - - - O N E W A Y - - - - -

Variable FSITESCR "F" site performance
By Variable NEWAGEGP

Analysis of Variance

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	4	218.1079	54.5270	2.0211	.1177
Within Groups	29	782.3707	26.9783		
Total	33	1000.4786			

- - - - - O N E W A Y - - - - -

Variable FSITESCR "F" site performance
By Variable NEWAGEGP

Multiple Range Tests: Tukey-B test with significance level .050

The difference between two means is significant if
MEAN(J)-MEAN(I) >= 3.6728 * RANGE * SQRT(1/N(I) + 1/N(J))
with the following value(s) for RANGE:

Step	2	3	4	5
RANGE	3.50	3.80	3.98	4.11

- No two groups are significantly different at the .050 level

- - - - - O N E W A Y - - - - -

Variable GSITESCR "G" site performance
By Variable NEWAGEGP

Analysis of Variance

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	4	5.5816	1.3954	.9756	.4360
Within Groups	29	41.4773	1.4303		
Total	33	47.0588			

- - - - - O N E W A Y - - - - -

Variable GSITESCR "G" site performance
By Variable NEWAGEGP

Multiple Range Tests: Tukey-B test with significance level .050

The difference between two means is significant if
MEAN(J)-MEAN(I) >= .8457 * RANGE * SQRT(1/N(I) + 1/N(J))
with the following value(s) for RANGE:

Step	2	3	4	5
RANGE	3.50	3.80	3.98	4.11

- No two groups are significantly different at the .050 level

- - - - - O N E W A Y - - - - -

Variable ISITESCR "I" site performance
By Variable NEWAGEGP

Analysis of Variance

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	4	10062.3584	2515.5896	2.9465	.0341
Within Groups	34	29027.5503	853.7515		
Total	38	39089.9087			

- - - - - O N E W A Y - - - - -

Variable ISITESCR "I" site performance
By Variable NEWAGEGP

Multiple Range Tests: Tukey-B test with significance level .050

The difference between two means is significant if
MEAN(J)-MEAN(I) >= 20.6610 * RANGE * SQRT(1/N(I) + 1/N(J))
with the following value(s) for RANGE:

Step	2	3	4	5
RANGE	3.47	3.76	3.94	4.07

(*) Indicates significant differences which are shown in the lower triangle

Mean	NEWAGEGP	Grp 5	Grp 3	Grp 4	Grp 2	Grp 1
19.4444	Grp 5					
44.5455	Grp 3					
47.4747	Grp 4					
56.6667	Grp 2					
73.3496	Grp 1	*				

- - - - - O N E W A Y - - - - -

```
     Variable  JSITESCR    "J" site performance
  By Variable  NEWAGEGP
```

Analysis of Variance

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	4	243.6880	60.9220	1.1267	.3633
Within Groups	29	1568.1226	54.0732		
Total	33	1811.8107			

- - - - - O N E W A Y - - - - -


```
     Variable  JSITESCR    "J" site performance
  By Variable  NEWAGEGP
```


Multiple Range Tests: Tukey-B test with significance level .050

```
The difference between two means is significant if
  MEAN(J)-MEAN(I)  >= 5.1997 * RANGE * SQRT(1/N(I) + 1/N(J))
  with the following value(s) for RANGE:
```

Step	2	3	4	5
RANGE	3.50	3.80	3.98	4.11

- No two groups are significantly different at the .050 level

- - - - - O N E W A Y - - - - -

Variable KSITESCR "K" site performance
By Variable NEWAGEGP

Analysis of Variance

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	4	5.6094	1.4023	.3060	.8720
Within Groups	34	155.8341	4.5834		
Total	38	161.4435			

- - - - - O N E W A Y - - - - -

Variable KSITESCR "K" site performance
By Variable NEWAGEGP

Multiple Range Tests: Tukey-B test with significance level .050

The difference between two means is significant if
MEAN(J)-MEAN(I) >= 1.5138 * RANGE * SQRT(1/N(I) + 1/N(J))
with the following value(s) for RANGE:

Step	2	3	4	5
RANGE	3.47	3.76	3.94	4.07

- No two groups are significantly different at the .050 level

This run (A-K) is for **atfault = 2**, no crash involvement.

- - - - - O N E W A Y - - - - -

Variable ASITESCR "A" site performance
By Variable NEWAGEGP

Analysis of Variance

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	5	405.3674	81.0735	2.3999	.0399
Within Groups	146	4932.2189	33.7823		
Total	151	5337.5863			

- - - - - O N E W A Y - - - - -

Variable ASITESCR "A" site performance
By Variable NEWAGEGP

Multiple Range Tests: Tukey-B test with significance level .050

The difference between two means is significant if
MEAN(J)-MEAN(I) >= 4.1099 * RANGE * SQRT(1/N(I) + 1/N(J))
with the following value(s) for RANGE:

Step	2	3	4	5	6
RANGE	3.45	3.72	3.88	4.00	4.09

(*) Indicates significant differences which are shown in the lower triangle

Mean	NEWAGEGP	Grp 6	Grp 4	Grp 3	Grp 2	Grp 5	Grp 1
85.7143	Grp 6						
92.7632	Grp 4						
95.8224	Grp 3						
96.6621	Grp 2						
96.9199	Grp 5						
97.3070	Grp 1		*				

- - - - - O N E W A Y - - - - -

Variable BSITESCR "B" site performance
By Variable NEWAGEGP

Analysis of Variance

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	5	1158.3817	231.6763	5.2397	.0002
Within Groups	149	6588.0850	44.2153		
Total	154	7746.4668			

- - - - - O N E W A Y - - - - -

Variable BSITESCR "B" site performance
By Variable NEWAGEGP

Multiple Range Tests: Tukey-B test with significance level .050

The difference between two means is significant if
MEAN(J)-MEAN(I) >= 4.7019 * RANGE * SQRT(1/N(I) + 1/N(J))
with the following value(s) for RANGE:

Step	2	3	4	5	6
RANGE	3.45	3.72	3.88	4.00	4.08

(*) Indicates significant differences which are shown in the lower triangle

Mean	NEWAGEGP	Grp 5	Grp 4	Grp 6	Grp 2	Grp 3	Grp 1
87.5000	Grp 5						
96.3530	Grp 4	*					
97.9167	Grp 6						
98.8253	Grp 2	*					
98.8958	Grp 3	*					
99.1111	Grp 1	*					

- - - - - O N E W A Y - - - - -

Variable CSITESCR "C" site performance
By Variable NEWAGEGP

Analysis of Variance

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	5	184.0743	36.8149	.7067	.6193
Within Groups	149	7762.4423	52.0969		
Total	154	7946.5166			

- - - - - O N E W A Y - - - - -

Variable CSITESCR "C" site performance
By Variable NEWAGEGP

Multiple Range Tests: Tukey-B test with significance level .050

The difference between two means is significant if
MEAN(J)-MEAN(I) >= 5.1038 * RANGE * SQRT(1/N(I) + 1/N(J))
with the following value(s) for RANGE:

Step	2	3	4	5	6
RANGE	3.45	3.72	3.88	4.00	4.08

- No two groups are significantly different at the .050 level

- - - - - O N E W A Y - - - - -

Variable DSITESCR "D" site performance
By Variable NEWAGEGP

Analysis of Variance

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	5	908.9814	181.7963	1.1043	.3606
Within Groups	149	24529.7020	164.6289		
Total	154	25438.6834			

- - - - - O N E W A Y - - - - -

Variable DSITESCR "D" site performance
By Variable NEWAGEGP

Multiple Range Tests: Tukey-B test with significance level .050

The difference between two means is significant if
MEAN(J)-MEAN(I) >= 9.0727 * RANGE * SQRT(1/N(I) + 1/N(J))
with the following value(s) for RANGE:

Step	2	3	4	5	6
RANGE	3.45	3.72	3.88	4.00	4.08

- No two groups are significantly different at the .050 level

- - - - - O N E W A Y - - - - -

Variable FSITESCR "F" site performance
By Variable NEWAGEGP

Analysis of Variance

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	5	74.9233	14.9847	.7263	.6048
Within Groups	143	2950.4480	20.6325		
Total	148	3025.3713			

- - - - - O N E W A Y - - - - -

Variable FSITESCR "F" site performance
By Variable NEWAGEGP

Multiple Range Tests: Tukey-B test with significance level .050

The difference between two means is significant if
MEAN(J)-MEAN(I) >= 3.2119 * RANGE * SQRT(1/N(I) + 1/N(J))
with the following value(s) for RANGE:

Step	2	3	4	5	6
RANGE	3.45	3.72	3.88	4.00	4.09

- No two groups are significantly different at the .050 level

- - - - - O N E W A Y - - - - -

Variable GSITESCR "G" site performance
By Variable NEWAGEGP

Analysis of Variance

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	5	7.8226	1.5645	.5365	.7483
Within Groups	146	425.7300	2.9160		
Total	151	433.5526			

- - - - - O N E W A Y - - - - -

Variable GSITESCR "G" site performance
By Variable NEWAGEGP

Multiple Range Tests: Tukey-B test with significance level .050

The difference between two means is significant if
MEAN(J)-MEAN(I) >= 1.2075 * RANGE * SQRT(1/N(I) + 1/N(J))
with the following value(s) for RANGE:

Step	2	3	4	5	6
RANGE	3.45	3.72	3.88	4.00	4.09

- No two groups are significantly different at the .050 level

- - - - - O N E W A Y - - - - -

Variable ISITESCR "I" site performance
By Variable NEWAGEGP

Analysis of Variance

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	5	20318.4946	4063.6989	4.8748	.0004
Within Groups	149	124208.1411	833.6117		
Total	154	144526.6358			

- - - - - O N E W A Y - - - - -

Variable ISITESCR "I" site performance
By Variable NEWAGEGP

Multiple Range Tests: Tukey-B test with significance level .050

The difference between two means is significant if
MEAN(J)-MEAN(I) >= 20.4158 * RANGE * SQRT(1/N(I) + 1/N(J))
with the following value(s) for RANGE:

Step	2	3	4	5	6
RANGE	3.45	3.72	3.88	4.00	4.08

(*) Indicates significant differences which are shown in the lower triangle

```
                          G G G G G G
                          r r r r r r
                          p p p p p p

                          6 5 4 3 2 1
   Mean       NEWAGEGP

  21.4286     Grp 6
  40.0253     Grp 5
  42.2754     Grp 4
  54.6212     Grp 3
  56.6895     Grp 2
  72.5606     Grp 1         * * * *
```

- - - - - O N E W A Y - - - - -

Variable JSITESCR "J" site performance
By Variable NEWAGEGP

Analysis of Variance

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	5	125.3201	25.0640	.1777	.9706
Within Groups	145	20448.7308	141.0257		
Total	150	20574.0509			

- - - - - O N E W A Y - - - - -

Variable JSITESCR "J" site performance
By Variable NEWAGEGP

Multiple Range Tests: Tukey-B test with significance level .050

The difference between two means is significant if
MEAN(J)-MEAN(I) >= 8.3972 * RANGE * SQRT(1/N(I) + 1/N(J))
with the following value(s) for RANGE:

Step	2	3	4	5	6
RANGE	3.45	3.72	3.88	4.00	4.09

- No two groups are significantly different at the .050 level

- - - - - O N E W A Y - - - - -

Variable KSITESCR "K" site performance
By Variable NEWAGEGP

Analysis of Variance

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	5	108.3687	21.6737	2.6852	.0235
Within Groups	150	1210.7299	8.0715		
Total	155	1319.0986			

- - - - - O N E W A Y - - - - -

Variable KSITESCR "K" site performance
By Variable NEWAGEGP

Multiple Range Tests: Tukey-B test with significance level .050

The difference between two means is significant if
MEAN(J)-MEAN(I) >= 2.0089 * RANGE * SQRT(1/N(I) + 1/N(J))
with the following value(s) for RANGE:

Step	2	3	4	5	6
RANGE	3.45	3.72	3.88	4.00	4.08

(*) Indicates significant differences which are shown in the lower triangle

Mean	NEWAGEGP	Grp 5	Grp 1	Grp 3	Grp 2	Grp 4	Grp 6
97.3810	Grp 5						
97.5652	Grp 1						
99.0665	Grp 3		*				
99.3127	Grp 2		*				
99.5370	Grp 4						
100.0000	Grp 6						

DPM PERFORMANCE: ALL SUBJECTS, URBAN SITES (A,B,D,I)
NO ACCIDENT/NOT AT FAULT ACCIDENT/AT FAULT ACCIDENT.

*"A" SITE PERFORMANCE, NO RECORDED ACCIDENTS.

Number of valid observations (listwise) = 154.00

Variable	Mean	Std Dev	Minimum	Maximum	Valid N	Label
ASITESCR	96.04	5.97	61	100	154	"A" site performance
ASEARCH	97.09	5.08	71	100	154	"A" search score
ASPEED	89.25	11.35	46	100	154	"A" speed score
ADIRCTL	72.43	14.49	39	100	154	"A" Dirc.CTRL score

*"B" SITE PERFORMANCE, NO RECORDED ACCIDENTS.

Number of valid observations (listwise) = 157.00

Variable	Mean	Std Dev	Minimum	Maximum	Valid N	Label
BSITESCR	97.98	7.05	25	100	157	"B" site performance
BSEARCH	98.40	5.24	50	100	157	"B" search score
BSPEED	83.04	10.31	54	100	157	"B" speed score
BDIRCTL	74.86	14.63	25	100	157	"B" Dirc.CTRL score

*"D" SITE PERFORMANCE, NO RECORDED ACCIDENTS.

Number of valid observations (listwise) = 157.00

Variable	Mean	Std Dev	Minimum	Maximum	Valid N	Label
DSITESCR	92.87	13.24	25	100	157	"D" site performance
DSEARCH	92.30	11.17	50	100	157	"D" search score
DSPEED	64.12	13.36	38	100	157	"D" speed score
DDIRCTL	82.06	17.83	31	100	157	"D" Dirc.CTRL score

*"I" SITE PERFORMANCE, NO RECORDED ACCIDENTS.

Number of valid observations (listwise) = 143.00

Variable	Mean	Std Dev	Minimum	Maximum	Valid N	Label
ISITESCR	58.06	30.74	0	100	157	"I" site performance
ISEARCH	94.87	9.22	63	100	143	"I" search score
ISPEED	80.08	16.51	0	100	144	"I" speed score
IDIRCTL	70.87	24.33	0	100	143	"I" Dirc.CTRL score

"A" SITE PERFORMANCE, NOT AT FAULT ACCIDENT INVOLVED.

Number of valid observations (listwise) = 39.00

Variable	Mean	Std Dev	Minimum	Maximum	Valid N	Label
ASITESCR	96.87	4.69	81	100	39	"A" site performance
ASEARCH	97.71	4.24	85	100	39	"A" search score
ASPEED	86.81	11.47	58	100	39	"A" speed score
ADIRCTL	71.28	17.16	36	100	39	"A" Dirc.CTRL score

"B" SITE PERFORMANCE, NOT AT FAULT ACCIDENT INVOLVED.

Number of valid observations (listwise) = 39.00

Variable	Mean	Std Dev	Minimum	Maximum	Valid N	Label
BSITESCR	99.00	3.14	83	100	39	"B" site performance
BSEARCH	99.10	2.34	90	100	39	"B" search score
BSPEED	82.59	11.76	40	96	39	"B" speed score
BDIRCTL	74.44	16.63	33	100	39	"B" Dirc.CTRL score

"D" SITE PERFORMANCE, NOT AT FAULT ACCIDENT INVOLVED.

Number of valid observations (listwise) = 38.00

Variable	Mean	Std Dev	Minimum	Maximum	Valid N	Label
DSITESCR	94.64	9.68	67	100	38	"D" site performance
DSEARCH	90.79	9.50	75	100	38	"D" search score
DSPEED	61.51	11.53	50	94	38	"D" speed score
DDIRCTL	78.50	18.59	31	100	38	"D" Dirc.CTRL score

"I" SITE PERFORMANCE, NOT AT FAULT ACCIDENT INVOLVED.

Number of valid observations (listwise) = 36.00

Variable	Mean	Std Dev	Minimum	Maximum	Valid N	Label
ISITESCR	70.04	31.14	0	100	38	"I" site performance
ISEARCH	97.99	5.56	75	100	36	"I" search score
ISPEED	74.79	19.39	25	100	36	"I" speed score
IDIRCTL	75.95	16.91	38	100	36	"I" Dirc.CTRL score

"A" SITE PERFORMANCE, AT FAULT ACCIDENT INVOLVED.

Number of valid observations (listwise) = 38.00

Variable	Mean	Std Dev	Minimum	Maximum	Valid N	Label
ASITESCR	94.27	9.11	60	100	38	"A" site performance
ASEARCH	93.63	9.57	54	100	38	"A" search score
ASPEED	91.54	9.47	60	100	38	"A" speed score
ADIRCTL	76.07	15.19	43	100	38	"A" Dirc.CTRL score

"B" SITE PERFORMANCE, AT FAULT ACCIDENT INVOLVED.

Number of valid observations (listwise) = 38.00

Variable	Mean	Std Dev	Minimum	Maximum	Valid N	Label
BSITESCR	95.85	8.63	63	100	38	"B" site performance
BSEARCH	94.03	9.83	69	100	38	"B" search score
BSPEED	83.73	11.08	50	100	38	"B" speed score
BDIRCTL	76.64	14.69	38	100	38	"B" Dirc.CTRL score

"D" SITE PERFORMANCE, AT FAULT ACCIDENT INVOLVED.

Number of valid observations (listwise) = 37.00

Variable	Mean	Std Dev	Minimum	Maximum	Valid N	Label
DSITESCR	93.09	10.86	67	100	37	"D" site performance
DSEARCH	89.74	13.32	53	100	37	"D" search score
DSPEED	66.31	13.17	44	94	37	"D" speed score
DDIRCTL	77.83	17.69	31	100	37	"D" Dirc.CTRL score

"I" SITE PERFORMANCE, AT FAULT ACCIDENT INVOLVED.

Number of valid observations (listwise) = 36.00

Variable	Mean	Std Dev	Minimum	Maximum	Valid N	Label
ISITESCR	54.96	32.07	0	100	39	"I" site performance
ISEARCH	91.37	14.53	40	100	36	"I" search score
ISPEED	80.44	14.90	50	100	36	"I" speed score
IDIRCTL	71.58	26.98	0	100	36	"I" Dirc.CTRL score

Older Subjects, Non-Crash-Involved, 5-Lane Signalized Int.

Number of valid observations (listwise) = 109.00

Variable	Mean	Std Dev	Minimum	Maximum	Valid N	Label
ASITESCR	95.52	6.50	61	100	109	"A" site performance
ASEARCH	96.81	5.75	71	100	109	"A" search score
ASPEED	91.43	8.92	61	100	109	"A" speed score
ADIRCTL	70.76	13.54	39	100	109	"A" Dir.Ctl.

Older Subjects, At-Fault Crash-Involved, 5-Lane Signalized Int.

Number of valid observations (listwise) = 25.00

Variable	Mean	Std Dev	Minimum	Maximum	Valid N	Label
ASITESCR	92.87	9.94	60	100	25	"A" site performance
ASPEED	93.32	8.76	60	100	25	"A" speed score
ASEARCH	92.32	11.07	54	100	25	"A" search score
ADIRCTL	75.20	15.59	43	100	25	"A" Dirc.CTRL score

Older Subjects, Not-At-Fault Crash-Involved, 5-Lane Signalized Int.

Number of valid observations (listwise) = 25.00

Variable	Mean	Std Dev	Minimum	Maximum	Valid N	Label
ASITESCR	95.56	5.24	81	100	25	"A" site performance
ASEARCH	97.19	4.28	86	100	25	"A" search score
ASPEED	86.56	10.89	58	100	25	"A" speed score
ADIRCTL	66.71	17.09	36	100	25	"A" Dirc.CTRL score

Older Subjects, Non-Crash-Involved, 4-Lane Signalized Int.

Number of valid observations (listwise) = 112.00

Variable	Mean	Std Dev	Minimum	Maximum	Valid N	Label
BSITESCR	97.53	8.17	25	100	112	"B" site performance
BSEARCH	98.01	6.02	50	100	112	"B" search score
BSPEED	83.97	9.51	55	100	112	"B" speed score
BDIRCTL	73.45	14.43	25	100	112	"B" Dirc.CTRL score

Older Subjects, At-Fault Crash-Involved, 4-Lane Signalized Int.

Number of valid observations (listwise) = 25.00

Variable	Mean	Std Dev	Minimum	Maximum	Valid N	Label
BSITESCR	94.36	10.09	63	100	25	"B" site performance
BSEARCH	92.92	10.42	69	100	25	"B" search score
BSPEED	86.79	7.15	71	100	25	"B" speed score
BDIRCTL	72.96	15.30	38	100	25	"B" Dirc.CTRL score

Older Subjects, Not-At-Fault Crash-Involved, 4-Lane Signalized Int.

Number of valid observations (listwise) = 25.00

Variable	Mean	Std Dev	Minimum	Maximum	Valid N	Label
BSITESCR	98.63	3.78	83	100	25	"B" site performance
BSEARCH	98.77	2.77	90	100	25	"B" search score
BSPEED	83.89	8.95	54	96	25	"B" speed score
BDIRCTL	70.51	17.74	33	100	25	"B" Dirc.CTRL score

Older Subjects, Non-Crash-Involved, Urban Right-Turn.

Number of valid observations (listwise) = 112.00

Variable	Mean	Std Dev	Minimum	Maximum	Valid N	Label
DSITESCR	92.09	14.33	25	100	112	"D" site performance
DSEARCH	91.51	11.43	50	100	112	"D" search score
DSPEED	66.41	14.17	43	100	112	"D" speed score
DDIRCTL	79.90	17.81	42	100	112	"D" Dirc.CTRL score

Older Subjects, At-Fault Crash-Involved, Urban Right-Turn.

Number of valid observations (listwise) = 25.00

Variable	Mean	Std Dev	Minimum	Maximum	Valid N	Label
DSITESCR	92.19	11.14	67	100	25	"D" site performance
DSEARCH	88.48	13.22	53	100	25	"D" search score
DSPEED	67.30	11.42	50	94	25	"D" speed score
DDIRCTL	73.92	19.70	3	100	25	"D" Dirc.CTRL score

Older Subjects, Not-At-Fault Crash-Involved, Urban Right-Turn.

Number of valid observations (listwise) = 25.00

Variable	Mean	Std Dev	Minimum	Maximum	Valid N	Label
DSITESCR	95.25	9.07	69	100	25	"D" site performance
DSEARCH	89.75	9.35	75	100	25	"D" search score
DSPEED	64.25	12.75	50	94	25	"D" speed score
DDIRCTL	77.32	20.41	31	100	25	"D" Dirc.CTRL score

Older Subjects, Non-Crash-Involved, 5-Lane Mid-Block Left-Turn.

Number of valid observations (listwise) = 99.00

Variable	Mean	Std Dev	Minimum	Maximum	Valid N	Label
ISITESCR	52.24	30.38	0	100	112	"I" site performance
ISEARCH	94.44	9.30	63	100	99	"I" search score
ISPEED	80.52	16.70	0	100	100	"I" speed score
IDIRCTL	66.17	24.46	0	100	99	"I" Dirc.CTRL score

Older Subjects, At-Fault Crash-Involved, 5-Lane Mid-Block Left-Turn.

Number of valid observations (listwise) = 23.00

Variable	Mean	Std Dev	Minimum	Maximum	Valid N	Label
ISITESCR	43.90	30.19	0	100	26	"I" site performance
ISEARCH	89.03	16.91	40	100	23	"I" search score
ISPEED	78.26	14.10	50	100	23	"I" speed score
IDIRCTL	65.36	28.97	0	100	23	"I" Dirc.CTRL score

Older Subjects, Not-At-Fault Crash-Involved, 5-Lane Mid-Block Left-Turn.

Number of valid observations (listwise) = 22.00

Variable	Mean	Std Dev	Minimum	Maximum	Valid N	Label
ISITESCR	64.65	34.58	0	100	24	"I" site performance
ISEARCH	97.08	6.80	75	100	22	"I" search score
ISPEED	74.09	21.56	25	100	22	"I" speed score
IDIRCTL	73.71	17.94	38	100	22	"I" Dirc.CTRL score

* * * C E L L M E A N S * * *

OVRALDPM % Overall DPM score
by OFFENSE
NEWAGEGP

Total Population

94.09
(237)

OFFENSE

0	1	2
94.86	94.71	89.19
(161)	(45)	(31)

NEWAGEGP

1	2	3	4	5	6
96.03	94.97	94.54	90.89	84.31	92.33
(73)	(61)	(59)	(28)	(13)	(3)

OFFENSE	NEWAGEGP 1	2	3	4	5	6
0	96.44	95.05	95.00	92.17	91.90	91.00
	(45)	(43)	(43)	(18)	(10)	(2)
1	95.30	95.17	93.00	93.60	.00	95.00
	(20)	(12)	(7)	(5)	(0)	(1)
2	95.50	94.00	93.56	83.60	59.00	.00
	(8)	(6)	(9)	(5)	(3)	(0)

* * * A N A L Y S I S   O F   V A R I A N C E * * *

OVRALDPM % Overall DPM score
by OFFENSE
NEWAGEGP
HIERARCHICAL sums of squares
Covariates entered FIRST

Source of Variatio	Sum of Squares	DF	Mean Square	F	Sig of F
Main Effects	2553.312	7	364.759	12.109	.00
OFFENSE	855.342	2	427.671	14.198	.000
NEWAGEGP	1697.971	5	339.594	11.274	.000
2-Way Interactions	2220.920	8	277.615	9.216	.000
OFFENSE NEWAGEGP	2220.920	8	277.615	9.216	.000
Explained	4774.232	15	318.282	10.567	.00
Residual	6656.907	221	30.122		
Total	11431.139	236	48.437		

245 cases were processed.
8 cases (3.3 pct) were missing.

* * * C E L L   M E A N S * * *

ASITESCR "A" site performance
by OFFENSE

Total Population

95.89
(231)

OFFENSE

0	1	2
96.38	95.69	93.47
(158)	(45)	(28)

* * * A N A L Y S I S   O F   V A R I A N C E * * *

ASITESCR "A" site performance
by OFFENSE
HIERARCHICAL sums of squares
Covariates entered FIRST

Source of Variation	Sum of Squares	DF	Mean Square	F	Sig of F
Main Effects	202.819	2	101.410	2.484	.086
OFFENSE	202.819	2	101.410	2.484	.086
Explained	202.819	2	101.410	2.484	.086
Residual	9307.068	228	40.820		
Total	9509.887	230	41.347		

245 cases were processed.
14 cases (5.7 pct) were missing.

* * M U L T I P L E   C L A S S I F I C A T I O N   A N A L Y S I S * *

ASITESCR "A" site performance
by OFFENSE

Grand Mean = 95.89

Variable + Category	N	Unadjusted Dev'n	Unadjusted Eta	Adjusted for Independents Dev'n	Adjusted for Independents Beta
OFFENSE					
0 no offenses	158	.49		.49	
1 speed offense	45	-.20		-.20	
2 veh ctrl offense	28	-2.42		-2.42	
			.15		.15

Multiple R Squared	.021
Multiple R	.146

* * * C E L L   M E A N S * * *

BSITESCR "B" site performance
by OFFENSE

Total Population

97.80
(234)

OFFENSE

0	1	2
98.45	99.05	92.30
(160)	(45)	(29)

* * * A N A L Y S I S   O F   V A R I A N C E * * *

BSITESCR "B" site performance
by OFFENSE

HIERARCHICAL sums of squares
Covariates entered FIRST

Source of Variation	Sum of Squares	DF	Mean Square	F	Sig of F
Main Effects	1015.768	2	507.884	11.642	.000
OFFENSE	1015.768	2	507.884	11.642	.000
Explained	1015.768	2	507.884	11.642	.000
Residual	10077.149	231	43.624		
Total	11092.917	233	47.609		

245 cases were processed.
11 cases (4.5 pct) were missing.

* * M U L T I P L E   C L A S S I F I C A T I O N   A N A L Y S I S * *

BSITESCR "B" site performance
by OFFENSE

Grand Mean = 97.80

Variable + Category	N	Unadjusted Dev'n	Unadjusted Eta	Adjusted for Independents Dev'n	Adjusted for Independents Beta
OFFENSE					
0 no offenses	160	.65		.65	
1 speed offense	45	1.25		1.25	
2 veh ctrl offense	29	-5.50		-5.50	
			.30		.30

Multiple R Squared	.092
Multiple R	.303

* * * C E L L   M E A N S * * *

CSITESCR "C" site performance
by OFFENSE

Total Population

97.22
(234)

OFFENSE

0	1	2
98.23	95.60	94.24
(160)	(44)	(30)

* * * A N A L Y S I S   O F   V A R I A N C E * * *

CSITESCR "C" site performance
by OFFENSE
HIERARCHICAL sums of squares
Covariates entered FIRST

Source of Variation	Sum of Squares	DF	Mean Square	F	Sig of F
Main Effects	546.014	2	273.007	2.829	.061
OFFENSE	546.014	2	273.007	2.829	.061
Explained	546.014	2	273.007	2.829	.061
Residual	22292.528	231	96.504		
Total	22838.542	233	98.019		

245 cases were processed.
11 cases (4.5 pct) were missing.

* * M U L T I P L E   C L A S S I F I C A T I O N   A N A L Y S I S * *

CSITESCR "C" site performance
by OFFENSE

Grand Mean = 97.22

Variable + Category	N	Unadjusted Dev'n	Unadjusted Eta	Adjusted for Independents Dev'n	Adjusted for Independents Beta
OFFENSE					
0 no offenses	160	1.01		1.01	
1 speed offense	44	-1.63		-1.63	
2 veh ctrl offense	30	-2.99		-2.99	
			.15		.15

Multiple R Squared .024
Multiple R .155

* * * C E L L   M E A N S * * *

DSITESCR "D" site performance
by OFFENSE

Total Population

93.19
(232)

OFFENSE

0	1	2
93.66	93.02	90.88
(160)	(43)	(29)

* * * A N A L Y S I S   O F   V A R I A N C E * * *

DSITESCR "D" site performance
by OFFENSE
HIERARCHICAL sums of squares
Covariates entered FIRST

Source of Variation	Sum of Squares	DF	Mean Square	F	Sig of F
Main Effects	191.469	2	95.734	.627	.535
OFFENSE	191.469	2	95.734	.627	.535
Explained	191.469	2	95.734	.627	.535
Residual	34945.658	229	152.601		
Total	35137.126	231	152.109		

245 cases were processed.
13 cases (5.3 pct) were missing.

* * M U L T I P L E   C L A S S I F I C A T I O N   A N A L Y S I S * *

DSITESCR "D" site performance
by OFFENSE

Grand Mean = 93.19

Variable + Category	N	Unadjusted Dev'n	Unadjusted Eta	Adjusted for Independents Dev'n	Adjusted for Independents Beta
OFFENSE					
0 no offenses	160	.47		.47	
1 speed offense	43	-.17		-.17	
2 veh ctrl offense	29	-2.32		-2.32	
			.07		.07

Multiple R Squared	.005
Multiple R	.074

* * * C E L L   M E A N S * * *

FSITESCR "F" site performance
by OFFENSE

Total Population

98.69
(221)

OFFENSE

0	1	2
98.97	98.68	97.03
(156)	(38)	(27)

* * * A N A L Y S I S   O F   V A R I A N C E * * *

FSITESCR "F" site performance
by OFFENSE
HIERARCHICAL sums of squares
Covariates entered FIRST

Source of Variation	Sum of Squares	DF	Mean Square	F	Sig of F
Main Effects	86.848	2	43.424	2.151	.119
OFFENSE	86.848	2	43.424	2.151	.119
Explained	86.848	2	43.424	2.151	.119
Residual	4400.273	218	20.185		
Total	4487.120	220	20.396		

245 cases were processed.
24 cases (9.8 pct) were missing.

* * M U L T I P L E   C L A S S I F I C A T I O N   A N A L Y S I S * *

FSITESCR "F" site performance
by OFFENSE

Grand Mean = 98.69

Variable + Category	N	Unadjusted Dev'n	Unadjusted Eta	Adjusted for Independents Dev'n	Adjusted for Independents Beta
OFFENSE					
0 no offenses	156	.29		.29	
1 speed offense	38	.00		.00	
2 veh ctrl offense	27	-1.66		-1.66	
			.14		.14

Multiple R Squared .019
Multiple R .139

* * * C E L L   M E A N S * * *

GSITESCR "G" site performance
by OFFENSE

Total Population

99.69
(226)

OFFENSE

0	1	2
99.72	99.74	99.44
(161)	(38)	(27)

* * * A N A L Y S I S   O F   V A R I A N C E * * *

GSITESCR "G" site performance
by OFFENSE

HIERARCHICAL sums of squares
Covariates entered FIRST

Source of Variation	Sum of Squares	DF	Mean Square	F	Sig of F
Main Effects	1.861	2	.931	.394	.675
OFFENSE	1.861	2	.931	.394	.675
Explained	1.861	2	.931	.394	.675
Residual	526.457	223	2.361		
Total	528.319	225	2.348		

245 cases were processed.
19 cases (7.8 pct) were missing.

* * M U L T I P L E   C L A S S I F I C A T I O N   A N A L Y S I S * *

GSITESCR "G" site performance
by OFFENSE

Grand Mean = 99.69

Variable + Category	N	Unadjusted Dev'n	Unadjusted Eta	Adjusted for Independents Dev'n	Adjusted for Independents Beta
OFFENSE					
0 no offenses	161	.03		.03	
1 speed offense	38	.05		.05	
2 veh ctrl offense	27	-.25		-.25	
			.06		.06
Multiple R Squared					.004
Multiple R					.059

* * * C E L L   M E A N S * * *

ISITESCR "I" site performance
by OFFENSE

Total Population

59.49
(234)

OFFENSE

	0	1	2
	58.29	67.86	53.59
	(160)	(44)	(30)

* * * A N A L Y S I S   O F   V A R I A N C E * * *

ISITESCR "I" site performance
by   OFFENSE

HIERARCHICAL sums of squares
Covariates entered FIRST

Source of Variation	Sum of Squares	DF	Mean Square	F	Sig of F
Main Effects	4357.148	2	2178.574	2.253	.107
OFFENSE	4357.148	2	2178.574	2.253	.107
Explained	4357.148	2	2178.574	2.253	.107
Residual	223403.448	231	967.114		
Total	227760.596	233	977.513		

245 cases were processed.
11 cases (4.5 pct) were missing.

* * M U L T I P L E   C L A S S I F I C A T I O N   A N A L Y S I S * *

ISITESCR "I" site performance
by   OFFENSE

Grand Mean =   59.49

Variable + Category	N	Unadjusted Dev'n	Unadjusted Eta	Adjusted for Independents Dev'n	Adjusted for Independents Beta
OFFENSE					
0 no offenses	160	-1.20		-1.20	
1 speed offense	44	8.37		8.37	
2 veh ctrl offense	30	-5.90		-5.90	
			.14		.14

Multiple R Squared	.019
Multiple R	.138

* * * C E L L   M E A N S * * *

JSITESCR "J" site performance
by OFFENSE

Total Population

96.69
(225)

OFFENSE

0	1	2
96.48	98.03	96.06
(160)	(38)	(27)

* * * A N A L Y S I S   O F   V A R I A N C E * * *

JSITESCR "J" site performance
by OFFENSE

HIERARCHICAL sums of squares
Covariates entered FIRST

Source of Variation	Sum of Squares	DF	Mean Square	F	Sig of F
Main Effects	85.655	2	42.828	.380	.685
OFFENSE	85.655	2	42.828	.380	.685
Explained	85.655	2	42.828	.380	.685
Residual	25050.927	222	112.842		
Total	25136.583	224	112.217		

245 cases were processed.
20 cases (8.2 pct) were missing.

* * M U L T I P L E   C L A S S I F I C A T I O N   A N A L Y S I S * *

JSITESCR "J" site performance
by OFFENSE

Grand Mean = 96.69

Variable + Category	N	Unadjusted Dev'n	Unadjusted Eta	Adjusted for Independents Dev'n	Adjusted for Independents Beta
OFFENSE					
0 no offenses	160	-.21		-.21	
1 speed offense	38	1.34		1.34	
2 veh ctrl offense	27	-.62		-.62	
			.06		.06
Multiple R Squared					.003
Multiple R					.058

* * * C E L L   M E A N S * * *

KSITESCR "K" site performance
by OFFENSE

Total Population

98.73
(236)

OFFENSE

	0	1	2
	98.80	98.99	97.96
	(162)	(44)	(30)

* * * A N A L Y S I S   O F   V A R I A N C E * * *

KSITESCR "K" site performance
by OFFENSE

HIERARCHICAL sums of squares
Covariates entered FIRST

Source of Variation	Sum of Squares	DF	Mean Square	F	Sig of F
Main Effects	21.318	2	10.659	1.238	.292
OFFENSE	21.318	2	10.659	1.238	.292
Explained	21.318	2	10.659	1.238	.292
Residual	2006.610	233	8.612		
Total	2027.928	235	8.629		

245 cases were processed.
9 cases (3.7 pct) were missing.

* * M U L T I P L E   C L A S S I F I C A T I O N   A N A L Y S I S * *

KSITESCR "K" site performance
by OFFENSE

Grand Mean = 98.73

Variable + Category	N	Unadjusted Dev'n	Unadjusted Eta	Adjusted for Independents Dev'n	Adjusted for Independents Beta
OFFENSE					
0 no offenses	162	.07		.07	
1 speed offense	44	.26		.26	
2 veh ctrl offense	30	-.76		-.76	
			.10		.10

Multiple R Squared	.011
Multiple R	.103

* * * C E L L   M E A N S * * *

ASITESCR "A" site performance
by OFFENSE
NEWAGEGP

Total Population

95.92
(229)

OFFENSE

0	1	2
96.42	95.69	93.47
(156)	(45)	(28)

NEWAGEGP

1	2	3	4	5	6
97.62	96.62	95.73	91.79	93.45	89.29
(72)	(60)	(57)	(28)	(10)	(2)

OFFENSE	NEWAGEGP 1	2	3	4	5	6
0	97.33	96.47	96.23	94.94	96.02	92.86
	(44)	(42)	(42)	(18)	(9)	(1)
1	97.66	97.82	93.64	87.58	.00	85.71
	(20)	(12)	(7)	(5)	(0)	(1)
2	99.11	95.24	94.91	84.66	70.37	.00
	(8)	(6)	(8)	(5)	(1)	(0)

* * * A N A L Y S I S   O F   V A R I A N C E * * *

ASITESCR "A" site performance
by OFFENSE
NEWAGEGP
HIERARCHICAL sums of squares
Covariates entered FIRST

Source of Variation	Sum of Squares	DF	Mean Square	F	Sig of F
Main Effects	1062.622	7	151.803	4.437	.000
OFFENSE	209.339	2	104.670	3.059	.049
NEWAGEGP	853.282	5	170.656	4.988	.000
2-Way Interactions	1039.194	8	129.899	3.797	.000
OFFENSE NEWAGEGP	1039.194	8	129.899	3.797	.000
Explained	2101.815	15	140.121	4.096	.000
Residual	7287.449	213	34.213		
Total	9389.264	228	41.181		

245 cases were processed.
16 cases (6.5 pct) were missing.

* * M U L T I P L E   C L A S S I F I C A T I O N   A N A L Y S I S * *

ASITESCR "A" site performance
by OFFENSE
NEWAGEGP

Grand Mean = 95.92

Variable + Category	N	Unadjusted Dev'n	Unadjusted Eta	Adjusted for Independents Dev'n	Adjusted for Independents Beta
OFFENSE					
0 no offenses	156	.50		.56	
1 speed offense	45	-.23		-.55	
2 veh ctrl offense	28	-2.45		-2.21	
			.15		.15
NEWAGEGP					
1 20-55	72	1.70		1.76	
2 65-69	60	.70		.64	
3 70-74	57	-.19		-.22	
4 75-79	28	-4.13		-3.99	
5 80-84	10	-2.47		-2.75	
6 85+	2	-6.63		-6.63	
			.30		.30
Multiple R Squared					.113
Multiple R					.336

* * * C E L L   M E A N S * * *

DSITESCR "D" site performance
by OFFENSE
NEWAGEGP

Total Population

93.35
(230)

OFFENSE

0	1	2
93.89	93.02	90.88
(158)	(43)	(29)

NEWAGEGP

1	2	3	4	5	6
94.57	91.92	95.12	92.38	88.01	91.67
(70)	(60)	(57)	(27)	(13)	(3)

OFFENSE \ NEWAGEGP	1	2	3	4	5	6
0	95.06	93.12	95.03	90.77	94.17	87.50
	(44)	(42)	(42)	(18)	(10)	(2)
1	94.44	89.58	91.96	96.25	.00	100.00
	(18)	(12)	(7)	(5)	(0)	(1)
2	92.19	88.19	98.39	94.79	67.50	.00
	(8)	(6)	(8)	(4)	(3)	(0)

* * * A N A L Y S I S   O F   V A R I A N C E * * *

DSITESCR "D" site performance
by OFFENSE
NEWAGEGP
HIERARCHICAL sums of squares
Covariates entered FIRST

Source of Variation	Sum of Squares	DF	Mean Square	F	Sig of F
Main Effects	1035.144	7	147.878	1.051	.396
OFFENSE	228.823	2	114.412	.813	.445
NEWAGEGP	806.321	5	161.264	1.147	.337
2-Way Interactions	2086.042	8	260.755	1.854	.069
OFFENSE NEWAGEGP	2086.042	8	260.755	1.854	.069
Explained	3121.186	15	208.079	1.479	.115
Residual	30098.237	214	140.646		
Total	33219.423	229	145.063		

245 cases were processed.
15 cases (6.1 pct) were missing.

* * M U L T I P L E   C L A S S I F I C A T I O N   A N A L Y S I S * *

DSITESCR "D" site performance
by OFFENSE
NEWAGEGP

Grand Mean = 93.35

Variable + Category	N	Unadjusted Dev'n	Unadjusted Eta	Adjusted for Independents Dev'n	Adjusted for Independents Beta
OFFENSE					
0 no offenses	158	.54		.58	
1 speed offense	43	-.33		-.58	
2 veh ctrl offense	29	-2.47		-2.33	
			.08		.08
NEWAGEGP					
1 20-55	70	1.22		1.27	
2 65-69	60	-1.43		-1.49	
3 70-74	57	1.77		1.74	
4 75-79	27	-.97		-.91	
5 80-84	13	-5.34		-5.25	
6 85+	3	-1.68		-1.88	
			.16		.16

Multiple R Squared	.031
Multiple R	.177

* * * C E L L   M E A N S * * *

ISITESCR "I" site performance
by OFFENSE
NEWAGEGP

Total Population

59.18
(232)

OFFENSE

0	1	2
57.82	67.86	53.59
(158)	(44)	(30)

NEWAGEGP

1	2	3	4	5	6
74.68	59.06	53.48	47.31	34.76	14.29
(72)	(59)	(57)	(28)	(13)	(3)

OFFENSE	NEWAGEGP 1	2	3	4	5	6
0	75.49	58.02	53.17	40.26	41.86	.00
	(44)	(42)	(42)	(18)	(10)	(2)
1	74.12	66.41	47.62	79.33	.00	42.86
	(20)	(11)	(7)	(5)	(0)	(1)
2	71.59	52.78	60.21	40.67	11.11	.00
	(8)	(6)	(8)	(5)	(3)	(0)

* * * A N A L Y S I S   O F   V A R I A N C E * * *

ISITESCR "I" site performance
by OFFENSE
NEWAGEGP
HIERARCHICAL sums of squares
Covariates entered FIRST

Source of Variation	Sum of Squares	DF	Mean Square	F	Sig of F
Main Effects	38524.055	7	5503.436	6.719	.000
OFFENSE	4546.870	2	2273.435	2.775	.065
NEWAGEGP	33977.185	5	6795.437	8.296	.000
2-Way Interactions	9609.426	8	1201.178	1.466	.171
OFFENSE NEWAGEGP	9609.426	8	1201.178	1.466	.171
Explained	48133.481	15	3208.899	3.918	.000
Residual	176927.803	216	819.110		
Total	225061.285	231	974.291		

245 cases were processed.
13 cases (5.3 pct) were missing.

* * M U L T I P L E   C L A S S I F I C A T I O N   A N A L Y S I S * *

ISITESCR "I" site performance
by OFFENSE
NEWAGEGP

Grand Mean = 59.18

Variable + Category	N	Unadjusted Dev'n	Unadjusted Eta	Adjusted for Independents Dev'n	Adjusted for Independents Beta
OFFENSE					
0 no offenses	158	-1.36		-.70	
1 speed offense	44	8.69		5.16	
2 veh ctrl offense	30	-5.58		-3.88	
			.14		.09
NEWAGEGP					
1 20-55	72	15.50		14.93	
2 65-69	59	-.12		-.19	
3 70-74	57	-5.70		-5.27	
4 75-79	28	-11.86		-11.64	
5 80-84	13	-24.41		-22.98	
6 85+	3	-44.89		-46.14	
			.40		.39
Multiple R Squared					.171
Multiple R					.414

* * * C E L L   M E A N S * * *

ASITESCR "A" site performance
by OFFENSE

Total Population

97.62
(72)

OFFENSE

	0	1	2
	97.33	97.66	99.11
	(44)	(20)	(8)

* * * A N A L Y S I S   O F   V A R I A N C E * * *

ASITESCR "A" site performance
by OFFENSE

HIERARCHICAL sums of squares
Covariates entered FIRST

Source of Variation	Sum of Squares	DF	Mean Square	F	Sig of F
Main Effects	21.511	2	10.755	.518	.598
OFFENSE	21.511	2	10.755	.518	.598
Explained	21.511	2	10.755	.518	.598
Residual	1433.560	69	20.776		
Total	1455.071	71	20.494		

75 cases were processed.
3 cases (4.0 pct) were missing.

* * M U L T I P L E   C L A S S I F I C A T I O N   A N A L Y S I S * *

ASITESCR "A" site performance
by OFFENSE

Grand Mean = 97.62

Variable + Category	N	Unadjusted Dev'n	Unadjusted Eta	Adjusted for Independents Dev'n	Adjusted for Independents Beta
OFFENSE					
0 no offenses	44	-.29		-.29	
1 speed offense	20	.05		.05	
2 veh ctrl offense	8	1.49		1.49	
			.12		.12

Multiple R Squared	.015
Multiple R	.122

* * * C E L L   M E A N S * * *

BSITESCR "B" site performance
by OFFENSE

Total Population

99.14
(72)

OFFENSE

	0	1	2
	99.07	98.96	100.00
	(44)	(20)	(8)

* * * A N A L Y S I S   O F   V A R I A N C E * * *

BSITESCR "B" site performance
by OFFENSE

HIERARCHICAL sums of squares
Covariates entered FIRST

Source of Variation	Sum of Squares	DF	Mean Square	F	Sig of F
Main Effects	6.780	2	3.390	.534	.588
OFFENSE	6.780	2	3.390	.534	.588
Explained	6.780	2	3.390	.534	.588
Residual	437.626	69	6.342		
Total	444.406	71	6.259		

75 cases were processed.
3 cases (4.0 pct) were missing.

* * M U L T I P L E   C L A S S I F I C A T I O N   A N A L Y S I S * *

BSITESCR "B" site performance
by OFFENSE

Grand Mean = 99.14

Variable + Category	N	Unadjusted Dev'n	Unadjusted Eta	Adjusted for Independents Dev'n	Adjusted for Independents Beta
OFFENSE					
0 no offenses	44	-.07		-.07	
1 speed offense	20	-.19		-.19	
2 veh ctrl offense	8	.86		.86	
			.12		.12

Multiple R Squared	.015
Multiple R	.124

* * * C E L L   M E A N S * * *

DSITESCR "D" site performance
by OFFENSE

Total Population

94.57
(70)

OFFENSE

	0	1	2
	95.06	94.44	92.19
	(44)	(18)	(8)

* * * A N A L Y S I S   O F   V A R I A N C E * * *

DSITESCR "D" site performance
by OFFENSE

HIERARCHICAL sums of squares
Covariates entered FIRST

Source of Variation	Sum of Squares	DF	Mean Square	F	Sig of F
Main Effects	56.295	2	28.148	.272	.763
OFFENSE	56.295	2	28.148	.272	.763
Explained	56.295	2	28.148	.272	.763
Residual	6933.137	67	103.480		
Total	6989.432	69	101.296		

75 cases were processed.
5 cases (6.7 pct) were missing.

* * M U L T I P L E   C L A S S I F I C A T I O N   A N A L Y S I S * *

DSITESCR "D" site performance
by OFFENSE

Grand Mean = 94.57

Variable + Category	N	Unadjusted Dev'n	Unadjusted Eta	Adjusted for Independents Dev'n	Adjusted for Independents Beta
OFFENSE					
0 no offenses	44	.49		.49	
1 speed offense	18	-.13		-.13	
2 veh ctrl offense	8	-2.39		-2.39	
			.09		.09

Multiple R Squared	.008
Multiple R	.090

* * * C E L L   M E A N S * * *

ISITESCR "I" site performance
by OFFENSE

Total Population

74.68
(72)

OFFENSE

0	1	2
75.49	74.13	71.59
(44)	(20)	(8)

* * * A N A L Y S I S   O F   V A R I A N C E * * *

ISITESCR "I" site performance
by OFFENSE

HIERARCHICAL sums of squares
Covariates entered FIRST

Source of Variation	Sum of Squares	DF	Mean Square	F	Sig of F
Main Effects	111.460	2	55.730	.085	.919
OFFENSE	111.460	2	55.730	.085	.919
Explained	111.460	2	55.730	.085	.919
Residual	45469.741	69	658.982		
Total	45581.201	71	641.989		

75 cases were processed.
3 cases (4.0 pct) were missing.

* * M U L T I P L E   C L A S S I F I C A T I O N   A N A L Y S I S * *

ISITESCR "I" site performance
by OFFENSE

Grand Mean = 74.68

Variable + Category	N	Unadjusted Dev'n	Unadjusted Eta	Adjusted for Independents Dev'n	Adjusted for Independents Beta
OFFENSE					
0 no offenses	44	.81		.81	
1 speed offense	20	-.55		-.55	
2 veh ctrl offense	8	-3.09		-3.09	
			.05		.05

Multiple R Squared .002
Multiple R .049

APPENDIX C

APPENDIX C

Table C-1. Direct Comparison of UFOV and DPM Performance Scores. UFOV Pass/Fail Criterion of 25.5.

	DPM > 87 (pass)	DPM ≤ 87 (fail)	Totals
UFOV < 25.5 (pass)	151 67.7%	3 18.8%	154
UFOV ≥ 25.5 (fail)	72 32.3%	13 81.2%	85
Totals	223	16	239
Percentages are based on predicting DPM category by UFOV performance. 164 out of 239 (68.2%) cases are categorized correctly.			

Table C-2. Direct Comparison of UFOV and DPM Performance Scores. UFOV Pass/Fail Criterion of 37.5.

	DPM > 87 (Pass)	DPM ≤ 87 (Fail)	Totals
UFOV ≤ 37.5 (Pass)	195 87.4%	8 50.0%	203
UFOV > 37.5 (Fail)	28 12.6%	8 50.0%	36
Totals	223	16	239
Percentages are based on predicting DPM category by UFOV performance. 203 out of 239 (84.9%) cases are categorized correctly.			

Table C-3. Direct Comparison of UFOV and DPM Performance Scores. UFOV Pass/Fail Criterion of 42.5.

	DPM > 87 (Pass)	DPM ≤ 87 (Fail)	Totals
UFOV ≤ 42.5 (Pass)	204 91.5%	10 62.5%	214
UFOV > 42.5 (Fail)	19 8.5%	6 37.5%	36
Totals	223	16	239
Percentages are based on predicting DPM category by UFOV performance. 210 out of 239 (87.9%) cases are categorized correctly.			

Table C-4. Direct Comparison of UFOV and DPM Performance Scores. UFOV Pass/Fail Criterion of 50.

	DPM > 87 (pass)	DPM ≤ 87 (fail)	Totals
UFOV < 50 (pass)	210 94.2%	12 75.0%	222
UFOV ≥ 50 (fail)	13 5.8%	4 25.0%	17
Totals	223	16	239
Percentages are based on predicting DPM category by UFOV performance. 214 out of 239 (89.5%) cases are categorized correctly.			

- - - - D I S C R I M I N A N T   A N A L Y S I S - - - -

On groups defined by XXCRSH crashes on record

245 (Unweighted) cases were processed.
6 of these were excluded from the analysis.
0 had missing or out-of-range group codes.
6 had at least one missing discriminating variable.
239 (Unweighted) cases will be used in the analysis.

Number of cases by group

XXCRSH	Number of cases Unweighted	Weighted	Label
0	161	161.0	no crashes
1	78	78.0	one or more crashes
Total	239	239.0	

Wilks' Lambda (U-statistic) and univariate F-ratio
with 1 and 237 degrees of freedom

Variable	Wilks' Lambda	F	Significance
OFFENSE	.86710	36.3245	.0000
MDOSAGE	.99919	.1919	.6617
OVRALDPM	.99998	.0048	.9448
TOTALSCO	.99921	.1865	.6662

- - - - D I S C R I M I N A N T   A N A L Y S I S - - - -

On groups defined by XXCRSH   crashes on record

Analysis number   1

Direct method: all variables passing the tolerance test are entered.

Minimum tolerance level.................. .00100

Canonical Discriminant Functions

Maximum number of functions.............. 1
Minimum cumulative percent of variance... 100.00
Maximum significance of Wilks' Lambda.... 1.0000

Prior probability for each group is .50000

Classification function coefficients
(Fisher's linear discriminant functions)

XXCRSH =	0 no crashes	1 one or more crashes
OFFENSE	6.8164801	8.1664435
MDOSAGE	.3540140	.3574587
OVRALDPM	2.3847721	2.4169585
TOTALSCO	.1367249	.1299545
(Constant)	-126.4250508	-130.2264345

Canonical Discriminant Functions

Fcn	Eigenvalue	Pct of Variance	Cum Pct	Canonical Corr		After Fcn	Wilks' Lambda	Chi-square	df	Sig
					:	0	.857076	36.244	4	.0000
1*	.1668	100.00	100.00	.3781	:					

* Marks the 1 canonical discriminant functions remaining in the analysis.

Standardized canonical discriminant function coefficients

	Func 1
OFFENSE	1.03608
MDOSAGE	.06934
OVRALDPM	.25812
TOTALSCO	-.12667

Structure matrix:

Pooled within-groups correlations between discriminating variables
and canonical discriminant functions
(Variables ordered by size of correlation within function)

	Func 1
OFFENSE	.95870
MDOSAGE	-.06969
TOTALSCO	-.06870
OVRALDPM	.01102

Canonical discriminant functions evaluated at group means (group centroids)

Group	Func 1
0	-.28304
1	.58423

Classification results -

Actual Group	No. of Cases	Predicted Group Membership 0	1
Group 0 no crashes	161	130 80.7%	31 19.3%
Group 1 one or more crashes	78	34 43.6%	44 56.4%

Percent of "grouped" cases correctly classified: 72.80%

Classification processing summary

245 (Unweighted) cases were processed.
0 cases were excluded for missing or out-of-range group codes.
6 cases had at least one missing discriminating variable.
239 (Unweighted) cases were used for printed output.

---- D I S C R I M I N A N T   A N A L Y S I S ----

On groups defined by XXCRSH   crashes on record

245 (Unweighted) cases were processed.
6 of these were excluded from the analysis.
0 had missing or out-of-range group codes.
6 had at least one missing discriminating variable.
239 (Unweighted) cases will be used in the analysis.

Number of cases by group

XXCRSH	Number of cases Unweighted	Weighted	Label
0	161	161.0	no crashes
1	78	78.0	one or more crashes
Total	239	239.0	

Wilks' Lambda (U-statistic) and univariate F-ratio
with 1 and 237 degrees of freedom

Variable	Wilks' Lambda	F	Significance
OFFENSE	.86710	36.3245	.0000
OVRALDPM	.99998	.0048	.9448
TOTALSCO	.99921	.1865	.6662
YOUNGOLD	.99621	.9006	.3436

```
- - - -   D I S C R I M I N A N T   A N A L Y S I S   - - - -

On groups defined by XXCRSH    crashes on record


Analysis number       1

Direct method:  all variables passing the tolerance test are entered.

     Minimum tolerance level..................  .00100

Canonical Discriminant Functions

     Maximum number of functions..............       1
     Minimum cumulative percent of variance...  100.00
     Maximum significance of Wilks' Lambda....  1.0000

Prior probability for each group is  .50000

Classification function coefficients
(Fisher's linear discriminant functions)

XXCRSH   =          0              1
             no crashes      one or more
                             crashes

OFFENSE         6.6731758      8.0093084
OVRALDPM        2.3521383      2.3825452
TOTALSCO         .1679429       .1640937
YOUNGOLD       12.1858844     12.0883344
(Constant)   -124.8371833   -128.1634164

                       Canonical Discriminant Functions


                  Pct of   Cum  Canonical  After  Wilks'
 Fcn Eigenvalue Variance  Pct     Corr       Fcn  Lambda  Chi-square  df
Sig

                                          :     0 .857249     36.196     4
.0000
  1*     .1665  100.00  100.00     .3778 :

   * Marks the 1 canonical discriminant functions remaining in the
analysis.
```

Standardized canonical discriminant function coefficients

	Func 1
OFFENSE	1.02619
OVRALDPM	.24402
TOTALSCO	-.07207
YOUNGOLD	-.05196

Structure matrix:

Pooled within-groups correlations between discriminating variables
and canonical discriminant functions
(Variables ordered by size of correlation within function)

	Func 1
OFFENSE	.95938
YOUNGOLD	-.15106
TOTALSCO	-.06874
OVRALDPM	.01103

Canonical discriminant functions evaluated at group means (group centroids)

Group	Func 1
0	-.28284
1	.58382

Classification results -

Actual Group	No. of Cases	Predicted Group Membership 0	1
Group 0 no crashes	161	130 80.7%	31 19.3%
Group 1 one or more crashes	78	34 43.6%	44 56.4%

Percent of "grouped" cases correctly classified: 72.80%

Classification processing summary

245 (Unweighted) cases were processed.
0 cases were excluded for missing or out-of-range group codes.
6 cases had at least one missing discriminating variable.
239 (Unweighted) cases were used for printed output.

- - - - D I S C R I M I N A N T   A N A L Y S I S - - - -

On groups defined by XXCRSH crashes on record

245 (Unweighted) cases were processed.
0 of these were excluded from the analysis.
245 (Unweighted) cases will be used in the analysis.

Number of cases by group

XXCRSH	Number of cases Unweighted	Weighted	Label
0	164	164.0	no crashes
1	81	81.0	one or more crashes
Total	245	245.0	

Wilks' Lambda (U-statistic) and univariate F-ratio
with 1 and 243 degrees of freedom

Variable	Wilks' Lambda	F	Significance
OFFENSE	.85132	42.4379	.0000
YOUNGOLD	.99374	1.5317	.2171
UFOVSPLT	1.00000	.0010	.9747
DPMSPLIT	.99623	.9197	.3385

- - - - D I S C R I M I N A N T   A N A L Y S I S - - - -

On groups defined by XXCRSH   crashes on record

Analysis number 1

Direct method: all variables passing the tolerance test are entered.

Minimum tolerance level.................. .00100

Canonical Discriminant Functions

Maximum number of functions.............. 1
Minimum cumulative percent of variance... 100.00
Maximum significance of Wilks' Lambda.... 1.0000

Prior probability for each group is .50000

Classification function coefficients
(Fisher's linear discriminant functions)

XXCRSH =	0 no crashes	1 one or more crashes
OFFENSE	1.9928482	3.3162397
YOUNGOLD	8.0445950	7.7444108
UFOVSPLT	12.4486212	12.3856954
DPMSPLIT	15.6828733	15.6901667
(Constant)	-29.6961160	-29.8725593

Canonical Discriminant Functions

Fcn	Eigenvalue	Pct of Variance	Cum Pct	Canonical Corr		After Fcn	Wilks' Lambda	Chi-square	df	Sig
					:	0	.848025	39.728	4	.0000
1*	.1792	100.00	100.00	.3898	:					

* Marks the 1 canonical discriminant functions remaining in the analysis.

Standardized canonical discriminant function coefficients

	Func 1
OFFENSE	.98421
YOUNGOLD	-.15452
UFOVSPLT	-.02208
DPMSPLIT	.00316

Structure matrix:

Pooled within-groups correlations between discriminating variables
and canonical discriminant functions
(Variables ordered by size of correlation within function)

	Func 1
OFFENSE	.98717
YOUNGOLD	-.18754
DPMSPLIT	-.14532
UFOVSPLT	.00481

Canonical discriminant functions evaluated at group means (group
centroids)

Group	Func 1
0	-.29629
1	.59990

Classification results -

Actual Group	No. of Cases	Predicted Group Membership 0	1
Group 0 no crashes	164	132 80.5%	32 19.5%
Group 1 one or more crashes	81	34 42.0%	47 58.0%

Percent of "grouped" cases correctly classified: 73.06%

Classification processing summary

245 (Unweighted) cases were processed.
0 cases were excluded for missing or out-of-range group codes.
0 cases had at least one missing discriminating variable.
245 (Unweighted) cases were used for printed output.

BIBLIOGRAPHY

BIBLIOGRAPHY

Bailey, Ian L., and Sheedy, James E., (1988). Vision Screening for Driver Licensure. Special Report 218, Vol. 2. Transportation Research Board, Washington, D.C. pp. 294-324.

Ball, Karlene, and Owsley, Cynthia (1991). Identifying Correlates of Accident Involvement for the Older Driver. Human Factors, 33(5) pp. 583-595.

Ball, Karlene, Owsley, Cynthia, Sloane, Michael E., Roenker, Daniel L., and Bruni, John R.. (1993). Visual Attention Problems as a Predictor of Vehicle Crashes in Older Drivers. Investigative Ophthalmology and Visual Science, October 1993, Vol. 34, No. 11, pp. 3110-3123.

Bhattacharyya, Gouri K., and Johnson, Richard A. (1977) Statistical Concepts and Methods. John Wiley & Sons, Inc. pp. 424-435.

Cerelli, E. (1989). Older Drivers: The Age Factor in Traffic Safety. Report DOT-HS-807-402. NHTSA, U.S. Department of Transportation.

Engum, Eric, Lambert, E. Warren, Scott, Kathryn, Pendergrass, Thomas, and Womac, Jeanine, (1989). Criterion-Related Validity of the Cognitive Behavioral Driver's Index. Cognitive Rehabilitation, July/August, 1989.

Evans, Leonard, (1991). Older-Driver Risks to Themselves and to Other Road Users. Transportation Research Record No. 1325. pp. 34-41.

Forbes, T.W., Nolan, R.O., Schmidt, F.L., Vanosdall, F.E., Smith, D.L., Burtnett, G.S., Counts, J.W., Greenwood, W.H., Gruber, F.J., Johnson, R.H., Lounsbury, J.W., Schlick, J.E., and Reuter, F.W. (1973). Driver Performance Measurement Research, Final Report. Vol. 1, Technical Report, Department of Psychology and Highway Traffic Safety Center, Michigan State University.

Gutowski, M and Field, T., (1979). The Graying of Suburbia. The Urban Institute, Washington, D.C.

Hennessy, David F., (1995) Phone conversation. California Department of Motor Vehicles Research and Development Section, 2415 First Avenue, Sacramento, CA 95818 phone: (916) 657-7048

Hess, Beth B., and Markson, Elizabeth W., (1991). Growing Old in America, 4th ed. Transaction Publishers, New Brunswick, NJ 08903.

Hills, B.L. and Burg, A. (1977). A re-analysis of California driver vision data: General findings. Report 768, Transport and Road Research Laboratory, Crowthorne, England, 1977

James, W. (1890). Principles of Psychology, London 1890

Kart, Cary S., Metress, Eileen K., Metress, Seamus P. (1992). Human Aging and Chronic Disease. University of Toledo, Jones and Bartlett Publishers, 20 Park Plaza, Boston, MA 02116 pp. 103-108.

Ketron, Inc., (1989). Task B Working Paper. Technical Proposal, Ketron serial no. KP 198-89. Ketron, Inc., Great Valley Corporate Center, 350 Technology Drive, Suite 20, Malvern, PA. 19355

Lerner, Neil D., and Ratte', Donna J., (1991). Problems in Freeway Use as Seen by Older Drivers. Transportation Research Record No. 1325. Washington, D.C. pp. 3-7.

Lerner, Neil D., and Sedney, Catherine A., (1988). Some Observations on Older Drivers. COMSIS Corporation, 11501 Georgia Avenue, Wheaton, MD. 20902.

Leske, M.C. (1983). The Epidemiology of Open-Angle Glaucoma: A Review. American Journal of Epidemiology, No. 118.

Lyles, Richard W., Stamatiadis, Polichronis, and Lighthizer, Dale R., (1991). Quasi-Induced Exposure Revisited. Accident Analysis and Prevention, Vol. 23, No. 4, pp. 275-285.

Maleck, Thomas L., and Hummer, Joseph E., (1986) Driver Age and Highway Safety. Transportation Research Record No. 1059, Washington, D.C. 20418.

McKelvey, F.X., Maleck, T.L., Stamatiadis, N., Stamatiadis, C., and Hardy, D., (1987). Relationship Between Driver Age and Highway Accidents. Report MTR-86-008A. Michigan Office of Highway Safety Planning, Lansing, MI.

McKelvey, Francis X., and Stamatiadis, Nikiforos, (1989) Highway Accident Patterns in Michigan Related to Older Drivers. Transportation Research Record No. 1210, Washington, D.C. 20418.

1970 Census of Population-Characteristics of the Population. U.S. Government Printing Office, Washington, D.C. 1973

1980 Census of Population-General Population Characteristics. U.S. Government Printing Office, Washington, D.C. 1981.

Nolan, R.O., Vanosdall, F.E., Smith, D.L., Counts, J.W., Greenwood, W.H., Gruber, F.J., Johnson, R.H., Schlick, J.E., Reuter, F.W., (1973). Driver Performance Measurement Research, Final Report, Vol. 2, Guide for Training Observer/Raters in the Driver Performance Measurement Procedure, Department of Psychology and Highway Traffic Safety Center, Michigan State University, Under Contract with National Highway Traffic Safety Administration.

Owsley, Cynthia, Ball, Karlene, Sloane, Michael E., Roenker, Daniel L., and Bruni, John R., (1991). Visual/Cognitive Correlates of Vehicle Accidents in Older Drivers, Psychology and Aging, Vol. 6, No. 3, pp. 403-415.

Partyka, S. (1983). Comparison of Age of Drivers in Two Car Fatal Crashes. Center for Statistics and Analysis, NHTSA, U.S. Department of Transportation.

Persson, Diane, (1993). The Elderly Driver: Deciding When to Stop. The Gerontologist, Vol. 33, No. 1, pp 88-91.

Planek, Thomas W., and Fowler, Richard C., (1971). Traffic Accident Problems and Exposure Characteristics of the Aging Driver. Journal of Gerontology, Vol 26, No. 2. pp. 224-230.

Sanders, Andries Frans, (1963). The Selective Process in the Functional Visual Field. TE Assen Bij, Van Gorcum and Company, N.V. Dr. H.J. Prakke and H.M.G. Prakke.

Sekuler, R. and Owsley, Cynthia. (1982). The Spatial Vision of Older Humans. Aging and Human Visual Function, Alan R. Liss, New York. pp. 161-172.

Special Committee on Aging, (1987). Aging America: Trends and Projections. U.S. Department of Health and Human Services.

Special Report 218, (1988) Transportation in an Aging Society. Vol. 1. Transportation Research Board, Washington, D.C. pp. 1-12.

SPSS for Windows: Base System User's Guide, Release 6.0. SPSS Inc., 444 N. Michigan Avenue, Chicago, Illinois, 60611.

State and Metropolitan Area Data Book-1991. U.S. Department of Commerce, August, 1991

Tarawneh, Mohammed S., McCoy, Patrick T., Bishu, Ramaratnam R., and Ballard, John L., Factors Associated With the Driving Performance of Older Drivers. Paper No. 930248 presented at Transportation Research Board, 72nd Annual Meeting, Washington, D.C., January, 1993.

Wolf, E. (1960). Glare and Age. Archives of Ophthalmology, Vol. 64. pp. 502-514.

Zhou, Min, (1994). Mobility Patterns of the Nest Generation of Older Persons. Thesis for Master of Science Degree, Michigan State University.

Zopf, Paul E. Jr. (1986). America's Older Population, Cap and Gown Press, Inc., Houston, Texas. 77258. pp. 1-28.