AN ABSTRACT OF THE THESIS OF

Katharine M. Hunter-Zaworski for the degree of Doctor of Philosophy in Civil Engineering presented on April 7,1988.

Title: The Performance of Drivers with Physical Limitations at T-Intersections

Redacted for Privacy

Abstract approved: Robert D. Layton

The research examines the effect of restricted head and neck movement on driving performance as measured by decision time at T-intersections. The traffic safety and human factors literature was reviewed, and very little was found concerning drivers with physical limitations. T-intersections were selected for study because most accidents involving drivers with diminished capacities occur at intersections, and T-intersections are simpler than four-way intersections. A laboratory study was selected to provide better experimental control, safety and repeatability. A unique methodology was used that employed a fixed base driving simulator which incorporated the use of video recordings of intersections to provide a 180 degree field of view. Eighteen intersections were studied with various levels of traffic volume and sight distance. The 72 test subjects were between the ages of 30-50, or 60-80, and half in each age group had restricted range of movement of their neck. The task for the subjects was to depress the brake pedal, watch the video presentations of the T-intersections on three screens and indicate when it was safe to make a left turn by releasing the brake pedal. The decision time was a measure of driving performance.

The study results confirmed the hypotheses that;

1. decision time increases with age, and age effects dominated the other factors which were studied,
2. decision time increases with age and level of impairment indicating that younger drivers are able to compensate for their impairments, but older drivers both with and without impairments are unable to make compensations in their driving performance,
3. traffic volume has a greater impact on decision time at intersections than sight distance,
4. skewed intersections are hazardous for drivers with neck impairments.

Further laboratory and field studies are recommended to validate the study results and to examine the problem of skewed intersections.

The Performance of Drivers with Physical Limitations

at T-Intersections

by

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A THESIS

submitted to

Oregon State University

in partial fulfillment of
the requirements for the
degree of

Doctor of Philosophy

Completed April 7, 1988

Commencement June 1988

APPROVED:

Redacted for Privacy

Professor of Civil Engineering in charge of major

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Date thesis is presented April 7,1988

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ACKNOWLEDGEMENT

A special thank you to Joseph, my Husband for his helpful suggestions, advice, support, and encouragement. I thank the Department of Transportation, Federal Highway Administration Graduate Research Fellowship Program for providing the opportunity to undertake this research at the Turner Fairbank Highway Research Center in McLean, Virginia. I acknowledge the guidance and support given to me by Dr. Truman Mast, at FHWA who supervised the research efforts. I thank Drs. Robert Layton and Robert Safford for their encouragement, direction and support of Human Factors in Transportation Research at Oregon State University.

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THE PERFORMANCE OF DRIVERS WITH PHYSICAL LIMITATIONS AT T-INTERSECTIONS

CHAPTER 1

INTRODUCTION

> "Driving in our society is as important, or more important, to handicapped persons as it is to other segments of our population. Personal use of an automobile is often a determinant factor both in employment and the satisfaction of the basic human needs, from food acquisition to the psychological and social requirements of every day life. A person unable to drive in our mobile society may lose the opportunity for personal freedom and independence." (Brainin, et al 1977).

The research examines the relationship between physical limitations that restrict head and neck movement and driving performance. The research has been initiated as a result of the increased accident rate statistics of drivers with diminished capacities and the need to determine the relationship between their driving performance and current road design standards (U.S. DOT Highway Statistics, 1980). Specifically, the research examines the effects of diminished range of movement of the neck on decision patterns at T-intersections in drivers who are between 30-50 and 60-80 years of age, half of which have neck movement limitations. A unique methodology using a driving simulator, which incorporated the use of video recordings of intersections, was used for the research. The facilities for this research are located at the Federal Highway Administration, Turner Fairbank Highway Research Center in McLean, Virginia.

Chapter 2 presents the background necessary to understand the problems of drivers with diminished capacities. The current state of knowledge on the subject is summarized in the literature review in Chapter 3. The research objectives, purpose, and hypothesis are stated in Chapter 4. The research design and methodology employed are described in Chapter 5. The research procedures, described in Chapter 6, explain the type of equipment used for the research. Finally, the research results and observations are summarized in Chapter 7. These results are discussed in Chapter 8. The research conclusions and recommendations are presented in Chapter 9.

CHAPTER 2
BACKGROUND

2.0 BACKGROUND OF THE PROBLEM

The accident rate statistics document the increase in accident rates of older drivers and drivers with diminished capacities on a miles driven basis and indicate the need to study the performance of these drivers (U.S. DOT, Highway Statistics, 1980). The population demographics show a dramatic increase in the percentage of older people in the total population in the year 2000 and beyond(Aging America, 1985). The majority of accidents, involving the older driver occur at intersections, during lane changing and turning maneuvers. These facts indicate the need to study the performance of drivers with physical limitations at intersections. The problems of drivers with diminished capacities that are related to aging and physical limitations are well documented and are summarized in the literature review in Chapter 3.

The problems of drivers with diminished capacities need to be understood to determine safer road design standards and operational and control strategies. A better understanding of these drivers characteristics will facilitate the design of education programs for these drivers to help them compensate for their limitations. Road design standards are used as the basis for the design of highways and streets. Human factors, vehicle characteristics and road geometric requirements form the basis of most of the standards. Many of the standards are based on the sight distance criterion which takes account of human factors and vehicle characteristics. The sight distance criterion is defined by a two term equation, a perception reaction term and a braking distance term. The effect of human factors is included in the perception reaction term, and the impact of vehicle-roadway characteristics is included in the braking distance term.

2.1 FUNDAMENTAL CONCEPTS

Perception reaction time, sight distance and gap acceptance, which are fundamental concepts to this research, are defined and discussed below. The study examines the behavior of drivers making a left turn in a T-intersection driving simulation. The left turn maneuver requires the driver to judge when there is an adequate gap in the traffic flow in both directions. The ability of the driver to judge gaps is based on the drivers' perception reaction time and also roadway geometrics, such as sight distance.

2.1.1. Perception Reaction Time

There is considerable variation in the transportation literature concerning both the definition and utilization of perception reaction time. Some authors include a factor for decision making, while other authors do not. This leads to confusion in interpretation of experimental results. Several perception reaction time definitions are included to provide an understanding of its nature and magnitude. The definition in the 1965 ITE Traffic Engineering Handbook for "reaction time" is "the brief interval between seeing, hearing, or feeling and the beginning of a response to the stimulus". However, it should be remembered that the major variations are in the nature and duration of the perception reaction elements, rather than the total perception reaction time from the initial stimulus to completion of the reaction.

Reaction times of drivers in traffic are more correctly called perception reaction times because perception of a situation is usually involved. Reaction time, according to Henderson (1986), is the interval between the presentation of a stimulus and a response. Reaction time involves detection, identification, decision and response. Brake reaction time, which is a component of perception-reaction time, is the time between when the driver recognizes the existence of a hazard and the instant the driver applies the brakes. Brake reaction time includes decision time and depends both on driver and vehicle characteristics. Under certain conditions, such as an emergency, the driver performs these tasks almost instantly. Under most other conditions the driver must subconsciously associate the object ahead with stationary objects adjacent to the roadway to determine that the object is also stationary or moving at a slow speed. These determinations take time and are dependent on the characteristics of the object and the driver. Vehicle speed and the roadway environment also influence reaction time according to AASHTO, the Policy on Geometric Design of Highways and Streets, 1984, published by the American Association of State Highway and Transportation Officials. The time for the brakes to engage is implicit in the brake reaction time.

Greenshields (1965) introduced the PIEV model of perception reaction time. This model includes Perception, Intellection, Emotion, and Volition. Perception (P), means perceiving an event or hazard. Intellection (I) is the understanding and comprehension of the event. Emotion (E) is the emotional reaction or decision regarding the event. Volition (V) is the evasive or motor response to the event. In an emergency, emotion may override all intellection and dictate the response (volition). The PIEV terms are in general additive, but it could also be argued that these terms overlap.

The definition of driver performance time used for this thesis is based on these definitions of perception reaction time. The perception time used herein is the time required for a driver to come to the realization that the brakes must be applied. Perception time varies between and within individuals due to variations in expectations, hazards, emotional state, optical ability, visibility and weather. Driver performance time is made up of perception of an event, cognition of the event, decision to respond to the event and finally motor reaction to the event. Driver performance time encompasses perception reaction time and implicitly includes decision time. In AASHTO, the perception reaction time includes a one second margin to accommodate drivers with slower reaction time, however that margin is often consumed in decision making. The AASHTO perception reaction time factor does not account for decision time, but rather uses a one second margin, which for many drivers with diminished capacities in complex situations is not large enough. Further discussion of the AASHTO policy and perception reaction time is included in Chapter 3.

2.1.2. Sight Distance

Driver perception-reaction time is included in the calculation of safe stopping sight distance. Sight distance is the length of roadway ahead that is visible to the driver. The minimum sight distance available on a roadway should be sufficiently long to enable a vehicle traveling at or near the design speed to stop before reaching a stationary object in its path. Calculations for stopping sight distance are based on a 3.5 foot height of eye and a 6 inch object height. Stopping sight distance is the sum of two distances: the distance traversed by the vehicle from the instant the driver sights an object necessitating a stop to the instant the brakes are applied, plus the distance required to stop a vehicle from the instant brake application begins (AASHTO 1984).

2.1.3. Gap Acceptance

The driver must make a judgement on gap length or lag time in order to complete a crossing or turning maneuver safely at an intersection. Polus (1983) defines gap acceptance as the minimum gap accepted by 50% of the drivers. Lag is defined as the time interval between arrival of a vehicle on a minor road at the STOP sign and the arrival of the next vehicle on the major road to a point opposite the stopped vehicle. Blumenfeld and Weiss (1979) and other authors agree that "gap acceptance" is variable between drivers, and individual drivers exhibit inconsistent gap acceptance behavior. Despite the variation in gap acceptance behavior, researchers have suggested empirical models of gap acceptance based on queue length, approach speed, age and sex of the driver, number of passengers and type of vehicle (Cooper, Storr, and Wennell,1977; Cooper and Wennell,1978; and Wennell and Cooper,1981). Blumenfeld et al, (1979) suggested that gap acceptance is also a function of major street traffic volumes. It was observed that males accept shorter gaps than females, and that drivers who accepted shorter gaps also completed maneuvers faster. The new

Highway Capacity Manual,(1985) is consistent with other researchers, citing that the speed of major street traffic, stop or yield control, type of crossing maneuver, and number of lanes all determine the minimum acceptable gap length. However, the manual does not take into consideration street traffic volume as a factor in gap acceptance.

2.2. BACKGROUND FOR RESEARCH

This research addresses the intersection problem since most serious accidents occur at intersections (U.S. DOT Highway Statistics, 1980). This research is very basic to understanding the intersection problem. The behavior of drivers with diminished capacities at intersections is not well understood due to the complexity of operation and the numerous factors involved. T-intersections were selected because; they are simpler than four way intersections, they permit better control of variables in a laboratory environment, and they eliminate other confounding variables. A laboratory facility for studying the behavior of drivers at simple intersections already existed at the Turner Fairbank Highway Research Center, where the research was undertaken. This equipment and facility were well suited to the study of T-intersections.

2.3 CLOSURE

The need to study the problems of older drivers and drivers with diminished capacities has been documented in accident rate and demographic statistics. The variation in definition of perception reaction time has created ambiguity in the interpretation of research results. The definition adopted for this intersection research includes factors for perception, cognition, decision and reaction times. Perception reaction time is important for defining the required sight distance which directly affects intersection design. Intersection turning maneuvers are based on gap acceptance. Current standards do not account for major street volumes despite indications that volume is an important factor. T-intersections were selected for study because they are simpler than four way intersections and permit better control of variables. Additional research in the laboratory or field would extend the results of this study to more complex intersection types.

CHAPTER 3
LITERATURE REVIEW

3.0 INTRODUCTION

The study of drivers with diminished capacities at intersections covers a broad spectrum of literature from human factors, gerontology, ophthalmology, and ergonomics to traffic engineering and experimental design. Significant studies have been and are currently being undertaken that examine the psychological and cognitive aspects of drivers with diminished capacities. These are complimentary to studies of physical limitations (Staplin, Breton, Haimo, Farber, and Byrnes, 1986). There appears to be a significant void in the literature on the biomechanical aspects of drivers with diminished capacities, and therefore this area was selected for the study. Vision is very important for information gathering in the driving task, and since vision and aging are closely related, they are included in the literature review. Traffic engineering literature that concerns intersection geometrics and sight distance is reviewed and summarized. The study is laboratory based and uses human subjects, therefore the literature review includes a brief discussion of experimental design and driving simulators.

3.1 DRIVER

3.1.1. Introduction

Drivers with diminished capacities have different sensory, cognitive and physical thresholds than other members of the driving public (Rees and

Botwinick, 1971). The implication of this is that these drivers require more stimuli for perception, or extra time to react as a result of physical limitations. Increased stimuli may be provided by higher contrasts or increased letter size on street signs. Often longer decision making time is required which results in a lengthened total driver response time. The longer decision time is due to increased time to gather and process the information. The older driver performance time has been studied and has been shown to be longer than for other age groups (Brainin, Naughton, Breedlove, 1977). It has been shown by Panek, Barrett, Stearns, and Alexander,(1977), that older persons perceive information and react to information at approximately the same rate as other age groups. However, they take a much longer time to make a decision, and thus require a longer perception reaction time (Yanik, 1986). Young drivers use a trial and error approach for decision making by quickly scanning the environment to gather information and making a quick decision which may or not be correct. However, older drivers delay acting until certain of a single correct event. It is suggested that the decision stage, rather than the perception, cognition and reaction stages, is the element that contributes to a longer driver performance time for older drivers (Yanik, 1986). There are a number of researchers who argue that older persons do not perceive, recognize or react at the same rate as younger individuals, and that the slower rate is a result of the natural aging process (Staplin, Breton, Haimo, Farber, and Byrnes, 1986). Part of the decrease in perception rate is accounted by increased visual accommodation time.

3.1.2. Physical Limitations

Many drivers with diminished capacities often have diminished range of motion or muscle weakness which affects their ability to react quickly. Vehicle modifications are often required to compensate for the decreased dexterity, strength, and range of movement. Older drivers have changing medical conditions that are a direct result of aging, these include changes in posture, decreased muscle power and coordination, tremors, retarded reflexes and slower adjustment to stimulus (Brainin, 1980). Many drivers who have sustained neck injuries have restricted range of movement of their neck as a result of the initial trauma, and may be more susceptible to further injury or disease. The decreased range of motion can have direct effect on turning movements such as lane changing. The accident statistics show that the older driver is much more likely to have accidents at intersections and during lane changing than under any other circumstances (Moore, Sedgley, and Sabey, 1982; Planck and Fowler, 1971).

3.1.3 Vision

Information must be gathered to make a decision, and in the driving task most of the information is visual. To gather visual information the environment must be scanned by using visual field and head movements. Age related disorders, trauma, as well as disease processes, affect range of motion of neck muscles. For example, arthritis can severely restrict head range of movement which causes increased problems due to blind spots, and thereby also affects overall driving performance. There are also decreases in visual accommodation and acuity with increasing age. Visual accommodation is the ability of the eye to adjust to different viewing distances. Visual acuity is the ability of the eye to discriminate or resolve fine detail. Glasses severely restrict lateral visual field capabilities, and therefore drivers who wear glasses should be expected to exhibit greater range of movement of the head and neck when gathering information at intersections. Eye glasses with heavy frames can further restrict the visual field.

Many studies have shown the relationship between deterioration in vision and age (Sivak, Olson, and Pastalan, 1981; Sivak, and Olson,1982; Freedman, Davit, Staplin, and Breton, 1985). The eye is a complex interconnection of parts which all age differently and at different rates. The aqueous and vitreous humor progressively become more solid from early childhood. The lens ages and causes several changes in vision. The lens increases in opacity and absorbs more light and also scatters more light, thereby passing less light to the retina. The lens grows thicker and is less able to adjust its shape which leads to presbyopia (long-sightedness). It yellows with age and leads to changes in color discrimination particularly along the blue yellow axis. All the changes in the lens characteristics have a direct effect on the driver's ability to read road signs and other traffic related information. The retina is a multi-layered structure, and its age related changes are very complex. The most common age related changes are detachment of the retina layers, decreases in vascular support and an accumulation of metabolic by-products. The speed of adaptation to darkness also decreases with age. This can cause problems for older drivers who drive from bright daylight into tunnels, or from sunlight to shade or from dark roadways to brightly lit intersections(Staplin et al, 1986).

The legibility distance for older drivers is 65-77 percent of those of younger drivers (Sivak et al, 1982). Legibility distance is the distance from the eye to a sign that can be read. This implies that the older driver has less distance and therefore less time to respond. Not only does a person's visual acuity deteriorate with age but higher illumination levels are required, due to less light being transmitted by the lens. Older people have inferior nighttime vision which is a result of visual acuity deficits due to changes in the pathology of the eye and not a decrease in information processing ability (Sivak et al, 1982; Yanik, 1986). It has also been suggested that the standard visual acuity tests that are given under high illumination levels during driving examinations may have questionable validity (Sivak et al, 1981). Visual acuity tests administered under different lighting conditions would provide a more accurate assessment of drivers' visual acuity. In recent years researchers have begun to distinguish between static and dynamic visual acuity. Static visual acuity represents the clarity of stationary objects, and dynamic acuity is the clarity with which objects are seen travelling at an angle to the viewer (Panek et al, 1977). Burg (1968) who has studied dynamic visual acuity suggests that dynamic visual acuity is far more representative of visual performance than static visual acuity. It has been noted that dynamic visual acuity deteriorates with age (Yanik, 1986).

3.1.4. Sex Differences

Many studies have noted differences in driving performance between male and female drivers. These differences first show up in young drivers where novice female drivers require more confidence in their ability to make decisions on turns and maneuvers. Novice male drivers require more caution and less recklessness in their driving behavior (Hagan, 1975). Accident data on older drivers indicates that older male drivers perform better than older female drivers (Planck and Fowler, 1971). Grubb(1986) observed that there was a marked increase in female involvement in fatal accidents at age 70 or older, which could be due either to the higher percentage of women in the over 70 population or the lack of driving experience by the majority of women in this age group. Grubb also cited a remark by Burg (1968) that females have a larger visual field than males across all age groups. The larger visual field that females have is not reflected in the accident data which imply that there are other factors that are affecting their driving. It is suspected that in the current generation of older drivers, the sex differences in the statistics are due to the general lack of driving experience by older women who generally relied on their spouse to do all the driving. The medical literature has documented that older women are much more likely to suffer osteoporosis due to loss of calcium resulting from a decrease in estrogen levels. Osteoporosis can lead to spinal deformity which in turn can affect head and trunk movement and posture, which increases the time required to gather information.

3.1.5 Age Problems

Older drivers have both physical and sensory deterioration which is a direct result of aging (Brainin, 1980; Rees et al, 1971; Planck et al, 1971). Some of these changes include changes in posture, muscle power, coordination, tremor, and retarded reflexes which show slow adjustment to stimuli. Many of these factors are present in younger drivers who are handicapped as a result of neurological conditions.

The influence of drugs and medication on driving behavior is often overlooked. Older persons are the highest percentage users of prescription drugs and also are more likely to suffer adverse drug reactions than any other population group. Illness and medication have been shown to have a definite effect on reaction time and therefore affect driving performance (Staplin et al, 1986). The effects of medication can often compound the problems of drivers with physical limitations.

The most common problems of older drivers are yielding right of way, turning, changing lanes, passing and failure to read traffic control devices (Yanik, 1985). Many older drivers also have problems judging speed and perceiving distance (Malfetti, 1985). Planck et al,(1971), have indicated that older drivers think they are driving too slowly so they speed up and follow too closely. This indicates that their perception of actual speed is inadequate.

Aging and many neurological conditions have a very slow onset and are insidious in nature so that deterioration in physical and sensory ability is very slow. Many drivers continue to drive as if their reactions and faculties have not changed, with the result that they are over-driving their capabilities (Brainin, 1980). Aging not only slows down physical responses, but it has been shown to affect information processing abilities. The decrease in sensory and perceptual information processing has been attributed to changes in vision and neural responses. The visual field of young adults is approximately 170 degrees, and it decreases to about 140 degrees in adults who are over fifty (Panek et al, 1977). Other researchers have found conflicting evidence on the decrease in visual field with age although the majority support the decrease in visual fields (Hooper and McGee, 1983). The changes in visual field are attributed to changes in the eye.

There are conflicts in the literature concerning age changes in cognitive processing, however there are a few areas of agreement. In general, older persons are more easily distracted and not able to screen out insignificant information (Welford, 1981). Studies have shown that there is a decrease in long term memory, information processing and the integration of information (Yanik, 1986). There does not appear to be any significant age difference in short term memory abilities. There are age differences in time event recall, which indicates differences in memory retrieval processing. Across all age groups there was no significant difference in reading speed (Staplin et al,1986). Driving behavior at intersections depends primarily on short term memory.

Several theories have been suggested for the increase in decision time for older drivers. Welford, (1981) has suggested that changes in information processing result from a difficulty of accepting a new stimulus in the midst of a current stimulus due to increased internal noise and higher sensory thresholds. Many older drivers tend to adopt driving strategies which optimize their performance by driving slower and at times when driving is less stressful, such as non rush-hour times (Yanik, 1986).

The decision phase is the throughput phase between perception and motor responses. The decision phase involves the processing of information and is dependent on experience, memory, emotions, and the number of alternative bits of information to be processed, for example, judgement of gap acceptability (McGee, Moore, Knapp, Sanders, 1978). There is general agreement in the literature that there are physical, visual and cognitive changes with age that individually and cumulatively have an effect on overall driving performance.

3.1.6 Ergonomics

Vehicle brake and accelerator pedal locations have a direct impact on reaction time, particularly brake reaction time. Differences in pedal height directly increases response time (Davis and Watts,1970). Ergonomic considerations on the size and the geometric relationship of the pedals are important. The brake and accelerator pedal should be separated by at least 2 inches (5.08cm) which is sufficiently far apart to avoid accidental compression of both pedals at the same time. The recommended distance is 6 inches(15.24cm) because the male shoe is approximately 5 inches (12.95cm) wide(Snyder, 1976). The dimensions of the seats were not mentioned as influencing reaction time. Low seats for older and smaller individuals can add more sight barriers, but these drivers usually use seat cushions to compensate for their size.

3.2 INTERSECTIONS

3.2.0 Introduction

Intersections require drivers to make decisions with regard to changing direction and crossing, present conflicting traffic flows, and often present changing roadway geometrics which increase driver workload. Increased accident rates at intersections appear to be related to the implementation of new traffic control devices, high traffic volumes and low sight distance (David and Norman, 1976; McGee et al, 1983). Polus (1985) points out that more restrictive signalization does not necessarily result in a decrease in accidents or unsafe movements.

3.2.1 Stopping Sight Distance

Stopping sight distance as discussed previously involves two basic terms, a term to account for perception reaction time and a term to account for the distance it takes for a vehicle to stop. The American Association of State Highway and Transportation Officials in the Policy on Geometric Design of Highways and Streets, published in 1984, states that the perception reaction time of 2.5 seconds, which is adopted for most design applications, is not valid for complex intersections for a typical driver,i.e. the 85th percentile driver. However, it does not make any suggestions concerning drivers with limitations. The study by Johansson and Rumar(1971), which is also referred to in AASHTO, was performed using able bodied subjects. Older drivers with their slow reaction times require longer stopping sight distances than are currently recommended in the design policies. The policies such as, AASHTO(1984), recommend a perception reaction time of 2.5 seconds, but research involving older subjects indicates that a perception reaction time of 3.2 seconds is preferred (McGee et al, 1983; Gordon, McGee, Hooper, 1984; Hooper and McGee 1983; Hostetter, McGee, Crowley, Seguin, and Dauber, 1986). Figures 3-1 and 3-2 are reproduced from figures II-14 and II-15 in the 1984 AASHTO policy and show the median

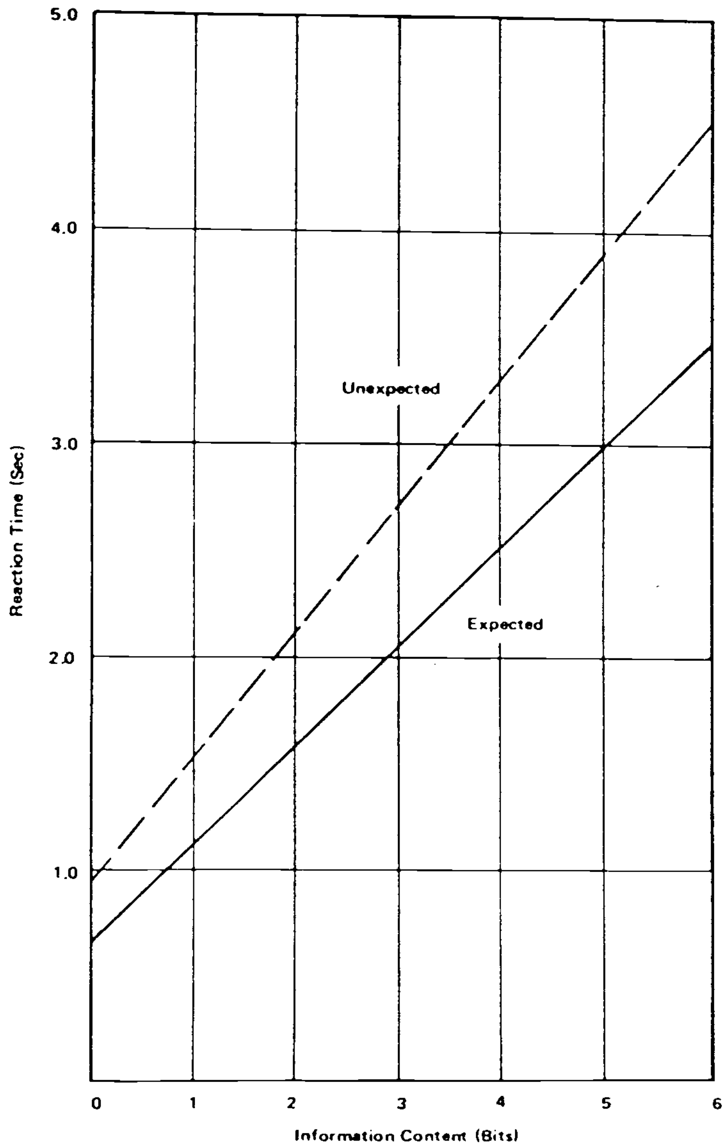

Figure 3-1 Median Driver Reaction Time to Expected and Unexpected Information

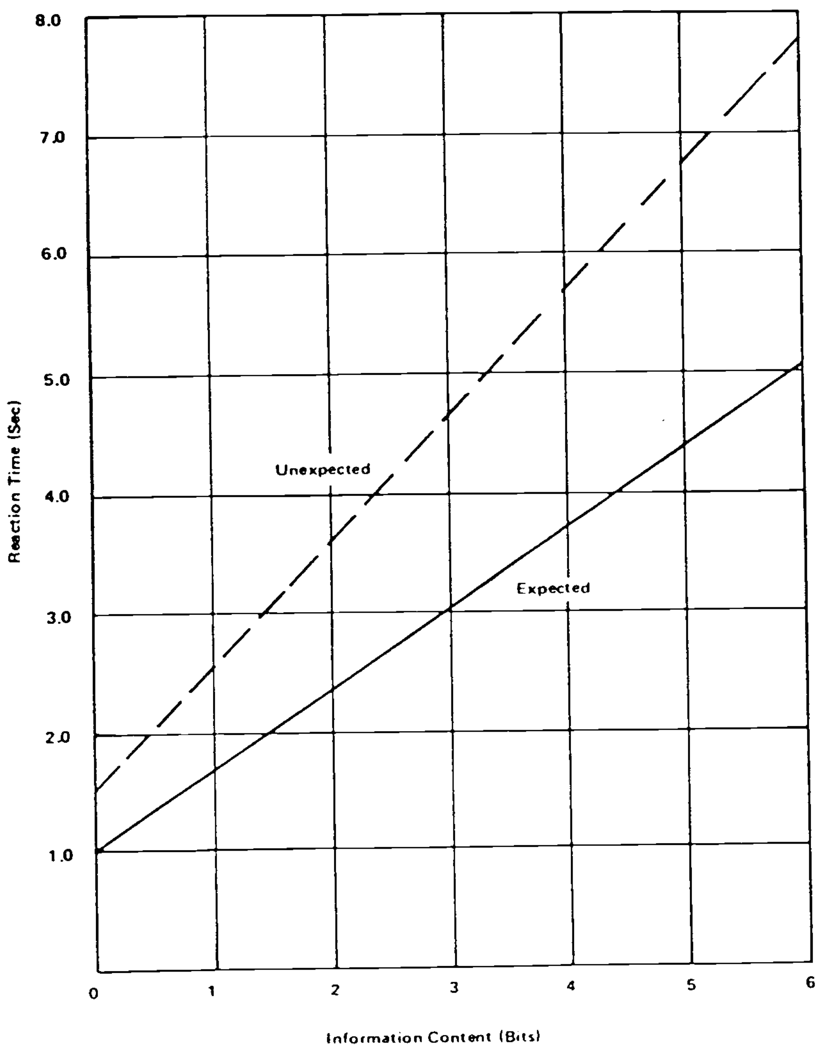

Figure 3-2 85th Percentile Driver Reaction Time to Expected and Unexpected Information and 85th percentile driver reaction time to expected and unexpected information, respectively. The figures show information in bits. A bit is a term used to quantify the amount of information needed to make a decision. Expected information is similar to anticipated information, for example, at a traffic signal a green light is expected to follow a red light. A longer perception reaction time necessarily increases the stopping sight distance since they are directly related.

There are other components to intersection sight distance that are a function of the intersection geometrics. For an uncontrolled intersection the driver must decide whether or not to proceed. This decision time is made up of the time to detect a situation, the time to decide what to do and the time to respond by either accelerating, or remaining stopped. At stop controlled intersections the driver must see the stop sign and prepare to stop. Once the vehicle is stopped, the driver must then determine if there is an acceptable gap length to cross the street successfully or complete a turning maneuver. A turning maneuver requires time to look in both directions, perceive that there is time to complete the maneuver, prepare to proceed, and complete the maneuver. There is consensus among researchers that there is a relationship between increased driver age and increased perception reaction time. The increased perception reaction time is a result of visual, cognitive and motor response impairments.

3.2.2 Decision Sight Distance

Decision sight distance as defined by Alexander and Lunenfeld(1975) is the distance required for a driver to detect an unexpected or otherwise difficult-to-perceive information source or hazard in a roadway environment that may be visually dulled, to recognize the hazard or its threat potential, select an appropriate speed and path, and initiate and complete the required maneuver safely and efficiently. Decision sight distance is much longer than stopping sight distance due to time required to maneuver the vehicle at speed rather than simply stopping. Decision sight distance requires the time to comprehend a complex condition, or one that is difficult to understand. Drivers require decision sight distance where there is a likelihood of error in information processing. Decision sight distance is an appropriate design control to evaluate conditions where a forced lane change is required such as upstream of an off-ramp.

AASHTO (1984) defines premaneuver time associated with decision sight distance as the time required for a driver to process information relative to a hazard. It consists of time to detect and recognize the hazard, time to decide on the proper maneuvers and to initiate required action. Detection and recognition times include time periods of latency, which is the delay between the time a hazard is presented and the time the eyes begin to move. Detection and recognition time includes eye movement to the hazard, eye fixation, recognition and perception. Decision and response initiation time occurs after perception and includes the identification of alternative maneuvers and the implementation of action. The final component is the time required to accomplish a vehicle maneuver. Decision sight distance is not directly related to this research, since the test subject is stopped at an intersection. The effects of a driver using poor judgement and pulling out into traffic at the wrong time require drivers approaching the intersection to take evasive action that is predicated on decision sight distance.

3.2.3. Intersection Geometrics

Studies have shown that intersection geometrics do not have as much influence on accident rates as human factors (David et al, 1976). Many studies of driver performance use accident data that has been collected using standardized accident data forms. The accident records are often ambiguous on causation and therefore careful consideration should be given to the interpretation of results that rely on this information. Unusual intersection geometrics can cause conflicts with driver expectancy, and contribute to decision, comprehension, perception or action failures. These failures contribute to the human factors failures at intersections which in turn contribute to an increased number of accidents at intersections (Moore et al, 1982). Accident data, due to the reporting methods, often obscure the real cause of accidents. For example, the reported cause of an accident may be human error as a result of unusual geometrics that conflict with driver expectancy, but the geometrics and traffic volumes which may be major contributors to the accidents are unreported. Accident data are often confusing and careful attention should be given in interpretation. David et al, (1976), have shown that human factors are involved in 83-93 percent of the accidents and of these, 42 percent are decision failures and 5 percent are action failures. These statistics further emphasize the importance of decision time in the perception reaction term.

3.3. EXPERIMENTAL DESIGN

There are no standard methods or guidelines for valid, unbiased and generalized research methods for the older driver. There are several considerations that should be noted concerning cross sectional and longitudinal designs. Cross sectional study designs are done at a single point in time and usually across a range of ages. This can lead to a misinterpretation of performance due to cultural and historical experience of the age cohorts. Another example of cross sectional study design is to study a symptom such as the effect of restricted head movement and to examine both young and old at the same time. A longitudinal study design tracks the performance over time and is prone to subject attrition leaving only the healthy subjects and therefore inflating the performance measures. The sampling strategy employed in this experiment is cross sectional with the subjects grouped according to age and level of impairment. The subject pool was very diverse and it was not anticipated that cultural or historical effects of the age cohorts would affect the study.

3.4. DRIVING SIMULATORS

> "An engineering definition of a simulator is a system or apparatus that has been designed to reproduce some aspects of a more complex system while at the same time avoiding the encumbering aspects of that system... A driving simulator is a stationary apparatus that presents to a driver most of the sensory stimulations and vehicle response characteristics that he experiences while driving on the road" (Hulbert, S., 1961).

The benefits of simulators studies must be weighed against the problems of validation. Driving simulators enable the study of driving behavior in a laboratory environment under dynamic yet controlled conditions. Unlike the road environment, many drivers can be tested under identical and repetitive conditions, and instrumentation can be used to record their responses (Mathewson, 1958). Validation is the transfer of training or information between the simulator and the real world. For research applications, it is the determination of high functional correspondence between performance results and real world findings (Moraal and Kraiss, 1981). According to Leonard and Wierwille,(1975), validation is the problem of obtaining parallel measures in the real world and the simulator and then making them congruent. The value of a simulator depends on its ability to elicit from the operator the same sort of response that he would make in a real situation (Blaauw, 1982). A driving simulator is used to study the behavior of drivers at T-intersections in order to provide control and repetition of the driving scenarios.

3.4.1. Simulator Studies (after Grubb, 1986)

There are numerous driving simulators available for experimental research. These simulators may be highly sophisticated moving base simulators (Hicks and Wierwille, 1979) or various part task simulators. In all simulations visual processing is a critical component. Some of the more sophisticated simulators have also attempted to provide the participants with auditory and proprioceptive (physical) sensations, but these simulators often cause motion sickness due to discrepancies between proprioceptive feedback and the expectations generated by the viewed perspective. Subjects in fixed base simulators often experience motion sickness which may be attributed to feedback discrepancies.

Many methods have been used to study driving behavior at intersections. These methods include; before and after studies, computer simulation studies, naturalistic observation studies, field driving experiments, and driving simulator studies. The method used is dependent on the type of study desired. Before and after studies are appropriate for studying the effect of signal changes on intersection operations. Computer simulation studies are particularly useful for planning purposes, or signal timing. Naturalistic observation studies are useful for gathering information and data for planning, or validating simulator studies. Field driving experiments are very limited in value due to safety problems, and lack of experimental control.

Simulations of intersections have been confounded by the perspective of the observer. In general, the observer would look down on an intersection, resulting in a distorted view of gaps. Intersection simulators require a wider field of view than is generally available on most simulators. The driver needs to view at least 180 degrees. The requirement for a wide field of view is very difficult and expensive to reproduce on an interactive simulator. A simpler method for presenting the wide field of view is to project the scene just as it was filmed with no capability for the driver to manipulate the images by the vehicle "controls". In these studies, the participant is generally asked to mimic the control movements necessary to follow the image viewed. The basic experimental equipment and laboratory to project a 180 degree perspective of intersections for the participants to mimic control movements has been established at the Turner Fairbank Highway Research Center in McLean, Virginia, therefore this technique was selected for the study. Chapter 6 includes a discussion of the equipment and the simulator used in the study.

3.5. CLOSURE

The physical, cognitive and visual abilities of drivers need to be understood in order to study the driving performance of drivers with diminished capacities at intersections. The research undertaken focuses on the physical, visual and aging characteristics of the driver. Sight distance, traffic volumes, and geometrics influence the function and safety of an intersection. A laboratory simulation was used to study the intersection problem using a cross sectional experimental design.

CHAPTER 4
RESEARCH OBJECTIVES
PURPOSE, PROBLEM STATEMENT, RESEARCH HYPOTHESIS

4.0 RESEARCH OBJECTIVES

The objective of the research is to gain a better understanding of the effects of physical limitations on driving behavior and decision making ability. Specifically, the research addresses the behavior of drivers at T-intersections to determine the relationships between physical limitations as measured by range of movement of the head and neck, and visual field, and driving performance as measured by decision time. Other relationships are examined concerning sight distance, traffic volumes, number of head turns, medication and glasses.

4.1 PURPOSE:

The purpose of the research is to determine if the "perception reaction" or driver performance time is adequate to account for the capabilities of drivers with diminished capacities, such as restricted range of movement of the neck or head, or visual field limitations. The specific application is the study of the operation of stop controlled T-intersections.

4.2 PROBLEM STATEMENT:

Specifically, the research addresses the performance time at intersections of drivers with physical limitations of the neck. Unsignalized T-intersections with varying geometrics and traffic volumes are studied to determine if the design criteria and sight distances are adequate for drivers with physical limitations to make decisions.

4.3 RESEARCH HYPOTHESIS:

The hypothesis is that drivers with diminished capacities require increased decision time at intersections. The physical limitations of the neck require extra time to gather information. It is anticipated that older drivers require increased decision time due to aging effects of vision and cognitive processing.

CHAPTER 5
EXPERIMENTAL METHODOLOGY

5.0 INTRODUCTION

The study examines the performance time of drivers with physical limitations at unsignalized intersections to determine the relationship between physical limitations of the neck and decision time. The T-intersections are unsignalized and have different geometrics and traffic volumes. The study is undertaken using a driving simulator in a laboratory environment due to the hazards and lack of experimental control of a field study. Three screens are used to provide a 180 degree field of view in the driving simulator. This is a more realistic method of providing the drivers' perspective of the roadway for the study of intersections than the other methods of intersection simulation. Section 3.4.1 discusses various simulator methods for the study of intersections. The laboratory is located in the Human Factors Section of the Federal Highway Administration Turner Fairbank Highway Research Facility, in McLean, Virginia. The study with subjects was undertaken in January and February 1987.

5.1 EXPERIMENTAL DESIGN

The experiment is a 2(age) X 2(impairment) X 3(sight distance) X 2(volume) factorial design, with repeated measures on sight distance and volume. The subjects are partitioned according to age and impairment, and there are two levels of traffic volume, and three levels of restricted sight distance. All the intersections are T-intersections. The independent variables are age, impairment of subjects, medication and whether they wore glasses. These are repeated over eighteen intersections with variations in traffic volume and sight distance.

The subjects are divided as follows:

(i) 30 to 50 years impaired, number of subjects = 15,

(ii) 30 to 50 years unimpaired, number of subjects = 15,

(iii) 60 to 80 years impaired, number of subjects = 15,

(iv) 60 to 80 years unimpaired, number of subjects = 15.

Figure 5-1 is a histogram of the distribution of subjects ages in the two groups. The median age for the 30-50 year age group is 40 years, and the median age for the 60-80 year age group is 67.

For this research, impairment is defined by a combined static range of movement of the head and visual field of less that 285 degrees, whereas a range from 285 to 360 degrees is defined as no impairment. There is no definitive definition of impairment level in the literature, therefore for this study, the choice of 284 degrees was based on the functional requirements for driving.

The two levels of traffic volumes are measured in terms of average gap length (g). Traffic volumes were measured in two ways. The highway records indicated the average daily traffic for the roadways, however the video taping was done during morning rush hour for some intersections and at midday for other intersections. Therefore, the traffic volume as measured in the video tape segment were used rather than the average daily traffic figures. Gap acceptance is discussed in section 2.1.3. Light traffic volumes consist of gap lengths of 8 seconds or longer on both traffic streams. Moderate traffic volumes had gaps of

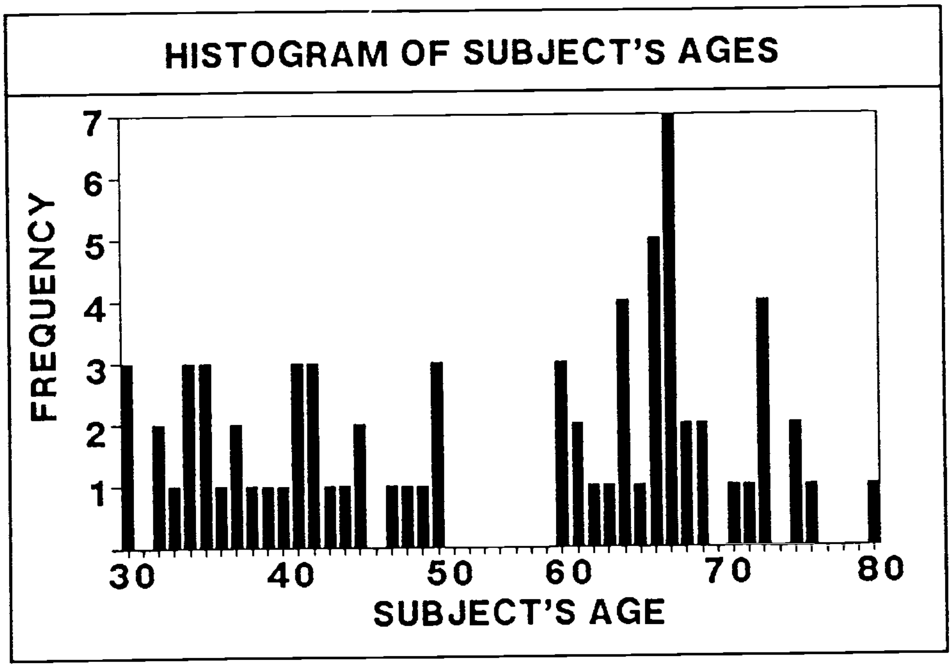

Figure 5-1 Histogram of Subject's Ages

less than 8 seconds in both traffic streams. Nine intersections had light traffic volumes, and nine intersections had moderate traffic volumes.

The AASHTO intersection sight distance definitions are used to calculate the required sight distance at each intersection, (Case IIIb). Case III are STOP controlled intersections on secondary roads. According to AASHTO,

> "the driver must have sufficient sight distance for a safe departure from the stopped position even though the approaching vehicle comes in view as the stopped vehicle begins its departure movements."

For a left turn into a intersection, Case III-B holds,

> " to turn left into the crossing roadway by first clearing traffic on the left and then to enter the traffic stream with vehicles from the right."

Figure 5-2 Case III-B shows a vehicle entering a cross road from a stopped position by clearing vehicles approaching from the left and then by turning left and entering the traffic stream approaching from the right. Figure 5-3 shows the detail of the criteria used in establishing the stopping sight distances shown on Figure 5-4. Figures 5-2, 5-3, and 5-4 are Figures IX-23, IX-24, IX-25 respectively, reproduced from the AASHTO Policy on Geometric Design. Field measurements of sight distance were made for each intersection and then each intersection was rated as either shorter than, equal to, or longer than the criteria. The three levels of restricted sight distance include:

(i) 95% or less than criteria, with a sample size of 6,

(ii) 95 to 105% of criteria, with a sample size of 6,

(iii) larger than 105% of criteria, with a sample size of 6.

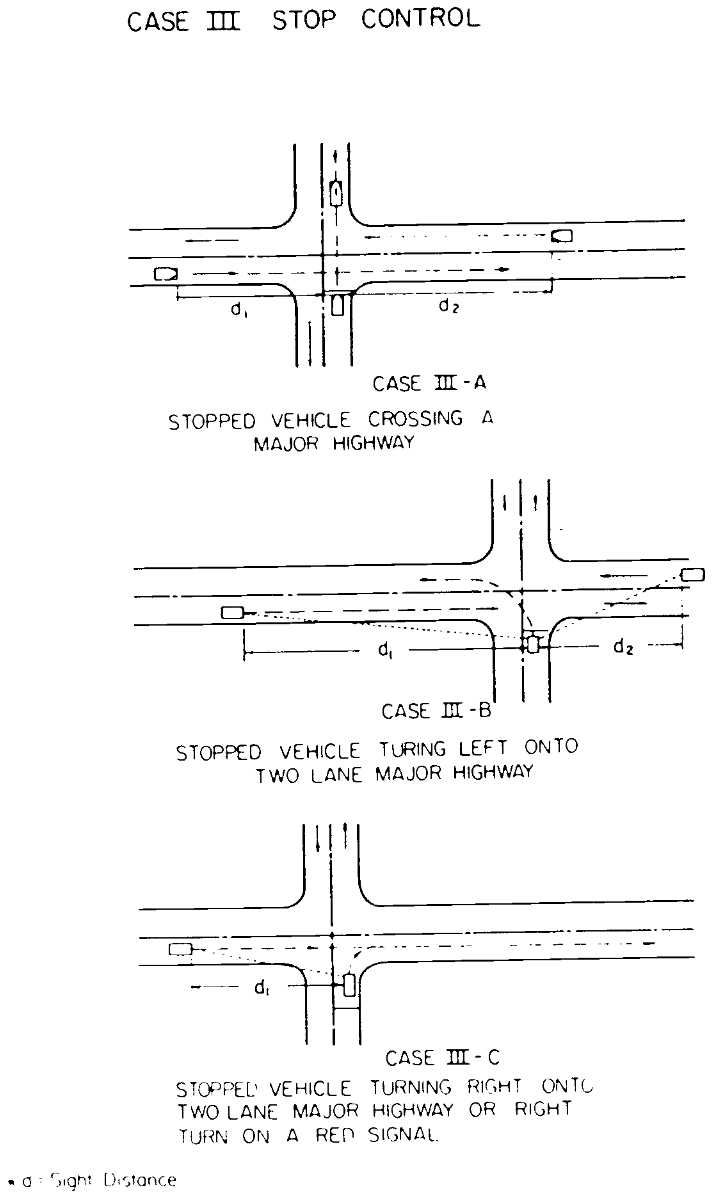

Figure 5-2 Intersection Sight Distance at At-grade Intersections (AASHTO Figure IX-23)

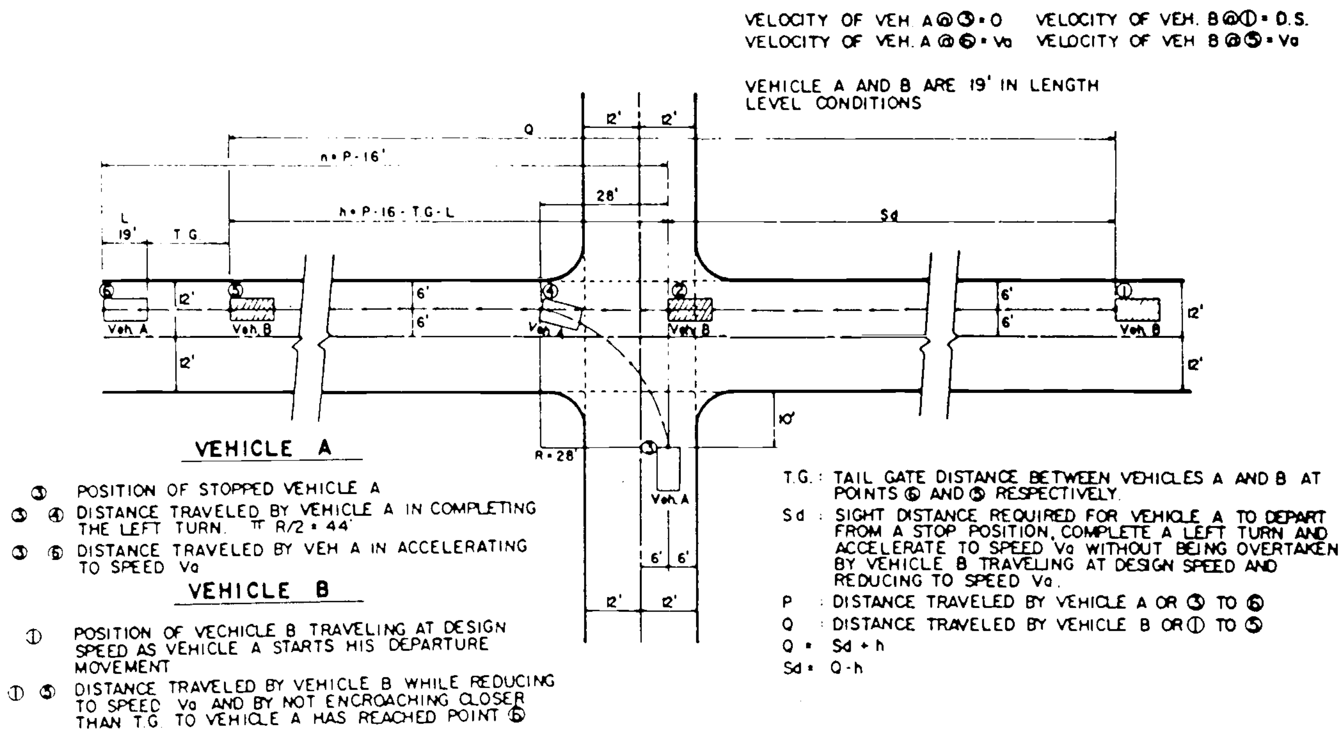

Figure 5-3 Case IIIB, Stopped Vehicle Turning Left onto two-lane major highway (AASHTO Figure IX-24)

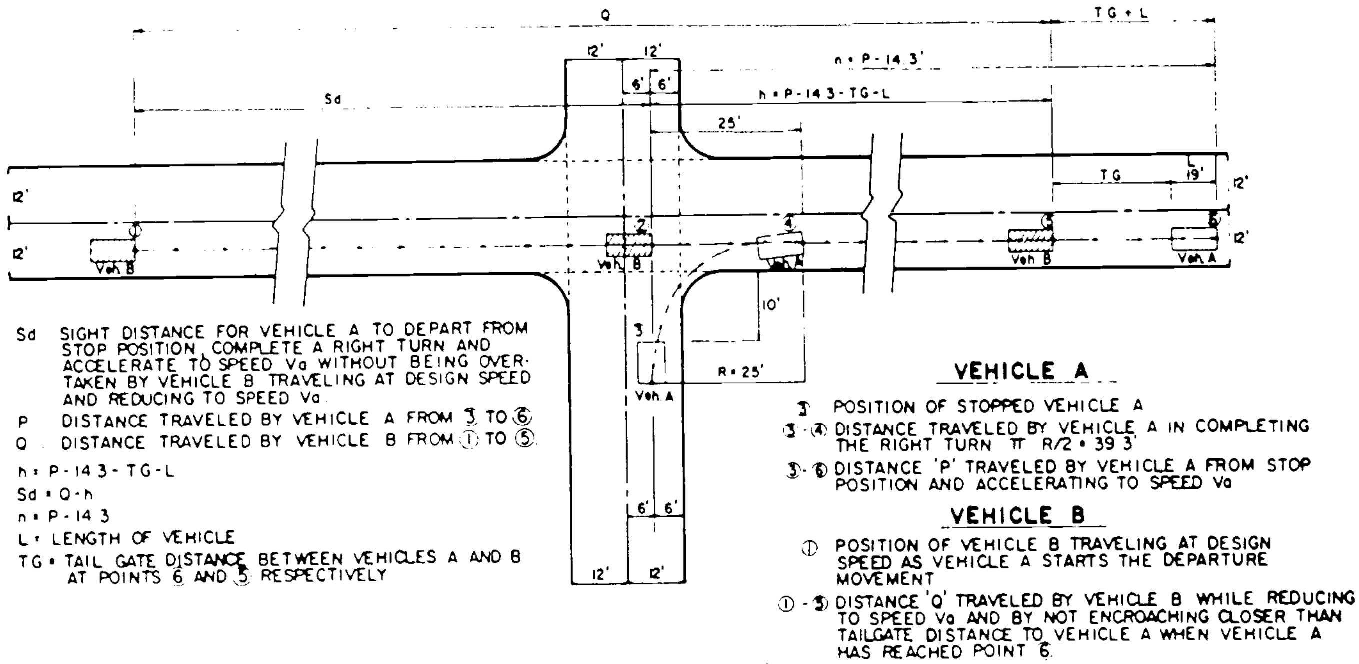

Figure 5-4 Case IIIC, Stopped Vehicle Turning Right onto two-lane major highway (AASHTO Figure IX-25)

Eighteen intersections were shown to each subject. Nine had low traffic volumes and nine had moderate traffic volumes. Of the eighteen intersections' sight distances, six were below standard, six were approximately at standard and six were greater than standard. The intersections were all located within a five mile radius of the Turner Fairbank Highway Research Center. The terrain is rolling so very few of the intersections were level. With the exception of one intersection, all intersections were at ninety degrees. All intersections were filmed in daylight, and on dry pavement.

The independent variables are subjects' age, impairment level, medication, whether they wore glasses for driving, traffic volume level and intersection sight distance. The measured or dependent variables are:

1. response time, that is determined by measuring time, from the tone indicating that an intersection presentation had begun, to the time the brake pedal was released in preparation for a left turn,
2. number of head turns during the response time for each intersection,
3. range of head movement, which is the maximum angle range from the left to right or right to left occurring during the response time,
4. static range of motion, which is the maximum head turn angle of each subject as measured by the goniometer prior to testing. The static range of motion measurement is the principle measure of impairment.
5. visual field, which is the maximum width of field of vision of each subject measured on the ortho rater prior to testing.

Response time is the principle dependent variable for the research.

CHAPTER 6

EXPERIMENTAL PROCEDURE

6.0 INTRODUCTION

The experimental procedure section discusses the protocol for the subjects, the equipment that was used and problems encountered with the equipment, the experimental procedures that were followed, data collection and pre-processing of data.

6.1 SUBJECTS

The study involved 72 participants between the ages of 30 and 50, and 60 to 80. Approximately one half of the subjects had some degree of physical limitation that restricted the range of movement of their head and neck but was not severe enough to require major vehicle modifications such as additional mirrors. Subjects were recruited as paid participants through local advertisements, and contacts with local agencies such as the Arthritis Foundation and the American Association of Retired Persons. Each participant was compensated $25.00 for their involvement in the study. All participants were required to have a valid driver's license and to drive an average of 10 or more miles per week.

The subjects exhibited a wide variety of driving behavior and physical skills. Many subjects who thought that they were not impaired had static neck range of movement of less than 105 degrees, and others who had arthritis showed no impairment in neck range of movement. Many of the subjects with arthritis were taking anti-inflammatory medication and also participated regularly in exercise programs sponsored by the Arthritis Foundation. In the 60-80 age group nearly all the subjects showed limited neck mobility. There was also large variability in driving skills in this age group. Some of the variability could be explained by the type of vehicle that they regularly drove, their lifestyle, and their attitude. The female subjects in both groups, in general, were much more cautious, and required many more practice intersections. Video film of two extra intersections were used for practice. The practice intersections had moderate traffic volumes and mixed sight distance. Most of the male subjects only required two practice intersections. Twelve of the subjects missed four or more intersections and therefore the final statistical analysis was performed using the data from 60 subjects. A missed intersection resulted from the subject removing his foot from the brake prior to the sound of the tone indicating the beginning of the measure of response time, as a result no data were collected for that subject at that intersection.

6.2 EQUIPMENT

6.2.1. Camcorders

A simulation of the driver's perspective of roadway intersections was constructed in a laboratory. Intersections were videotaped by using three video camcorders (Panasonic PV-200) mounted on a vehicle. The vehicle was at the stopped position at the T-intersection of a minor road and the major road. The three video camcorders were mounted on top of a 1979 Dodge at angles that provided a 180 degree field of view (straight forward, and centered 75 degrees from straight forward). The three camcorders were fixed to a platform on the roof of the vehicle. Figure 6-1 shows the vehicle with the mounted camcorders. Figure 6-2 shows the camcorders on the platform. The platform was fixed in position and not able to rotate like a driver's head or neck. The camcorders were fixed with respect to the roadway geometry which caused distortion in the pictures of intersections that were not at right angles. The measured and camcorder sight distances were different because the camcorders could not compensate for elevation changes such as roadway bumps and sags. The focal point for the three camcorders was in the center of the vehicle at the same distance back from the front of the vehicle as the driver's eyes.

The center camcorder was a different model than the two side camcorders. It was intended that the three video tapes would be synchronized by starting and stopping the camcorders simultaneously using a single switch in the vehicle. The center camcorder's internal mechanism did not start or stop recording at the same rate as the two side camcorders so that the three video tapes were not synchronized. However, all camcorders had the same film speed. The focal width of the lenses was fixed at 30 degrees and since there were only three camcorders, 90 degrees or half of the visual field was covered. Figure 6-3 shows the width of field of the camcorders. In future research, more camcorders could be used to get a broader picture to compensate for the lack of coverage of visual field, however this increases the cost, complexity, and problems in synchronization of the films.

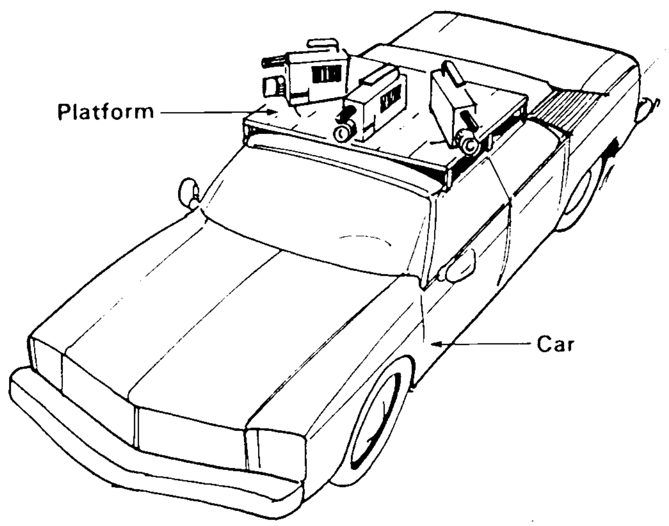

Figure 6-1 Vehicle with the Mounted Camcorders

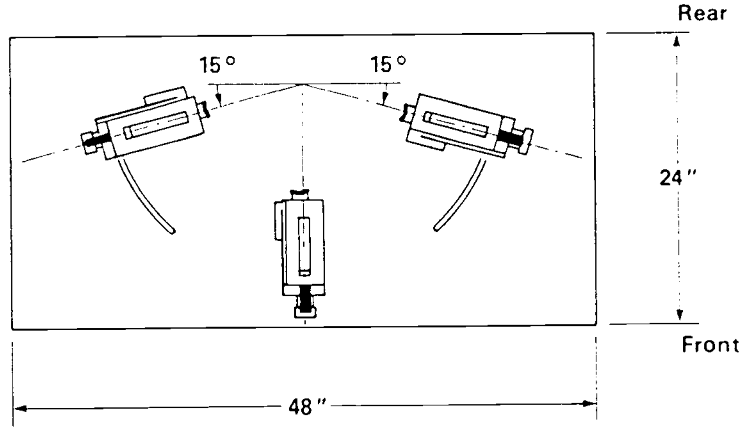

Figure 6-2 Camcorders on Roof Platform

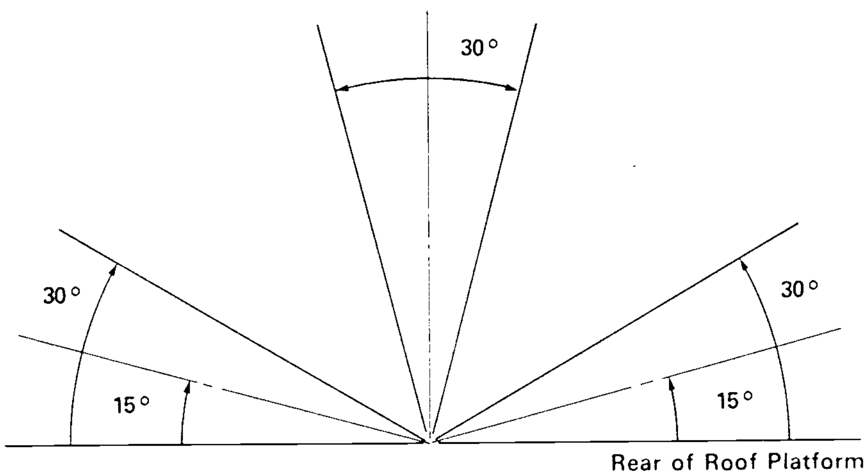

Figure 6-3 Width of Field of Cameras

6.2.1.2. Filming Process

The filming process consisted of selecting and video taping unsignalized T-intersections that provided the appropriate combination of sight distance and traffic volume. The vehicle, with the camcorders mounted for video taping the intersection, stopped at the stop sign on a minor road in a position to prepare for a left turn onto the major road. The recording session at each intersection took a longer time than a vehicle would have normally been required to stop to make a left turn, and as a result the vehicle was in a vulnerable position. The vehicle was equipped with a warning flasher, but still there were problems with vehicles queuing up behind the stopped vehicle. There was no control over traffic volumes although about half of the intersections were filmed during the morning rush hour. The length of filming done at each intersection was approximately proportional to traffic volume(30-90 seconds). As mentioned previously, the width of visual field was limited by the camera lenses. The final filming was confined to cloudy, dry weather. The sun caused distortion due to glare and shadows. The camcorders were not protected from the rain, and wet roads also caused too much glare. After each intersection was filmed, the lenses were covered and the camcorders were run for 30 to 50 seconds to provide a separation on the tape between the intersections.

6.2.2. Playback Equipment

The three video tapes were played back to the participants using three VHS video-recorders (JVC model HR-D142U), each connected to one of three rear screen projection systems with 114 cm, diagonal screens (Mitsubishi model

VS-459-R). The participants viewed the screens from a fixed based Aetna Drivotrainer console that was positioned 142 cm. from the center of the middle screen. The two side screens were positioned at 75 degree angles from the straight ahead position which corresponded to those of the camcorders that taped the intersection pictures, and covered 180 degree field of view.

The gaps between the three screens require the subject viewing the display to fill in the images mentally which reduces the synchronization problem. Figure 6-4 shows the laboratory layout of the screens, drivotrainer, VHS players and data acquisition equipment.

6.2.2.1. Video Tapes

There was a lack of control of synchronization due to the discrepancies in the camcorders and the VHS players. The video tapes were very sensitive to ambient room temperature. When either the VHS players or the room got too warm, the tapes would stretch, and the synchronization would be lost. There was significant variation between and within the tapes daily and also over the six week period of testing with subjects. No equipment or budget existed for editing the VHS video tapes. The start/stop speeds of the VHS players were variable since they were designed for domestic rather than scientific use.

6.2.3. Head Angle Measurement Device

Subjects wore a hard hat device that measured dynamic head range of movement. The hard hat device was equipped with a potentiometer that was

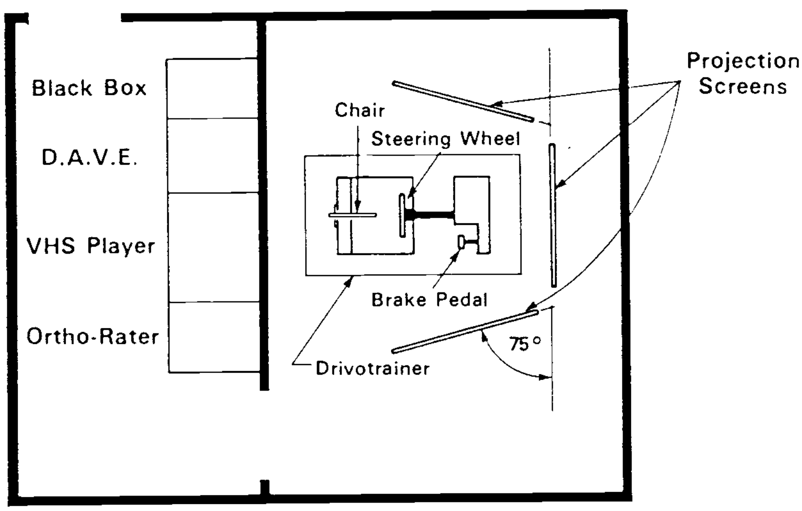

Figure 6-4 Laboratory Layout

calibrated to measure head angles at a resolution of one degree and was sampled every 0.01 seconds. The hard hat was connected to a horizontal bar that was a piece of teflon rod that permitted the hat to slide in and out freely. The horizontal bar was hinged to an adjustable vertical post that was fixed to the back of a seat but was free to rotate forward and backward so the subject could bend forward. The only major problem with the head measurement mechanism was the weight of the hard hat assembly for some of the older female subjects. The hard hat mechanism did not restrict the subjects' head movement. Figure 6-5 shows the drivotrainer and helmet assembly. Figure 6-6 shows the head angle measurement device. The subjects' visual field was tested using the Bausch & Lomb Orthorater. The static range of movement of the subjects' head and neck was measured using a standard international SFTR pocket goniometer. The standard international SFTR pocket goniometer is a device used by physical therapists and physiatrists for measuring joint angles.

6.2.4. Data Acquisition Equipment

The data acquisition system consisted of two major devices a 'black box', and D.A.V.E., which is an acronym for Driver Analysis Vehicle Equipment. Figure 6-7 shows the data acquisition equipment components. D.A.V.E. included the DC/DC converter, data recorder, control box, power supplies and car battery.

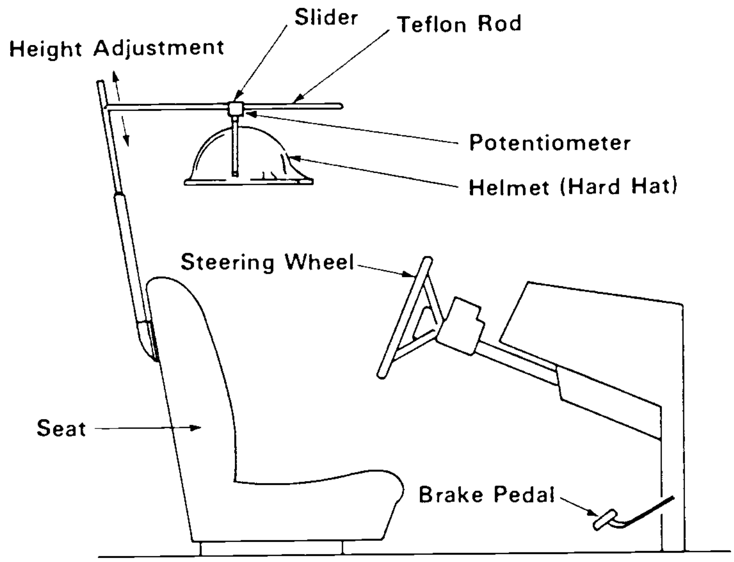

Figure 6-5 Drivotrainer and Helmet Assembly

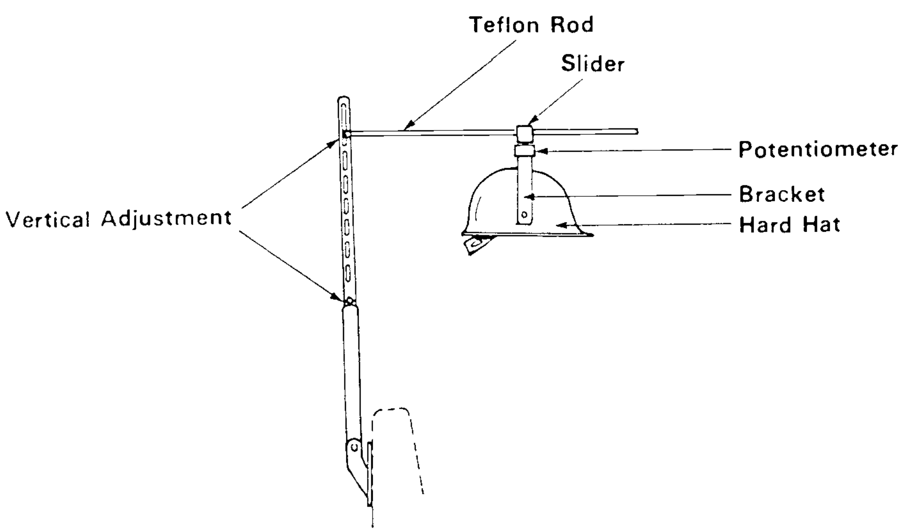

Figure 6-6 Head Angle Measurement Device

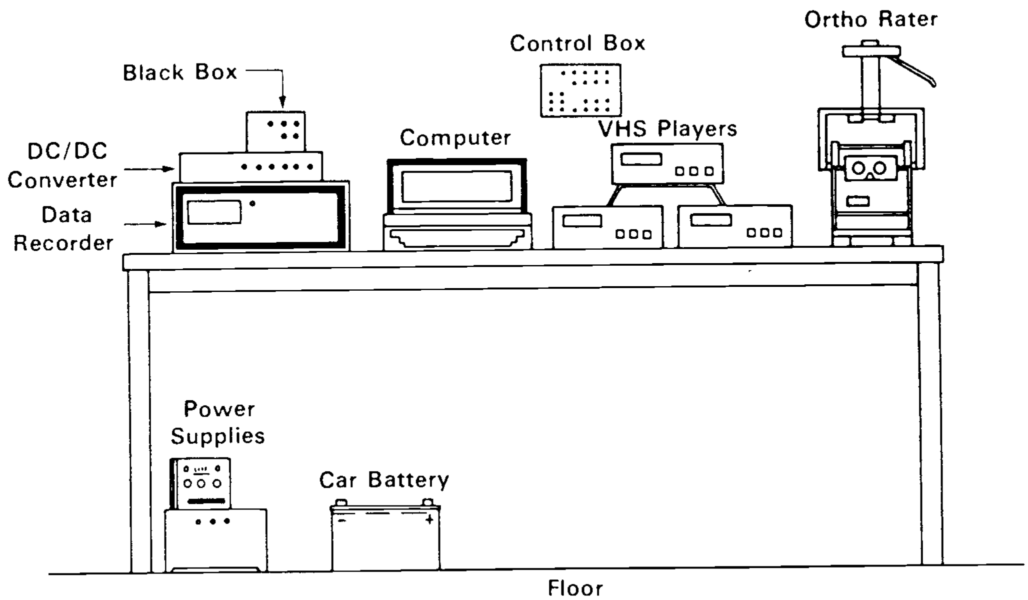

Figure 6-7 Data Acquisition Equipment Components

6.2.4.1. Black Box

The black box was a small box that was used to collect the head angle measurements, increment the intersection counter, and measure decision time. The voltage from the potentiometer on the helmet was fed to the black box for pre-processing prior to passing on to D.A.V.E. The video tape on the center screen had an audible beep that was used to signal to the subject and the data acquisition system that decision timing was beginning. The beep not only started the timing interval but it also incremented the intersection counter. The intersection timer voltage increased from 0 volts before the beep to plus 0.5 volts during the timing interval until the brake pedal was released. The beep consistently started the timing interval, but it did not always increment the counter, therefore an event switch was used to enter the intersection number each time manually. Subjects were asked to depress the brake pedal before each intersection was shown. This in effect closed the switch between the minus 12 volt power supply to the black box. When the subject decided to make a left turn, he released the brake which opened the switch and caused the timing voltage to drop back to zero.

There were many problems encountered with the data acquisition system during testing with subjects. Some of these included, early calibration problems with the potentiometer, and the timer voltage would not always return to zero at the end of an intersection. Other problems were a result of the design of the black box. All intersections had to be given sequentially and without repetition. Since there were no provisions for backing up and repeating an intersection when a subject forgot to keep the brake depressed until the beep sounded, those data were lost. As a result many subjects have incomplete records.

6.2.4.2. D.A.V.E.(Driver Analysis Vehicle Equipment)

The D.A.V.E. system functioned as a data recorder. D.A.V.E. is a data acquisition system that was designed to operate in a vehicle for use on field trials. Initially D.A.V.E. was plugged into a wall outlet, but after repeated break downs due to inconsistencies in the building power and D.A.V.E.'s sensitivity to high frequency noise, power was supplied from a 12 volt car battery. The battery power was then fed through a D.C. to D.C. converter, since three different output voltages were required. Other inputs to D.A.V.E., apart from those from the black box, included a portable computer for entering diagnostic and header information, the event switch to mark the intersections manually, and the control box. The black box inputs to D.A.V.E. consisted of the head angle voltage, the timer interval voltage, and the intersection counter voltage. D.A.V.E. functioned as an analog to digital converter and converted the input voltages to digital format output (binary) which was then recorded on preformatted data cartridge tapes. Figure 6-8 shows the block diagram of the data acquisition system.

After data collection, the data tapes were taken to a tape reader which was a mini computer. The data tapes were read and stored on computer disks. A small program was written to pre-process the data. This eliminated storing unnecessary data from the intervals between intersections, and permitted simple statistical analysis to be performed. The preprocessing analysis is discussed in

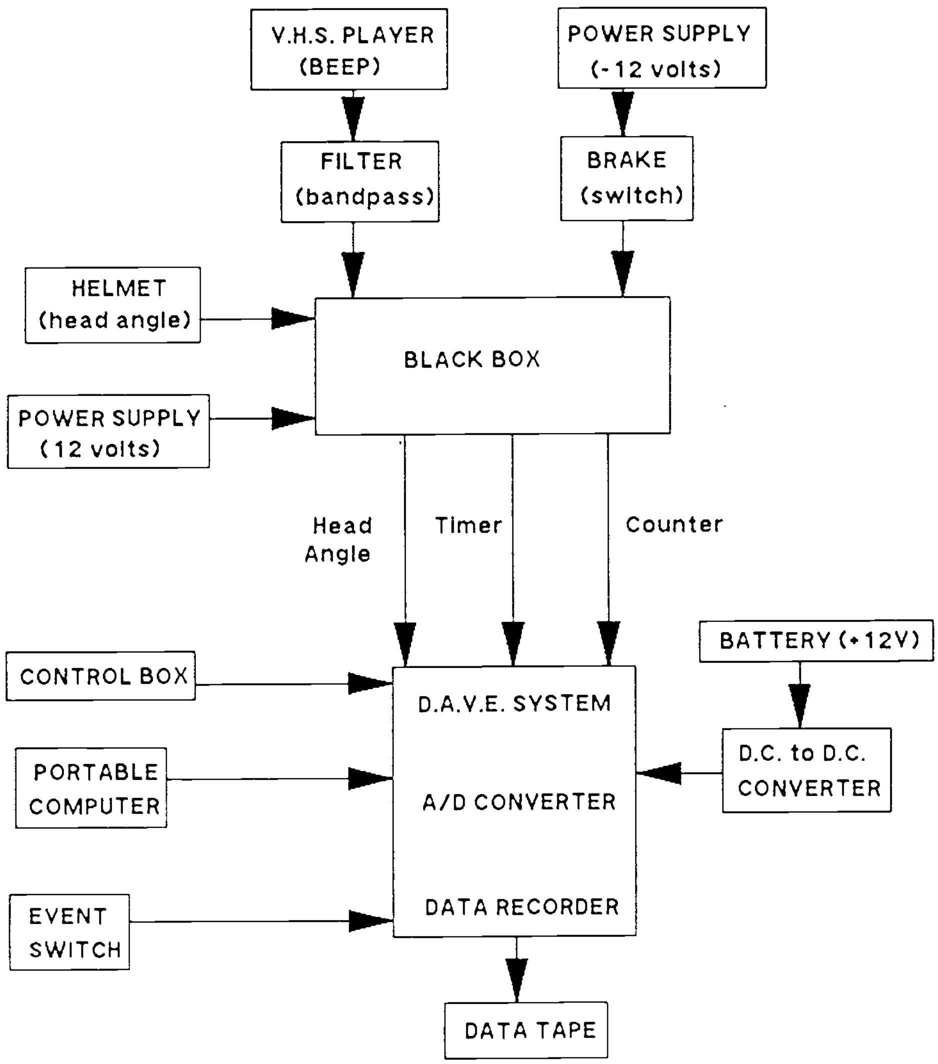

Figure 6-8 Block Diagram of the Data Acquisition System

section 6.4.1 at the end of the data collection section. Tapes were made of the preprocessed data. These were transferred to the Computer Center at the National Institutes of Health, for computer processing of the data and statistical analysis.

6.3 EXPERIMENTAL PROCEDURE

The participants were pre-screened over the telephone to determine whether or not they met the criteria for participation, as well as to explain the general nature of the research and their participation.

At the beginning of the experiment the general purpose of the research was outlined in the instruction sheets, and each participant was asked to sign an informed consent form. Appendix A includes copies of the instruction sheet, informed consent forms and data forms. After the introduction, the following information was collected as part of the experimental design: participant's age, sex, description of impairment, whether they wear glasses for driving, head and neck static range of movement, visual field, and medications and reasons for use.

The questioning was followed by a neck and head range of movement test, and a visual field test. The initial procedures took approximately 30 minutes to complete. Afterwards, the participants were allowed a short break. The participants were then introduced to the simulator, and permitted a few minutes to become accustomed to the equipment. The participants were also given instructions for the test and permitted to ask any questions concerning the test procedures or equipment.

The task for the subjects was to watch video presentations of the intersections on the three screens. Prior to presentation of each intersection, the intersection was announced at which point the subject depressed the brake pedal. There were a few seconds of run in of the scene then the audible beep was heard which signalled to the subject that decision timing was beginning. The subjects would watch the scene and when they felt it was safe, then they would indicate they were ready to make a left turn by releasing the brake pedal. The release of the brake pedal would signal the end of the intersections presentation and there would be a pause of one to two minutes prior to the presentation of the next intersection. The video films covered half of the visual range therefore the test subjects had to mentally fill in the visual image between the screens. The test subjects had to judge when there were acceptable gaps in both the left and right traffic streams. In general, the traffic volumes were low in one or both traffic streams.

Two trial intersections, which were often repeated for practice, were presented then eighteen test intersections were presented sequentially and without repetition to each participant. For some participants subjective responses to each intersection were made during a short period after the presentation of each intersection. Response information was recorded on a data sheet and a data acquisition system for analysis at a later time. The data acquisition system recorded the response time, and the degree of head movement. After the presentation of the final intersection, each participant was debriefed and paid.

6.4 DATA COLLECTION

The following data were collected as part of the experimental design: participant's age, sex, description of impairment, whether they wear glasses for driving, head and neck static range of movement, visual field, and medications and reasons for use. For each participant at each intersection the following information was collected: number and degree of head movements, and response time.

6.4.1. Preprocessing Analysis

The data were analyzed, and the following calculations were made for each subject and at each intersection: decision time, number of head turns, decision time divided by the total number of head turns, maximum head angle on the left and right side, range of angle of movement, mean left and right angle, standard deviation of left and right angle, and number of right and left head turns. Calculations were made over all intersections for each subject and include the following; number of good intersections (n), sum of decision time over good intersections (n), average decision time, and the sum total number of head turns over good intersections(n). The zero position for head angle is straight ahead over the front of the vehicle. At skewed intersections the geometrics of the intersection are reflected in the discrepancy between the maximum left and right head angle.

CHAPTER 7

EXPERIMENTAL RESULTS

7.0 INTRODUCTION

This chapter includes a summary of the statistical analysis that was performed on the experimental data. Statistical data are presented in Appendix B. Appendix B includes analysis of variance (ANOVA) tables and a summary of means and standard deviations. Regression equations for relationships of average decision time versus age, and range of motion versus head turn angle are also included in Appendix B.

The experimental results were split into two segments; totals across all subjects and all intersections(totals) and individual intersection summaries across all subjects. The statistical results of the intersections summaries were similar to the statistical results for the totals of all subjects at all intersections. More error was introduced into the totals since the decision time was averaged over all the "correct" intersections for each subject, and each intersection had a different time interval depending on traffic volume and geometrics. Many of the older subjects did not follow instructions correctly and misjudged several intersections. As a result the data could not be used for those intersections, and the intersections were judged to be "incorrect". Therefore, the totals results only represent the "correct" intersections driven by each subject. This introduces bias since there were intersections that were more consistently "incorrect" than others. Individual intersection statistics were examined in order to eliminate errors resulting from different intersection time intervals, sight distance, volumes and geometrics. Summary statistics are shown for four intersections:

(i) poor sight distance and low volume,

(ii) mixed sight distance and low volume,

(iii) good sight distance and high volume,

(iv) good sight distance and low volume.

Data were gathered for all 72 subjects at all 18 intersections through four channels every 0.01 seconds. The large amount of data and the subsequent statistical analysis precluded indepth analysis of all eighteen intersections. Four intersections were selected, for the indepth analysis because they had complete data sets and were representative of sight distance and traffic volume combinations. Intersections with high volumes presented the most difficulty for test subjects. Most of these had incomplete data sets and were not selected for indepth analysis. Some of the intersections with very difficult geometrics also had poor video representation and therefore incomplete data sets.

Relationships were considered significant if the probability of a type I error was 25% or less. The type I error is often referred to as a level of significance test. Type I error is the error of rejecting a true hypothesis, whereas a type II error is the error of not rejecting a hypothesis when it is false. This research is fundamental and unique, and therefore it is more important to not reject a true hypothesis than to mistakingly accept a false hypothesis. For example, the costs of type II errors out weigh the costs of a low level of significance. If the level of significance was set too low for example at 0.05, then it is likely that significant variables would be overlooked and type II errors would be made. The most significant results are explained and are related to the literature and results from other sources.

7.1 EXPERIMENTAL RESULTS

7.1.1. Totals Summary

The totals summary statistics give a general impression of the relationships that are significant. Subject's age was coded into two groups, subjects age 30-50 years were in group 1, and subjects age 60-80 were in group 2. The totals summary statistics depict the relationships of decision time versus age code; sex; impairment; glasses; medication; functional level; age and sex; age and glasses; age and impairment; age, sex and medication; and age, sex and impairment. Figure 7-1 is a histogram depicting the statistical significance levels of the relationships.

Standard statistical terminology is used in summary tables. P-value is the smallest level of significance for a particular hypothesis and corresponds to a type I error. For example, a P-value of 0.25 or greater would indicate that the variable is not significant and that there is very little possibility of making a type II error.

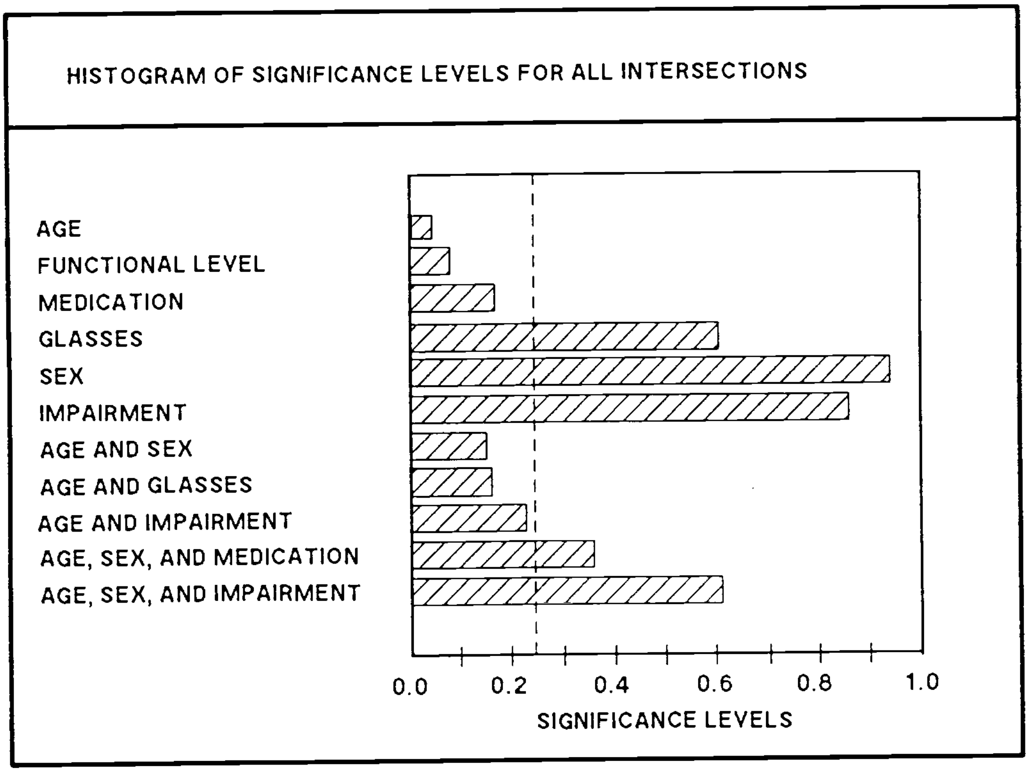

Figure 7-1 Histogram of Significance Levels for all Intersections

7.1.1.1. Average Decision Time versus Age for all Intersections

The ANOVA shows that the relationship of average decision time versus age is significant at the 4 percent level. The means and standard deviations of average decision time versus age are shown in Figure 7-2, and the values are shown in Table 7-1. The values indicate that older drivers take two seconds longer to decided to turn at T-intersections than younger drivers. The standard deviations for the older drivers are 0.43 seconds larger than those of younger drivers which indicates greater inconsistency in this segment of the population. Both the longer decision time and inconsistency of the older driver support the hypothesis that age influences response time. These hypotheses are suggested in the literature and a review of highway accident data (Brainin, Naughton, Breedlove, 1977; Yanik, 1986; and U.S. DOT Highway Statistics, 1980).

7.1.1.2 Average Decision Time versus Functional Level for all Intersections

The ANOVA indicates that the relationship of average decision time versus functional level is significant at the 8 percent level. The definition of functional level is a combination of age and impairment level:

(a) functional level 1 = 30-50 years and no impairment,

(b) functional level 2 = 30-50 years and impairment,

(c) functional level 3 = 60-80 years and no impairment,

(d) functional level 4 = 60-80 years and impairment.

Impairment is defined by a combined static range of movement of the head and visual field of less that 285 degrees, whereas no impairment ranges from

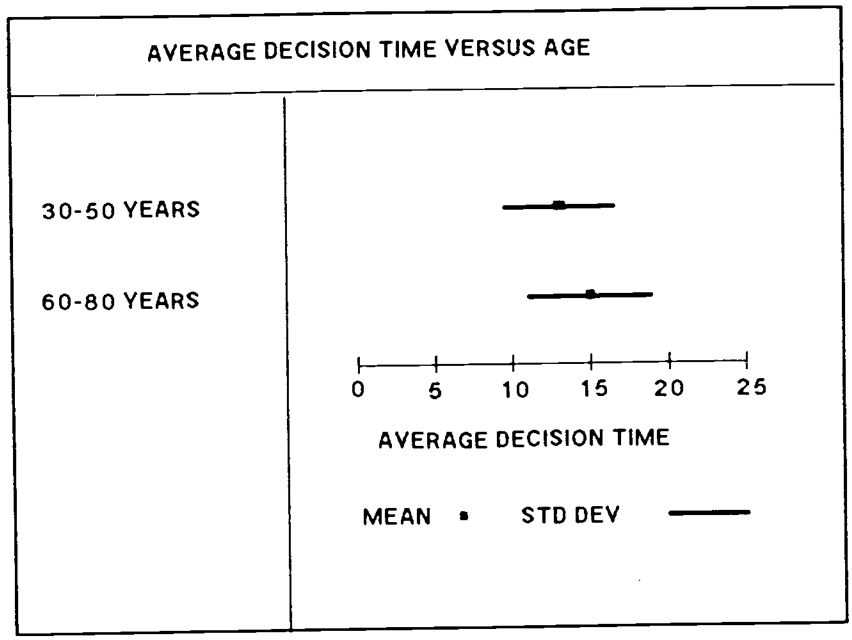

Figure 7-2 Average Decision Time Versus Age for all Intersections

TABLE 7-1 AVERAGE DECISION TIME (sec) VERSUS AGE (p=0.04, C.V.=29.88)		
AGE	MEAN	STD.DEV.
30-50	11.3	3.45
60-80	13.3	3.88

285 to 360 degrees. There is no definitive definition of impairment level in the literature, therefore for this study, the choice of 284 degrees was arbitrarily based on the functional requirements for driving. The means and standard deviations of average decision time versus functional level are shown in Figure 7-3, and the values are shown in Table 7-2.

There is an increase in the mean decision time with functional level, however the increase in decision time between the younger and older age groups is approximately two seconds. The 1.25 second increase in standard deviation with impairment can be explained by the wide diversity of severity of impairment and the less consistent driving behavior in this subject group. It is interesting to note that average decision time versus impairment is not significant ($p=0.85$). The implication of these results is that the younger impaired drivers are able to compensate in their driving behavior for their impairment, but the older drivers either impaired or unimpaired, are unable to make the necessary compensations. Average decision time versus age and impairment is significant at the 22 percent level. The means and standard deviations of average decision time versus age and impairment are shown in Figure 7-4 and the values are shown in Table 7-3. The ANOVA also show that there were no interactions between age and impairment ($p=0.60$). Likewise, there were no interactions between age, sex or impairment.

Table 7-3 is similar to Table 7-2, which is one factor, functional level, at four levels. Table 7-3 is two factors, age and impairment, at two levels each. The trends in the two tables are the same but the specific means and standard

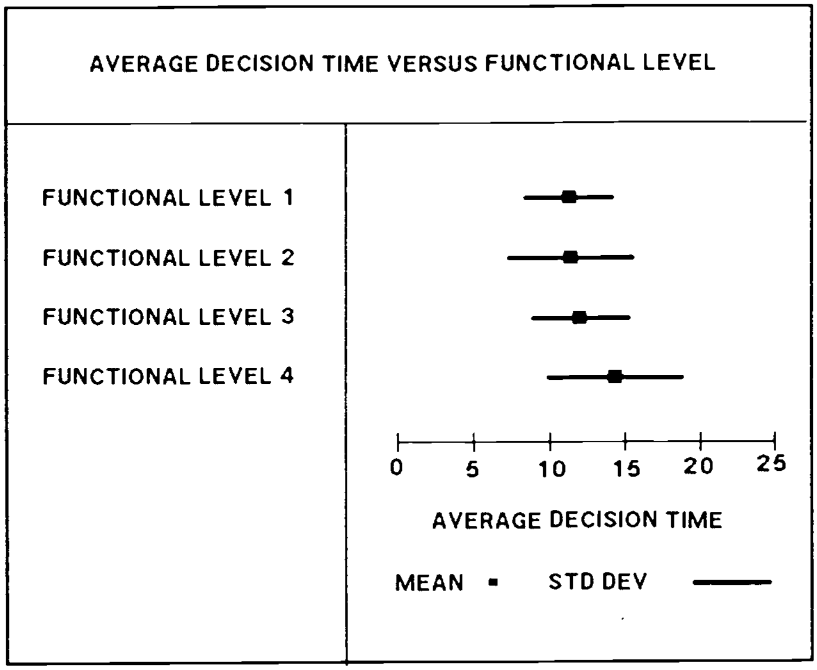

Figure 7-3 Average Decision Time Versus Functional Level for all Intersections

TABLE 7-2 AVERAGE DECISION TIME (sec) VERSUS FUNCTIONAL LEVEL(1-4) (p=0.08, C.V.=29.66)		
FUNCTIONAL LEVEL	MEAN	STD.DEV.
1 30-50, UNIMPAIRED	11.3	2.87
2 30-50, IMPAIRED	11.4	4.09
3 60-80, UNIMPAIRED	12.1	3.08
4 60-80, IMPAIRED	14.4	4.35

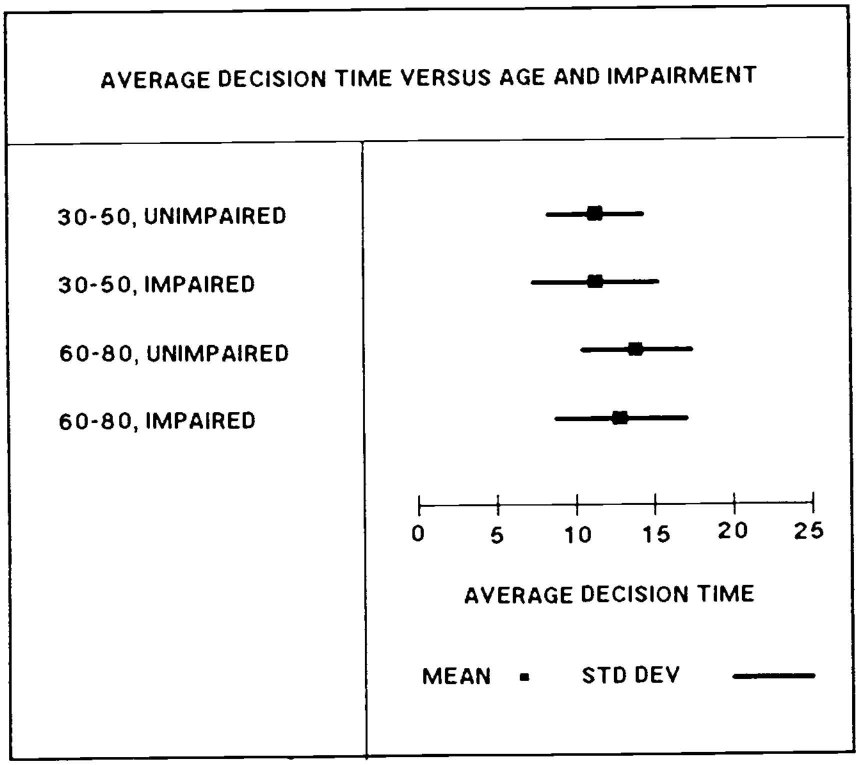

Figure 7-4 Average Decision Time Versus Age and Impairment for all Intersections

TABLE 7-3 AVERAGE DECISION TIME (sec) VERSUS AGE AND IMPAIRMENT (p=0.22, C.V.=30.07)

AGE AND IMPAIRMENT	MEAN	STD.DEV.
30-50, UNIMPAIRED	11.3	2.97
30-50, IMPAIRED	11.3	3.95
60-80, UNIMPAIRED	13.9	3.41
60-80, IMPAIRED	12.9	4.17

deviations are different. Both tables indicate increasing mean decision time with age and increasing dispersion of average decision time.

7.1.1.3. Average Decision Time versus Subjects' Sex for all Intersections

The ANOVA shows that there was no significant difference in decision time due to the sex of the subject, however the relationship of average decision time versus age and sex was significant at the 15 percent level. Also, there was no significant interaction between age and sex. The means and standard deviations of the relationship of average decision time versus age and sex are shown in Figure 7-5 and the values are shown in Table 7-4.

In this study, younger males have a 0.4 second longer decision time than younger females, but older males have a 1.6 second shorter decision time than older females. The standard deviations increase with age, and young males show the most consistent behavior ($s=2.95$), while older males are the most inconsistent ($s=3.97$). The longer decision time taken by the older females of 14.1 seconds is supported in the literature which suggests that the current generation of older female drivers lack the experience of their male counterparts, but the younger generation of female and male drivers are more equally matched in terms of driving experience (Grubb, 1986; Planck and Fowler, 1971). There is no significant interaction between age and sex.

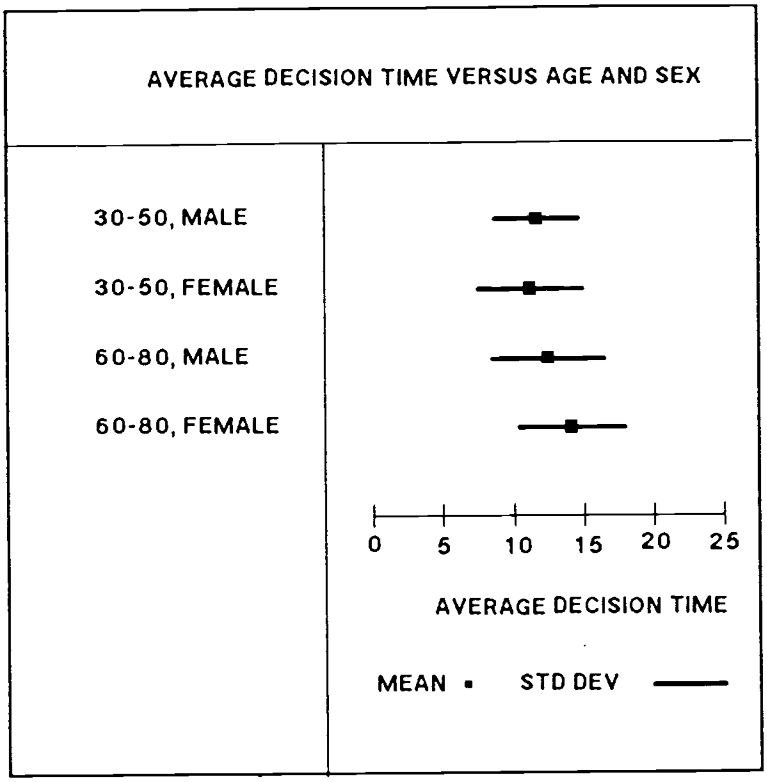

Figure 7-5 Average Decision Time Versus Age and Sex for all Intersections

TABLE 7-4 AVERAGE DECISION TIME (sec) VERSUS AGE AND SEX (p=0.15, C.V.=30.04)

AGE AND SEX	MEAN	STD.DEV.
30-50, MALE	11.6	2.95
30-50, FEMALE	11.2	3.67
60-80, MALE	12.5	3.97
60-80, FEMALE	14.1	3.73

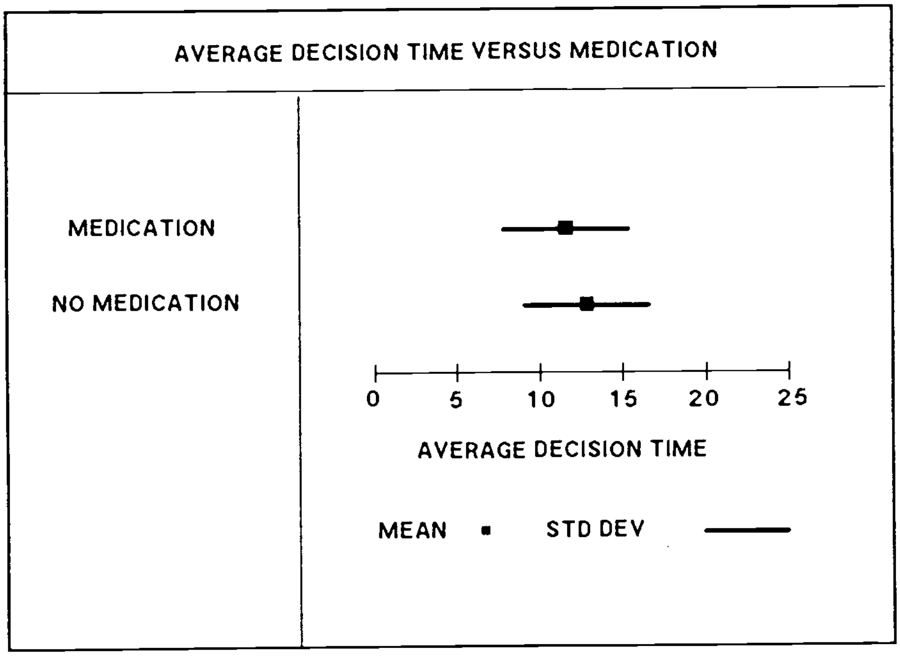

Figure 7-6 Average Decision Time Versus Medication for all Intersections

TABLE 7-5 AVERAGE DECISION TIME (sec) VERSUS MEDICATION (p=0.16, C.V.=30.40)

MEDICATION	MEAN	STD.DEV.
MEDICATION	11.5	3.71
NO MEDICATION	12.8	3.74

7.1.1.4. Average Decision Time versus Medication

The ANOVA shows that the relationship of average decision time versus medication is significant at the 16 percent level. The means and standard deviations of average decision time versus medication are shown in Figure 7-6,and the values are shown in Table 7-5. Table 7-5 shows that subjects on medication took 1.3 seconds less time to make a decision than those not on any medications. The most common reason for medication was arthritis or high blood pressure. Table 7-6 indicates that very few of the prescribed medications have any effect on reaction time. These results do not suggest that the influence of medication should not be studied, but rather it merely indicates that in the subject sample used in this study medication did not have any detrimental effect on performance. The relationship of average decision time versus age, sex and medication is significant at the 35 percent level, and there were no significant interactions between age, sex, or medication.

7.1.1.5. Average Decision Time versus Glasses

The ANOVA shows that the relationship of average decision time versus age and glasses is significant at the 16 percent level. The means and standard deviations of average decision time versus age and glasses are shown in Figure 7-7, and the values are shown in Table 7-7.

The summary of means and standard deviation show that the younger drivers with glasses have a 0.8 second shorter decision time than younger drivers

TABLE 7-6

LIST OF MEDICATIONS TAKEN BY SUBJECTS

MEDICATION	REASON	SIDE EFFECTS THAT AFFECT REACTION TIME
Clinoril(2)*	Arthritis	none
Disalcid(2)	Arthritis	none
Feldene(2)	Arthritis	none
Methotrexate(2)	Arthritis	none
Napersin(4)	Arthritis	none
Placquenil	Arthritis	none
Prednozone(4)	Arthritis	none
Aldazide	Hypertension	none
Blockadrin	Beta blocker	may affect reactions
Coumadin(2)	Phlebitis	none
Diazide	Diuretic	none
Isordil	Hypertension	none
Lasix	Diuretic	none
Loupressor	Beta blocker	may affect reactions
Maxide	Diuretic	none
Reserpin(2)	Hypertension	none
Tenormin(2)	Beta blocker	may affect reactions
Vasotec	Hypertension	none
Asidrex(2)	Diuretic	none
Synthroid(6)	Hypothyroid	speed up reactions
Entext	Allergy	may affect reactions
Seldane	Allergy	none
Ornaid	Allergy	none
Isoprel	Asthma	none
Dimalor	Diabetes	none
Insulin(2)	Diabetes	none
Parnate	Depression	may affect reactions
Dilantin	Seizures	may affect reactions
Darvocet	Pain	may affect reactions
Motrin	Pain	may affect reactions
Percaset	Pain	may affect reactions

*( ) Indicates the number of subjects on the same medication

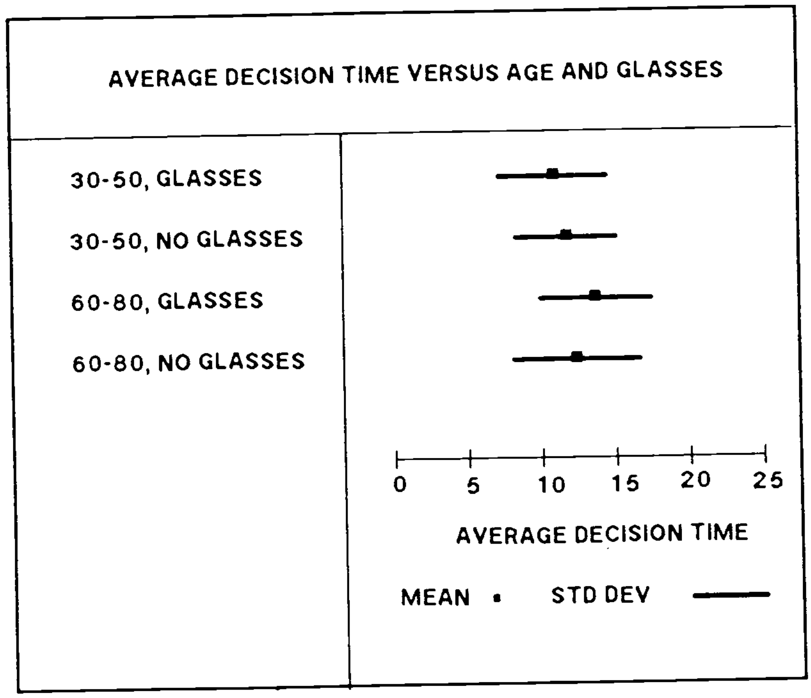

Figure 7-7 Average Decision Time Versus Age and Glasses for all Intersections

TABLE 7-7 AVERAGE DECISION TIME (sec) VERSUS AGE AND GLASSES (p=0.16, C.V.=30.09)

AGE AND GLASSES	MEAN	STD.DEV.
30-50, GLASSES	10.9	3.63
30-50, NO GLASSES	11.7	3.35
60-80, GLASSES	13.7	3.72
60-80, NO GLASSES	12.4	4.24

without glasses. This relationship is reversed for the older drivers, where older drivers without glasses have a 1.3 second shorter decision time than older drivers with glasses. Of the older drivers, 66 percent wore glasses for driving compared to approximately 50 percent of the younger drivers. It was anticipated that there would be a significant relationship for drivers who wore glasses since they need to turn their head farther to gather information. It can therefore be concluded that age effects are stronger than the effect of glasses. There were no significant interactions between age and glasses.

7.1.2. Intersection Summary

Four intersections were analyzed in depth, since these intersections were representative of difficulty, sight distance and traffic volume. Many of the other intersections had incomplete data sets and therefore were not selected for the in-depth analysis. The first intersection of study has poor sight distance on the left and low traffic volume. The second intersection of study has poor sight distance and no traffic on the left, and has good sight distance and low volume on the right. The third intersection of study has good sight distance in both directions and high traffic volume. The fourth intersection of study has good sight distance in both directions and low traffic volume.

The first, second and fourth intersections were examined to determine the relationships of decision time versus age; sex; impairment code; glasses; medication; functional level; age and sex; age and glasses; age and impairment; age, sex and medication; and age, sex, and impairment. The third intersection had high traffic volume and most subjects across all ages did not make a turn.

This is reflected in the low standard deviations. The relationships of decision time versus age and sex; age and glasses; age and impairment; age, sex and medication; and age, sex, and impairment were not studied for this intersection.

7.1.2.1 Intersection with Poor Sight Distance and Low Volume

The only relationship that is not significant for this intersection is average decision time versus medication. All other relationships ranged in significance from 0 to 13 percent. Figure 7-8 is a histogram depicting the significance levels of the relationships.

Figure 7-9 shows the means and standard deviations for average decision time versus functional level, and the values are shown in Table 7-8. Average decision time increases with functional level for this intersection. Increasing functional level is increasing age and impairment. However, the standard deviation for functional level 2 (30-50 years and impaired) is 0.30 seconds smaller than functional level 1 (30-50 years and unimpaired). All other standard deviations increase with functional level. This is consistent with the totals results across all intersections and all subjects.

Figure 7-10 shows the means and standard deviations for average decision time versus age, and the values are shown in Table 7-9. Age effects are clearly evident as shown in the 1.6 second increase in the means and the 1.19 increase in standard deviation. Younger drivers may be able to decide and react more quickly at this intersection where the sight distance is poor, but approach volumes are low, or they may be less cautious.

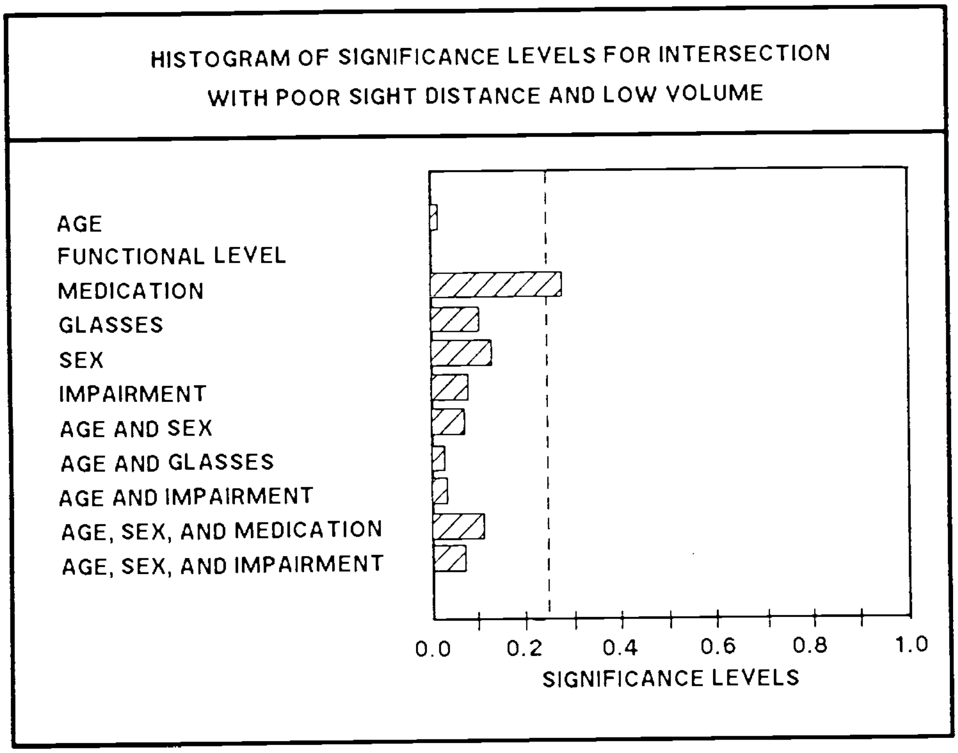

Figure 7-8 Histogram of Significance Levels for Intersection with Poor Sight Distance and Low Volume

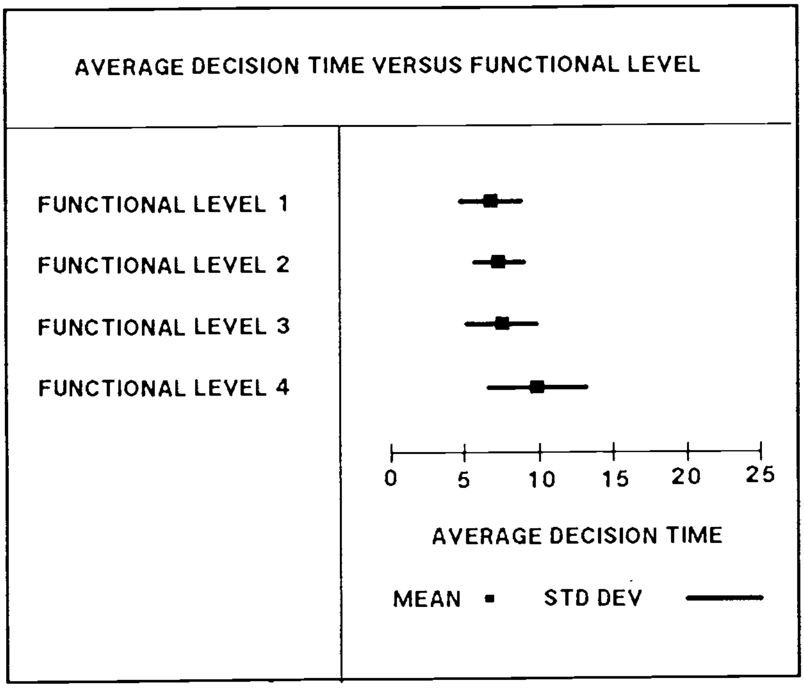

Figure 7-9 Average Decision Time Versus Functional Level for an Intersection with Poor Sight Distance and Low Volume

TABLE 7-8 AVERAGE DECISION TIME (sec) VERSUS FUNCTIONAL LEVEL(1-4):at an intersection with poor sight distance and low volume (p=0.00, C.V.=30.43)

FUNCTIONAL LEVEL	MEAN	STD.DEV.
1 30-50, UNIMPAIRED	6.8	2.00
2 30-50, IMPAIRED	7.4	1.70
3 60-80, UNIMPAIRED	7.5	2.27
4 60-80, IMPAIRED	9.9	3.30

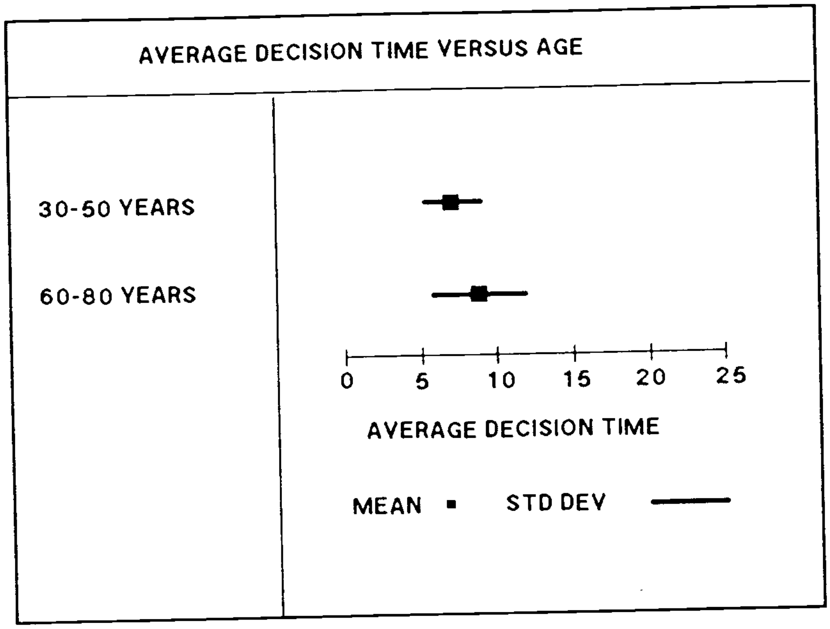

Figure 7-10 Average Decision Time Versus Age for an Intersection with Poor Sight Distance and Low Volume

TABLE 7-9 AVERAGE DECISION TIME (sec) VERSUS AGE:at an intersection with poor sight distance and low volume (p=0.02, C.V.=31.96)

AGE	MEAN	STD.DEV.
30-50	7.1	1.85
60-80	8.7	3.04

Figure 7-11, shows the means and standard deviations for average decision time versus age and glasses, and the values are shown in Table 7-10. There is interaction between age and glasses, but it is the age effects which dominate the increase in means and standard deviations of the older age group.

Figure 7-12 shows the means and standard deviations for average decision time versus age, and impairment, and the values are shown in Table 7-11. There are increases in the means of average decision time with age and impairment level and also a significant increase in the standard deviation with age. The 0.5 second difference in means of the (30-50) age group versus the 1.70 second difference in the (60-80) age group shows that the younger impaired drivers are better able to compensate for their impairments.

Figure 7-13 shows the means and standard deviations for average decision time versus age, sex, and impairment, and the values are shown in Table 7-12. The standard deviations show an increase with age, and there is the largest inconsistency among 60-80 year old males with impairments. The 30-50 year old females have shorter mean average decision times than their male counterparts. Except for the 30-50 year old male drivers, there is an increase in mean average decision time with impairment level.

Figure 7-14 shows the means and standard deviations for average decision time versus age and sex, and the values are shown in Table 7-13. In contrast to the totals results for the relationship of average decision time versus age and sex, the females show a 0.3-0.4 second shorter decision time and also more consistent behavior as reflected in the smaller standard deviations.

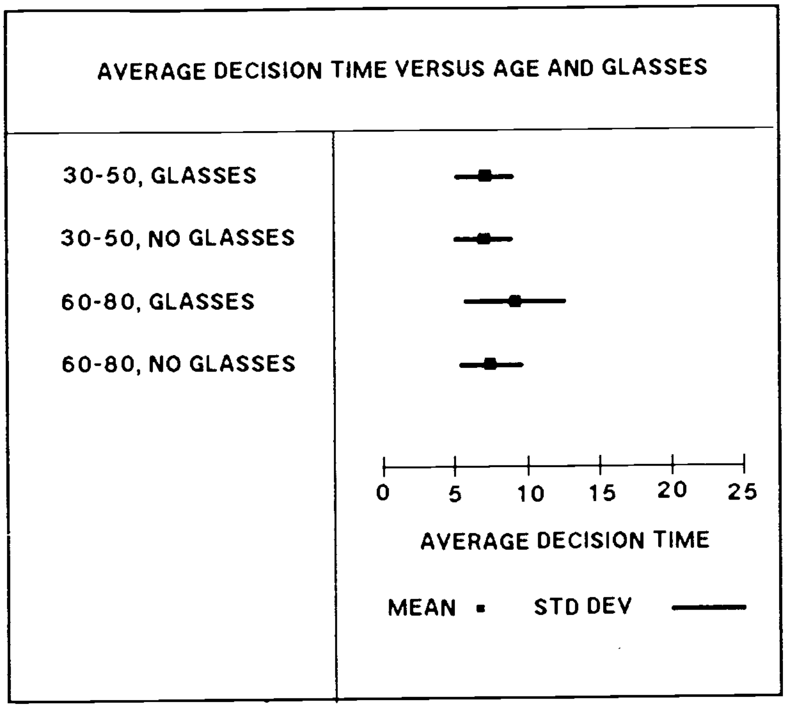

Figure 7-11 Average Decision Time Versus Age and Glasses for an Intersection with Poor Sight Distance and Low Volume

TABLE 7-10 AVERAGE DECISION TIME (sec) VERSUS AGE AND GLASSES:at an intersection with poor sight distance and low volume (p=0.03, C.V.=31.64)

AGE AND GLASSES	MEAN	STD.DEV.
30-50, GLASSES	7.1	1.89
30-50, NO GLASSES	7.0	1.87
60-80, GLASSES	9.2	3.33
60-80, NO GLASSES	7.5	2.06

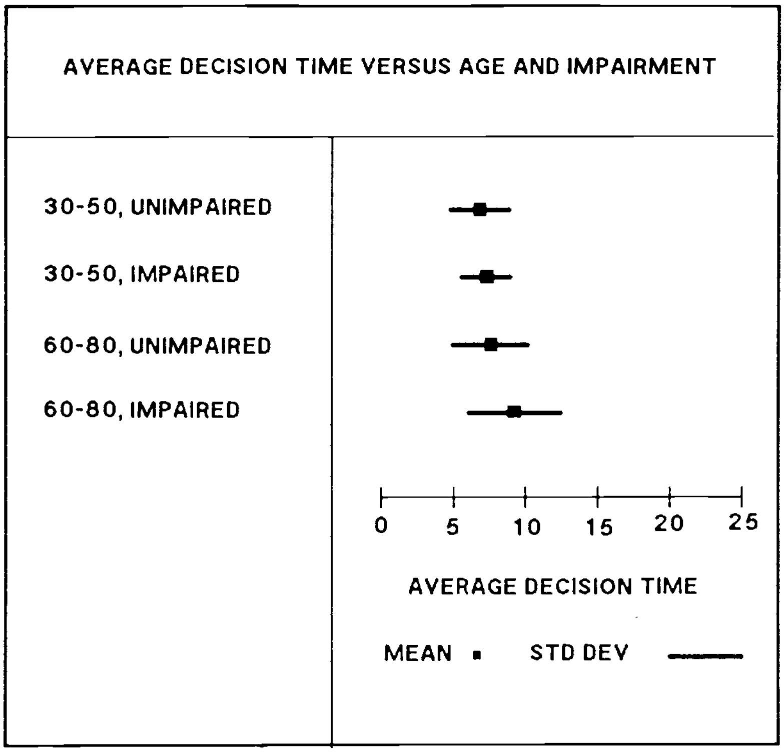

Figure 7-12 Average Decision Time Versus Age and Impairment for an Intersection with Poor Sight Distance and Low Volume

TABLE 7-11 AVERAGE DECISION TIME (sec) VERSUS AGE AND IMPAIRMENT:at an intersection with poor sight distance and low volume (p=0.03, C.V.=31.63)

AGE AND IMPAIRMENT	MEAN	STD.DEV.
30-50, UNIMPAIRED	6.8	2.05
30-50, IMPAIRED	7.3	1.68
60-80, UNIMPAIRED	7.6	2.64
60-80, IMPAIRED	9.3	3.16

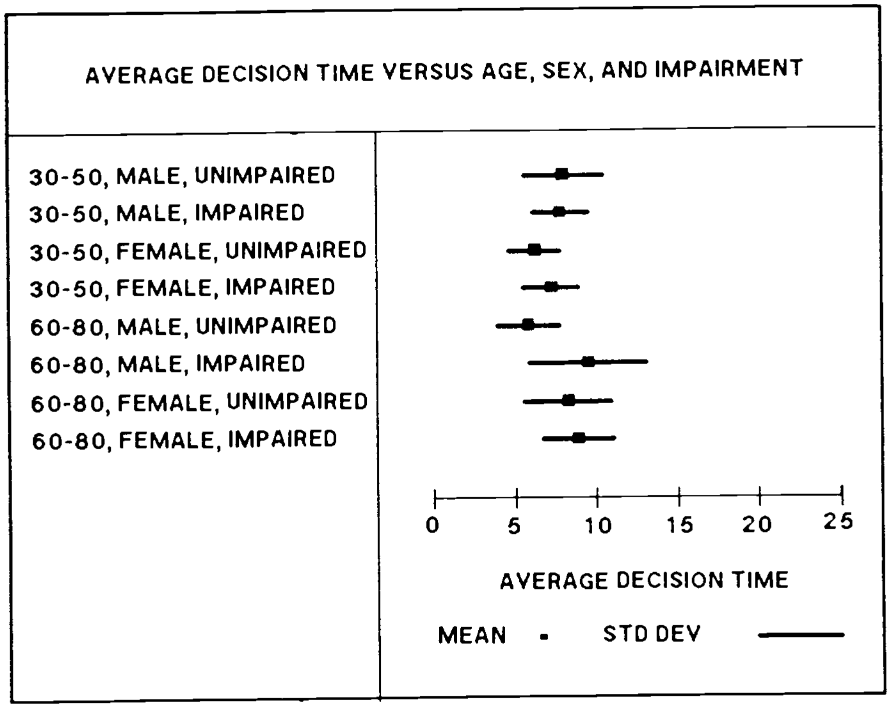

Figure 7-13 Average Decision Time Versus Age, Sex and Impairment for an Intersection with Poor Sight Distance and Low Volume

TABLE 7-12 AVERAGE DECISION TIME (sec) VERSUS AGE, SEX, AND IMPAIRMENT: at an intersection with poor sight distance and low volume (p=0.07, C.V.=31.49)

AGE, SEX, AND IMPAIRMENT	MEAN	STD.DEV.
30-50, MALE, UNIMPAIRED	8.0	2.43
30-50, MALE, IMPAIRED	7.8	1.69
30-50, FEMALE, UNIMPAIRED	6.2	1.48
30-50, FEMALE, IMPAIRED	7.2	1.73
60-80, MALE, UNIMPAIRED	5.8	1.83
60-80, MALE, IMPAIRED	9.5	3.60
60-80, FEMALE, UNIMPAIRED	8.3	2.66
60-80, FEMALE, IMPAIRED	8.9	2.15

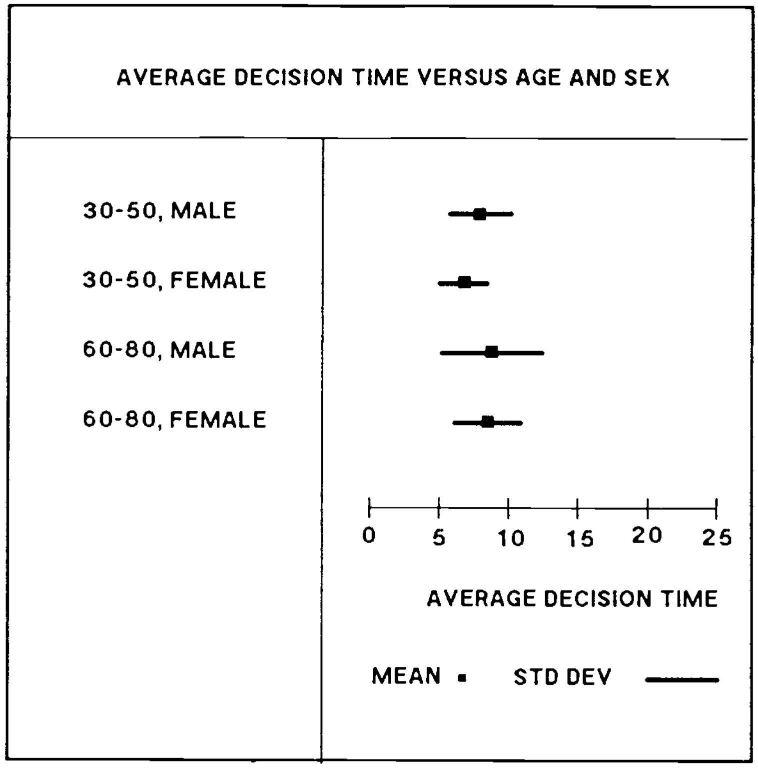

Figure 7-14 Average Decision Time Versus Age and Sex for an Intersection with Poor Sight Distance and Low Volume

TABLE 7-13 AVERAGE DECISION TIME (sec) VERSUS AGE AND SEX:at an intersection with poor sight distance and low volume (p=0.07, C.V.=32.16)

AGE AND SEX	MEAN	STD.DEV.
30-50, MALE	7.9	2.15
30-50, FEMALE	6.7	1.68
60-80, MALE	8.8	3.60
60-80, FEMALE	8.5	2.38

Figure 7-15 shows the means and standard deviations for average decision time versus impairment, and the values are shown in Table 7-14. The impaired group of drivers has a 1.2 second longer average decision time than the non-impaired group which is consistent with the totals summary and the literature. As expected, the impaired group of drivers exhibits more inconsistent driving behavior. This is shown in the (0.45 second) larger standard deviation. The poor sight distance at this intersection may contribute to the longer decision time of the impaired group.

Figure 7-16 shows the means and standard deviations for average decision time versus glasses, and the values are shown in Table 7-15. The average decision time for drivers with glasses is 0.9 seconds longer than drivers with out glasses. Also the 1.04 second difference in standard deviation shows that the drivers with out glasses demonstrate more consistent behavior. Subjects with glasses may have had more difficulty with the poor sight distance conditions.

Figure 7-17 shows the means and standard deviations for average decision time versus age, sex and medication, and the values are shown in Table 7-16. The 30-50 year age group of subjects has a slightly shorter average decision time than the older group. Female subjects have shorter average decision times than their male counterparts. The most unexpected result is that drivers on medication have shorter average decision times than those drivers not on medication. Few of the medications that were taken would have any effect on reaction time.

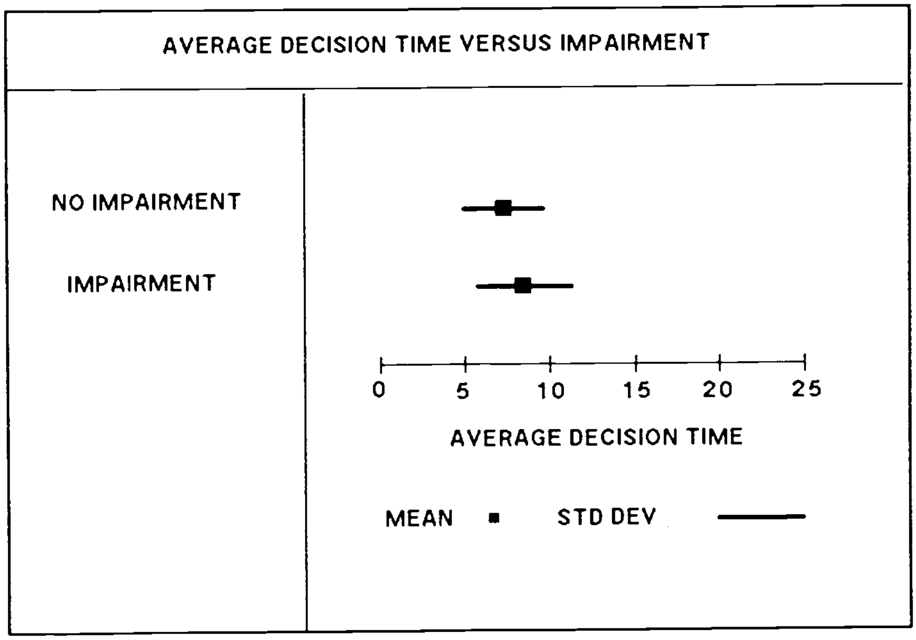

Figure 7-15 Average Decision Time Versus Impairment for an Intersection with Poor Sight Distance and Low Volume

TABLE 7-14 AVERAGE DECISION TIME (sec) VERSUS IMPAIRMENT: at an intersection with poor sight distance and low volume (p=0.08, C.V.=32.75)

IMPAIRMENT	MEAN	STD.DEV.
NO IMPAIRMENT	7.2	2.30
IMPAIRMENT	8.4	2.75

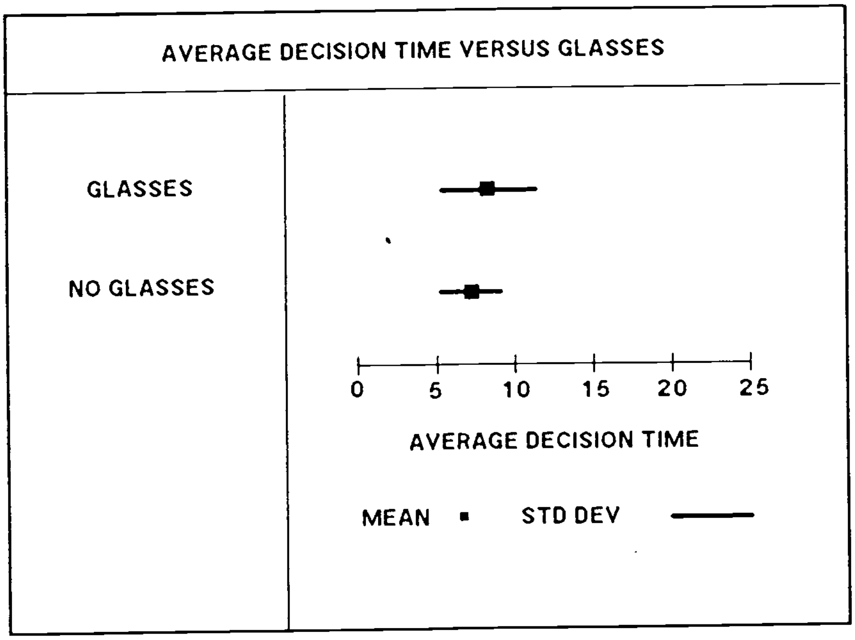

Figure 7-16 Average Decision Time Versus Glasses for an Intersection with Poor Sight Distance and Low Volume

TABLE 7-15 AVERAGE DECISION TIME (sec) VERSUS GLASSES: at an intersection with poor sight distance and low volume (p=0.10, C.V.=32.81)

GLASSES	MEAN	STD.DEV.
GLASSES	8.3	2.96
NO GLASSES	7.2	1.92

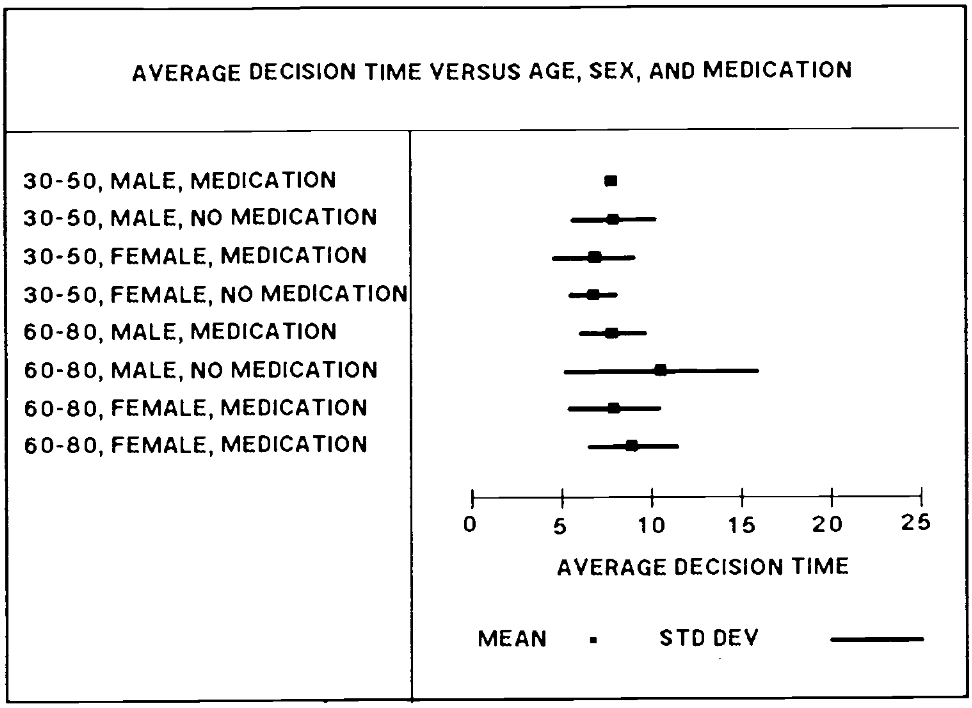

Figure 7-17 Average Decision Time Versus Age, Sex, and Medication for an Intersection with Poor Sight Distance and Low Volume

TABLE 7-16 AVERAGE DECISION TIME (sec) VERSUS AGE, SEX, AND MEDICATION: at an intersection with poor sight distance and low volume (p=0.11, C.V.=31.89)

AGE, SEX, AND MEDICATION	MEAN	STD.DEV.
30-50, MALE, MEDICATION	7.8	0.00
30-50, MALE, NO MEDICATION	7.9	2.33
30-50, FEMALE, MEDICATION	6.8	2.21
30-50, FEMALE, NO MEDICATION	6.7	1.23
60-80, MALE, MEDICATION	7.8	1.76
60-80, MALE, NO MEDICATION	10.5	5.27
60-80, FEMALE, MEDICATION	7.9	2.47
60-80, FEMALE, NO MEDICATION	8.9	2.41

Figure 7-18 shows the means and standard deviations for average decision time versus sex, and the values are shown in Table 7-17. Female subjects have a 1.1 second shorter average decision time than the male subjects, and the male subjects show greater inconsistency in driving behavior which is indicated in the 1.04 larger standard deviation.

The relationships for the intersection with low volume and poor sight distance show that there is more inconsistency among the older age group, drivers with impairments, and male drivers. The significance levels are much lower than for the totals which indicate the greater sensitivity of analysis of individual intersections.

7.1.2.2. Intersection with Mixed Sight Distance and Low Volume

The intersection has poor sight distance and no traffic on the left, and has good sight distance and low volume on the right, and therefore the decision time was consistent for most subjects. Figure 7-19 is a histogram depicting the significance levels of the relationships. The significant relationships were average decision time versus: functional level; age, sex, and medication; age and glasses; age; and medication. The relationships for average decision time versus: impairment; age and impairment; sex; age and sex; glasses; and age, sex, and impairment were considered insignificant, that is, no difference in decision times were found with these variables.

Figure 7-20 shows the means and standard deviations for average decision time versus functional level, and the values are shown in Table 7-18. In

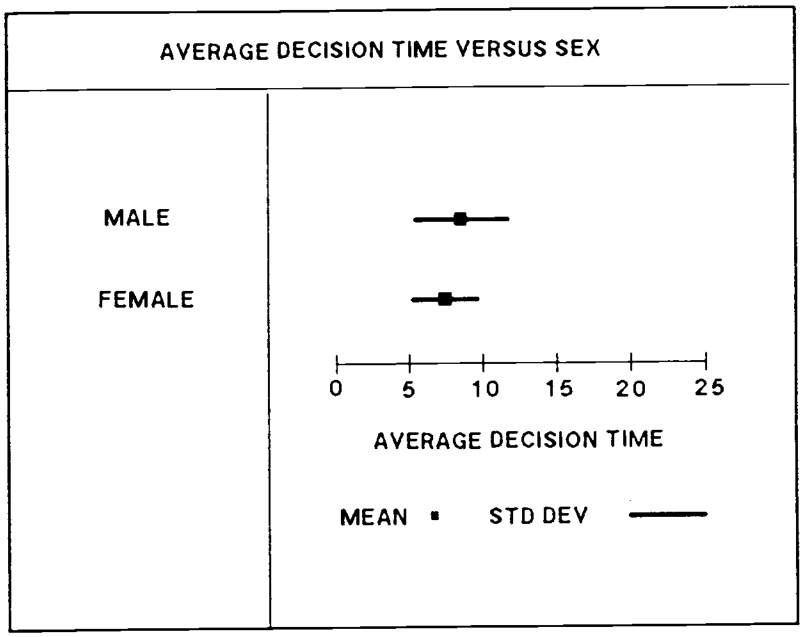

Figure 7-18 Average Decision Time Versus Sex for an Intersection with Poor Sight Distance and Low Volume

TABLE 7-17 AVERAGE DECISION TIME (sec) VERSUS SEX: at an intersection with poor sight distance and low volume (p=0.13, C.V.=32,91)

SEX	MEAN	STD.DEV.
MALE	8.5	3.17
FEMALE	7.4	2.13

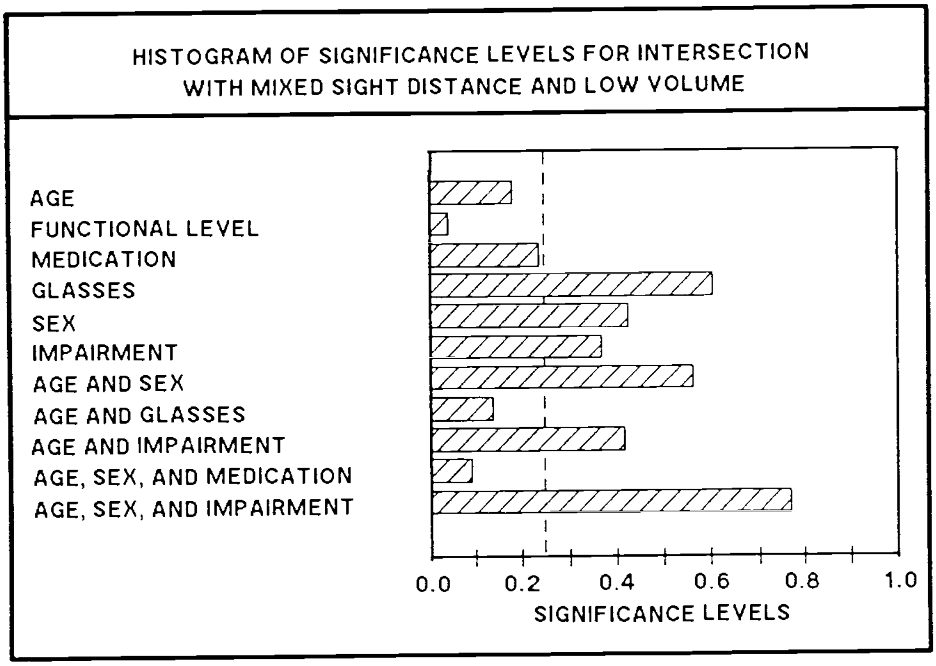

Figure 7-19 Histogram of Significance Levels for an Intersection with Mixed Sight Distance and Low Volume

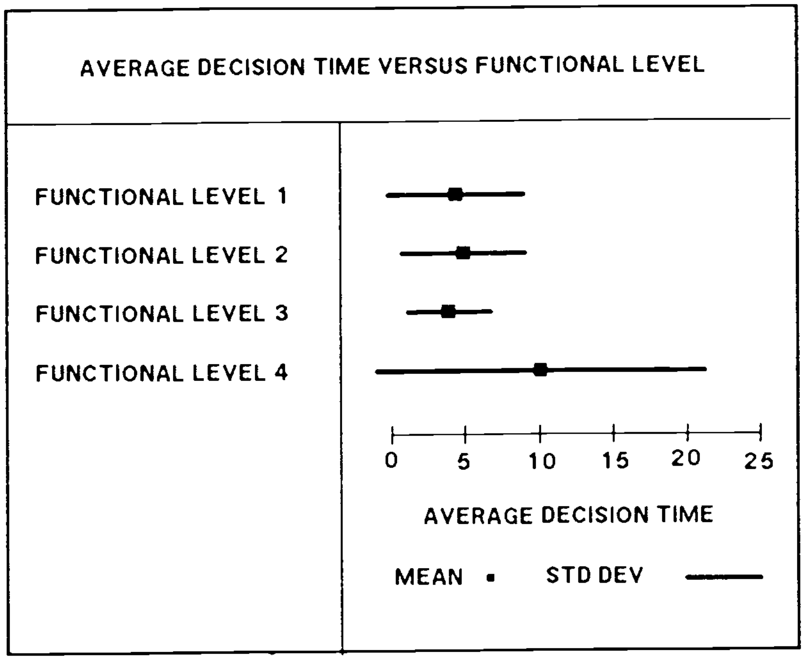

Figure 7-20 Average Decision Time Versus Functional Level for an Intersection with Mixed Sight Distance and Low Volume

TABLE 7-18 AVERAGE DECISION TIME (sec) VERSUS FUNCTIONAL LEVEL(1-4): at an intersection with mixed sight distance and low volume (p=0.04, C.V.=112.07)

FUNCTIONAL LEVEL	MEAN	STD.DEV.
1 30-50, UNIMPAIRED	4.4	4.57
2 30-50, IMPAIRED	4.9	4.17
3 60-80, UNIMPAIRED	3.9	2.79
4 60-80, IMPAIRED	10.1	11.13

general, average decision time increases with functional level for this intersection, however functional level 3, age 60-80 and unimpaired, indicates both a lower average decision time and lower standard deviation. Subjects of 60-80 who are impaired, functional level 4, had a significantly higher average decision time and standard deviation.

Figure 7-21 shows the means and standard deviations for average decision time versus age, sex and medication, and the values are shown in Table 7-19. The inconsistency in volume and sight distance at this intersection generate some inconsistency in the response of the subjects. The 30-50 year age group of subjects has a slightly shorter average decision time than the older group. There was one male subject in the 30-50 age group on medication who took a long time to make a decision to turn at this intersection. In general, the subjects not on medication had longer average decision times. The large inconsistency in behavior at this intersection is reflected in the large standard deviations, particularly for the 60-80 age males not on medication. The ANOVA for the relationship of average decision time versus age, sex and medication shows significant interaction between age and medication (2 percent), and age, sex and medication (16 percent). There is an increase in inconsistency with age, and those drivers not on medication.

Figure 7-22 shows the means and standard deviations for average decision time versus age and glasses, and the values are shown in Table 7-20. The 60-80 age subjects with glasses have both the longest average decision time and the largest standard deviation, and this is consistent with the predicted results.

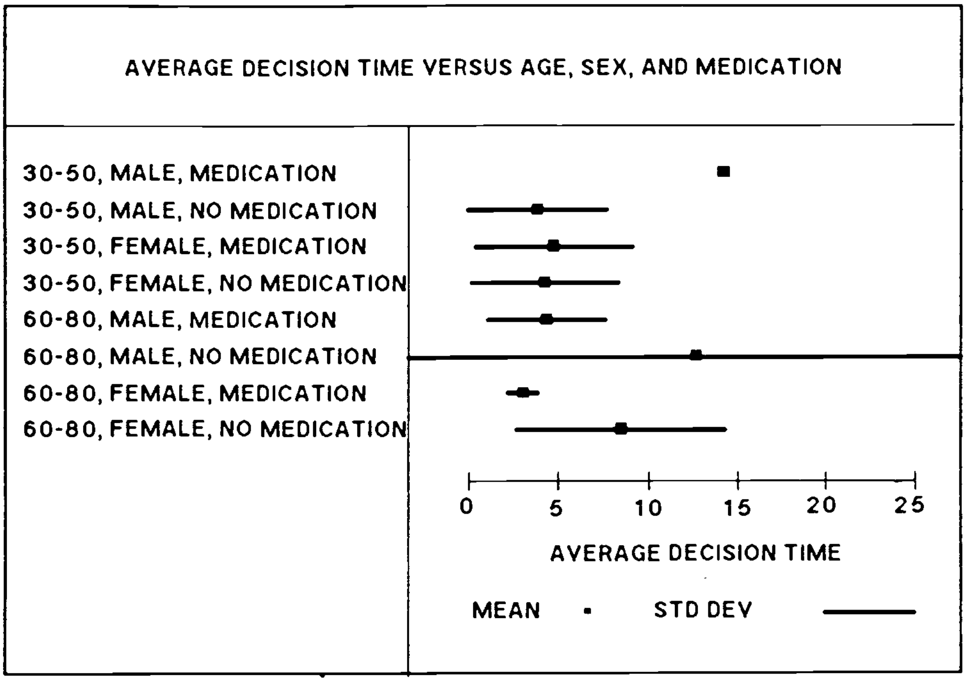

Figure 7-21 Average Decision Time Versus Age, Sex, and Medication for and Intersection with Mixed Sight Distance and Low Volume

TABLE 7-19 AVERAGE DECISION TIME (sec) VERSUS AGE, SEX, AND MEDICATION: at an intersection with mixed sight distance and low volume (p=0.09, C.V.=111.81)

AGE, SEX, AND MEDICATION	MEAN	STD.DEV.
30-50, MALE, MEDICATION	14.2	0.00
30-50, MALE, NO MEDICATION	3.8	3.87
30-50, FEMALE, MEDICATION	4.7	4.35
30-50, FEMALE, NO MEDICATION	4.2	4.10
60-80, MALE, MEDICATION	4.3	3.29
60-80, MALE, NO MEDICATION	12.6	16.66
60-80, FEMALE, MEDICATION	3.0	0.81
60-80, FEMALE, NO MEDICATION	8.5	5.84

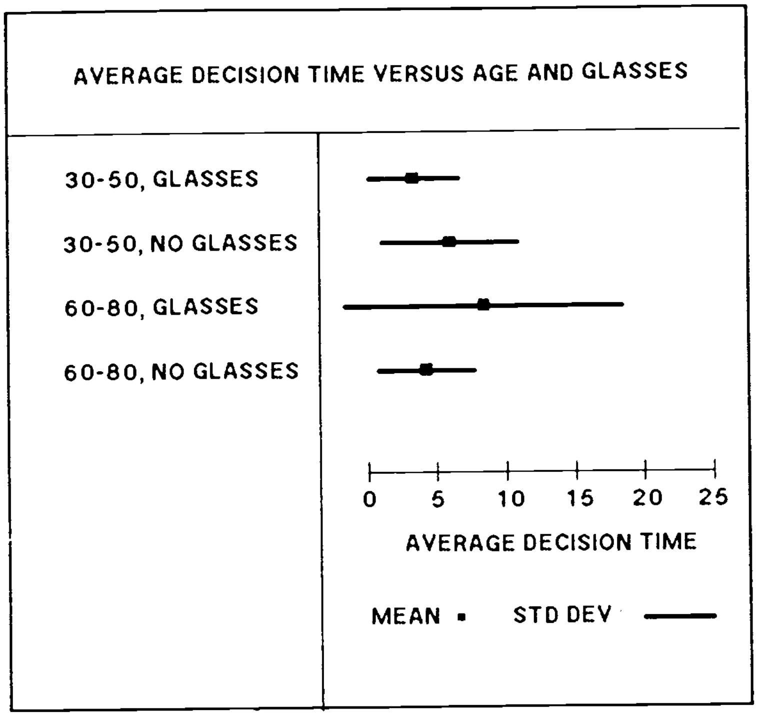

Figure 7-22 Average Decision Time Versus Age and Glasses for an Intersection with Mixed Sight Distance and Low Volume

TABLE 7-20 AVERAGE DECISION TIME (sec) VERSUS AGE AND GLASSES: at an intersection with mixed sight distance and low volume (p=0.13, C.V.=114.66)

AGE AND GLASSES	MEAN	STD.DEV.
30-50, GLASSES	3.3	3.19
30-50, NO GLASSES	5.9	4.91
60-80, GLASSES	8.4	10.00
60-80, NO GLASSES	4.2	3.47

The most inconsistent result is the 30-50 age subjects without glasses who have both a longer average decision time and a larger standard deviation than the 60-80 age subjects without glasses. The interaction between age and glasses is significant at the 5 percent level.

Figure 7-23 shows the means and standard deviations for average decision time versus age, and the values are shown in Table 7-21. Age effects are clearly evident as shown in the 2.4 second increase in the means and the 4.24 increase in standard deviation. These results are consistent with both the predicted results and those seen in the literature. This intersection would be expected to have larger decision times and variations in decision time for the older driver due to the confusion caused by inconsistent volume and sight distance conditions.

Figure 7-24 shows the means and standard deviations for average decision time versus medication, and the values are shown in Table 7-22. These results are inconsistent with the predicted results. The subjects on medication have shorter average decision time and smaller standard deviations.

7.1.2.3. Intersection with Good Sight Distance and High Volume

The intersection had high traffic volume on the right and many subjects decided not make a turn. Unlike most other intersections the only significant relationship was decision time versus sex at the 5 percent level. Figure 7-25 is a histogram depicting the significance levels of the relationships.

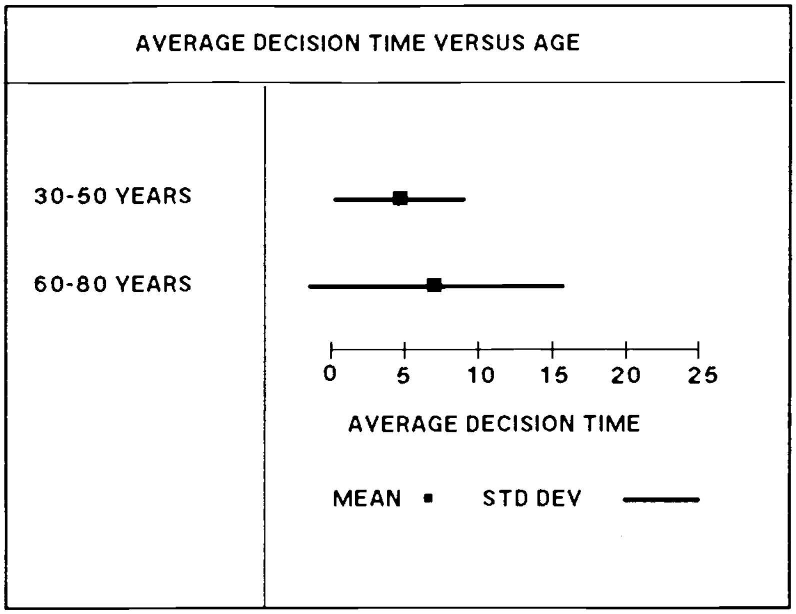

Figure 7-23 Average Decision Time Versus Age for an Intersection with Mixed Sight Distance and Low Volume

TABLE 7-21 AVERAGE DECISION TIME (sec) VERSUS AGE: at an intersection with mixed sight distance and low volume (p=0.18, C.V.=116.46)

AGE	MEAN	STD.DEV.
30-50	4.6	4.32
60-80	7.0	8.56

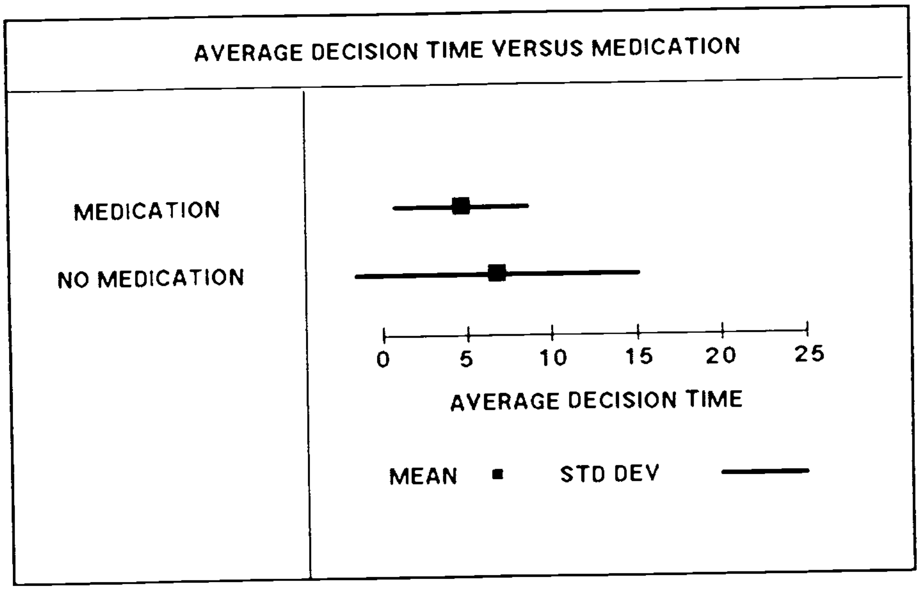

Figure 7-24 Average Decision Time Versus Medication for an Intersection with Mixed Sight Distance and Low Volume

TABLE 7-22 AVERAGE DECISION TIME (sec) VERSUS MEDICATION: at an intersection with mixed sight distance and low volume (p=0.24, C.V.=116.90)

MEDICATION	MEAN	STD.DEV.
MEDICATION	4.6	3.88
NO MEDICATION	6.7	8.28

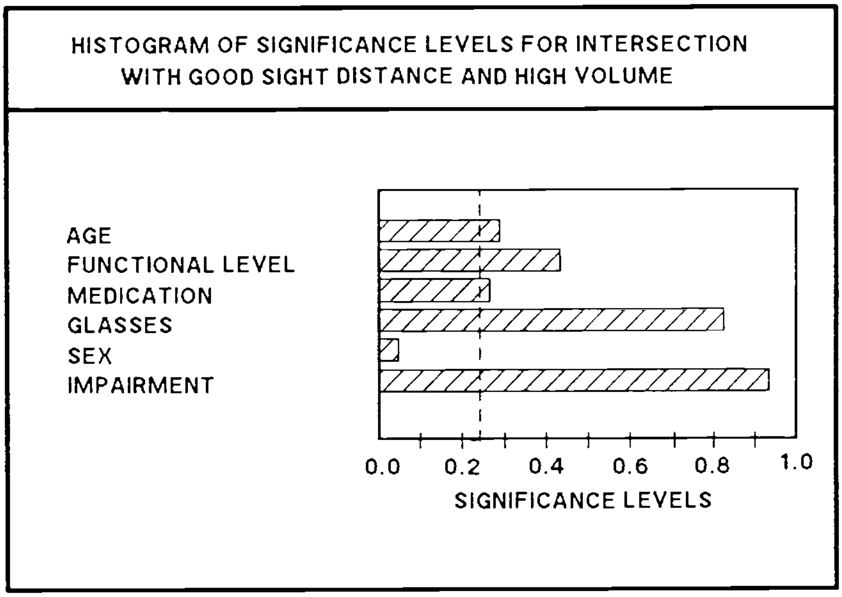

Figure 7-25 Histogram of Significance Levels for Intersection with Good Sight Distance and High Volume

Figure 7-26 shows the means and standard deviations for average decision time versus sex of the subject, and the values are shown in Table 7-23. The average decision time for female subjects was 3.6 seconds less than for male subjects, and male subjects were more inconsistent as is reflected in the 0.93 larger standard deviation. The high volume conditions at this intersection had a greater impact on decision time than either the sight distance conditions or the characteristics of the drivers.

7.1.2.4. Intersection with Good Sight Distance and Low Volume

The intersection that had low volume and good sight distance was also done consistently by most subjects. Figure 7-27 is a histogram depicting the significance levels of the relationships. The relationships of significance are decision time versus age; age and glasses; and glasses at the 11, 15, and 25 percent levels of significance. The relationships which are insignificant are average decision time versus: functional level; age and sex; age and impairment; medication; age, sex, and medication; sex; age, sex, and impairment; and impairment.

Figure 7-28 shows the means and standard deviations for average decision time versus age, and the values are shown in Table 7-24. The 60-80 year age group has an average decision time of 1.5 seconds longer than the 30-50 year age group. The older age group also has a 0.23 second larger standard deviation. These results are consistent with the hypothesis and supported in the literature. The low volume with good sight distance at this intersection

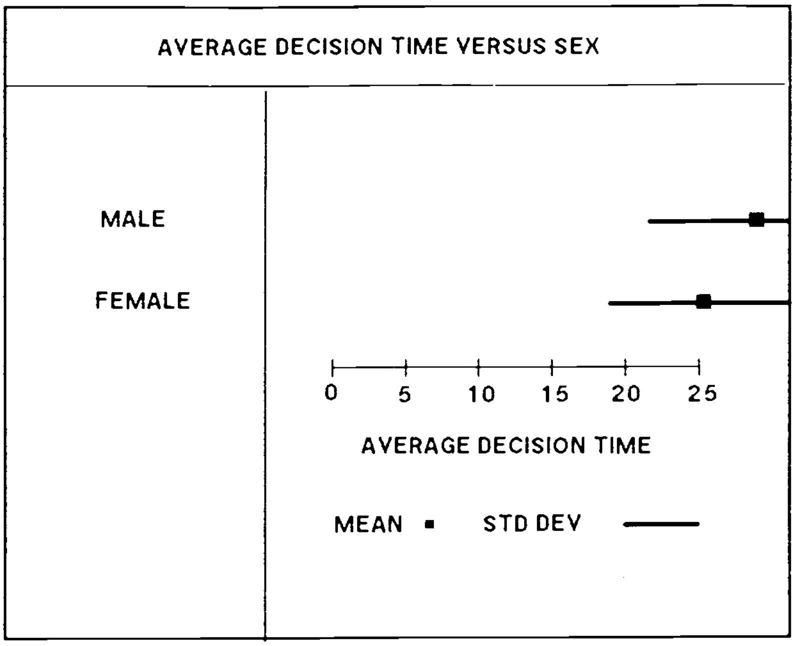

Figure 7-26 Average Decision Time Versus Sex for an Intersection with Good Sight Distance and High Volume

TABLE 7-23 AVERAGE DECISION TIME (sec) VERSUS SEX: at an intersection with good sight distance and high volume (p=0.05, C.V.=25.30)

SEX	MEAN	STD.DEV.
MALE	29.0	7.33
FEMALE	25.4	6.40

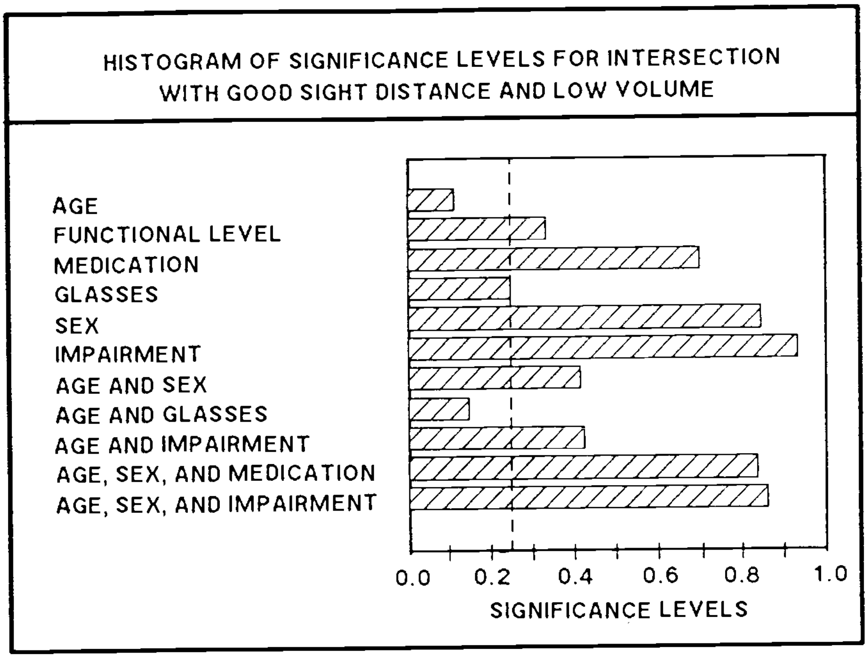

Figure 7-27 Histogram of Significance Levels for Intersection with Good Sight Distance and Low Volume

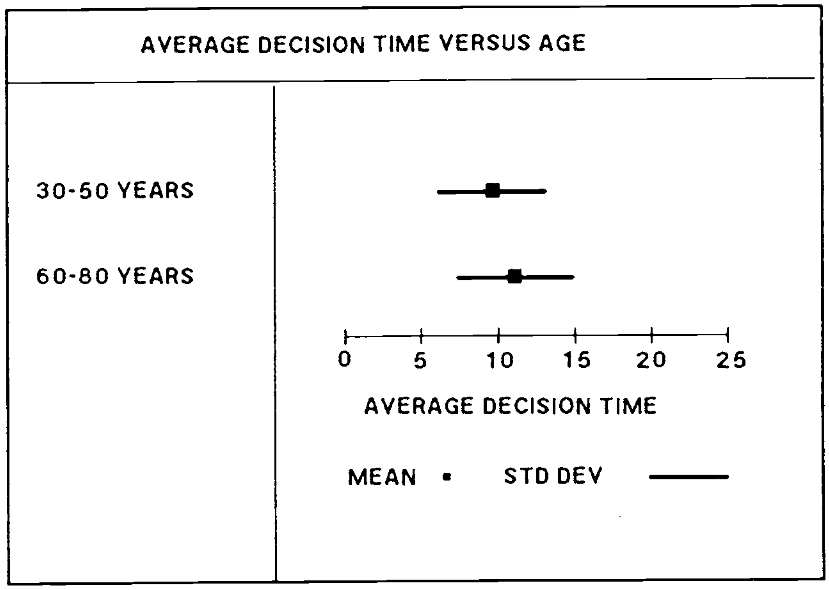

Figure 7-28 Average Decision Time Versus Age for an Intersection with Good Sight Distance and Low Volume

TABLE 7-24 AVERAGE DECISION TIME (sec) VERSUS AGE: at an intersection with good sight distance and low volume (p=0.11, C.V.=33.8)

AGE	MEAN	STD.DEV.
30-50	9.6	3.39
60-80	11.1	3.62

results in older drivers taking longer to determine that it is safe to enter the intersection.

Figure 7-29 shows the means and standard deviations for average decision time versus age and glasses, and the values are shown in Table 7-25. The strongest result is both the large and small standard deviations of the 60-80 year age group. The 60-80 age group without glasses exhibits both the longest average decision time and the largest standard deviation. The interaction of age and glasses is significant at the 16 percent level. The good sight distance makes it possible for younger drivers without glasses to determine faster that it is safe to enter the intersection.

Figure 7-30 shows the means and standard deviations for average decision time versus glasses, and the values are shown in Table 7-26. If the effect of age is not considered, the effect of glasses is seen to increase decision time. Subjects with glasses have a 1.1 second longer average decision time but a 1.90 second shorter standard deviation which indicates more consistent driving behavior.

The individual intersection results are consistent with the Totals results. They support the hypothesis that older drivers and those with physical limitations take longer to make a decision at intersections. The results are also consistent with the reviewed literature.

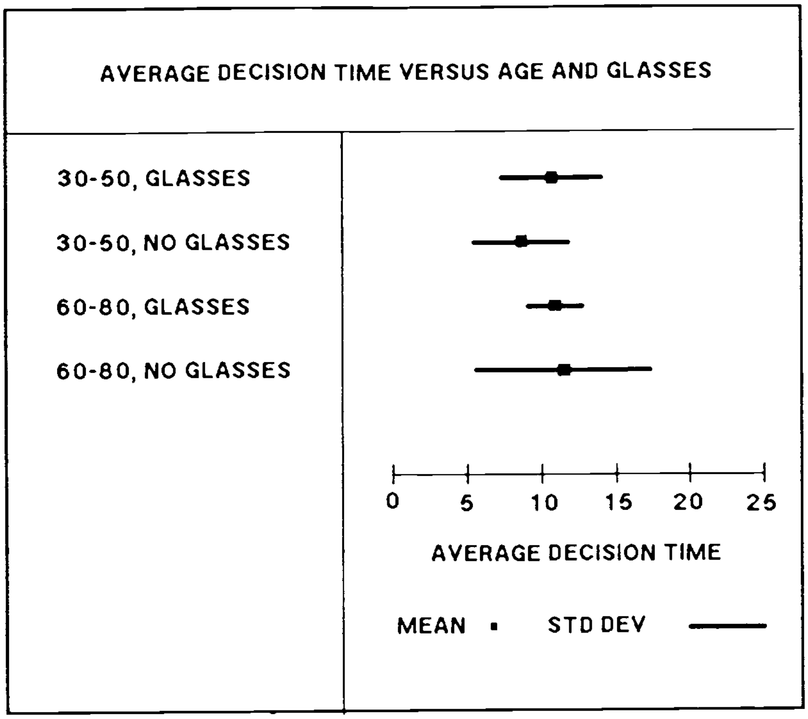

Figure 7-29 Average Decision Time Versus Age and Glasses for an Intersection with Good Sight Distance and Low Volume

TABLE 7-25 AVERAGE DECISION TIME (sec) VERSUS AGE AND GLASSES: at an intersection with good sight distance and low volume ($p=0.25$, C.V.=33.62)

AGE AND GLASSES	MEAN	STD.DEV.
30-50, GLASSES	10.7	3.40
30-50, NO GLASSES	8.6	3.16
60-80, GLASSES	10.9	1.89
60-80, NO GLASSES	11.5	5.87

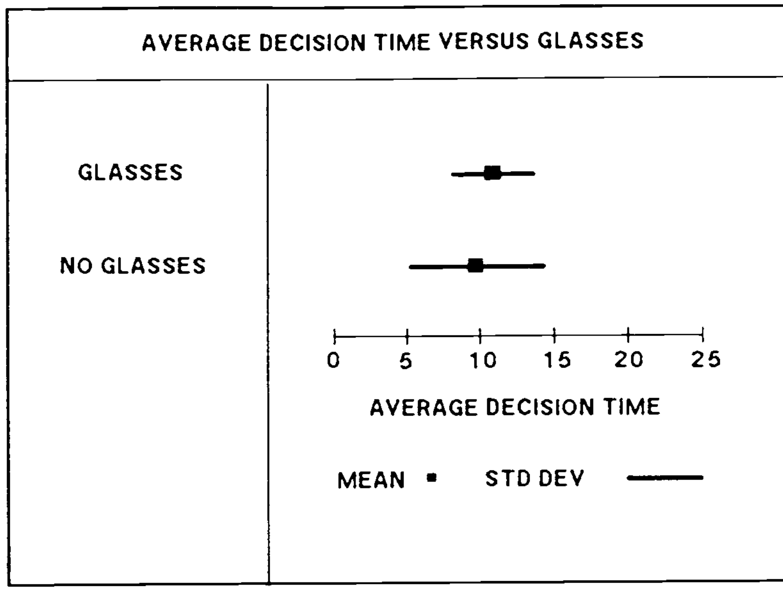

Figure 7-30 Average Decision Time Versus Glasses for an Intersection with Good Sight Distance and Low Volume

TABLE 7-26 AVERAGE DECISION TIME (sec) VERSUS GLASSES: at an intersection with good sight distance and low volume (p=0.15, C.V.=34.20)

GLASSES	MEAN	STD.DEV.
GLASSES	10.8	2.61
NO GLASSES	9.7	4.51

7.1.3. Intersection Geometrics

All the intersections were rated according to sight distance and volume. The relationships of decision time versus volume, sight distance, and volume and sight distance were examined. The relationship of decision time versus volume was most significant at the 7 percent level.

Figure 7-31 shows the means and standard deviations for average decision time versus volume, and the values are shown in Table 7-27. Intersections with high traffic volumes have average decision times that are 6.6 seconds longer than intersections with low volume. The large standard deviation is due to the greater inconsistency in decision times associated with high volume intersections.

Figure 7-32 shows the means and standard deviations for average decision time versus sight distance, and the values are shown in Table 7-28. This relationship is significant at the 11 percent level. Studying the means for decision time versus sight distance, there is very little difference between poor (9.54) and AASHTO sight distance criteria (9.50) but good sight distance has a mean of (17.61).

Figure 7-33 shows the means and standard deviations for average decision time versus volume and sight distance and the values are shown in Table 7-29. This relationship is significant at the 8 percent level. In general, the intersections with a good sight distance also had very high volumes and therefore had long time intervals. However, the intersections with poor or

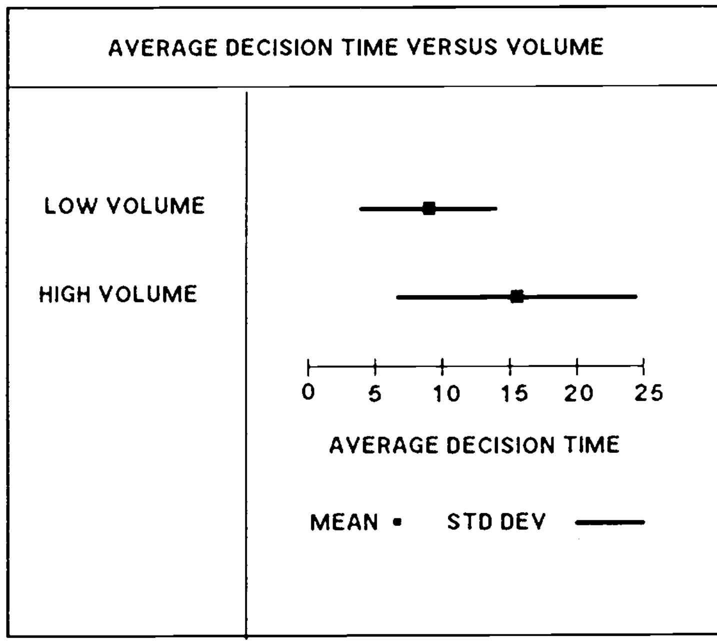

Figure 7-31 Average Decision Time Versus Volume

TABLE 7-27 AVERAGE DECISION TIME (sec) VERSUS VOLUME (p=0.07, C.V.=58.40)

VOLUME	MEAN	STD.DEV.
LOW VOLUME	8.9	4.89
HIGH VOLUME	15.5	8.82

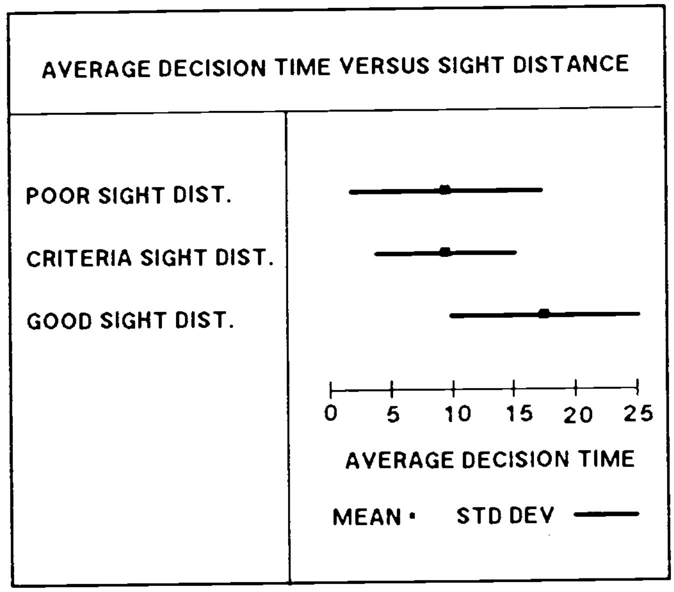

Figure 7-32 Average Decision Time Versus Sight Distance

TABLE 7-28 AVERAGE DECISION TIME (sec) VERSUS SIGHT DISTANCE (p=0.11, C.V.=57.87)		
SIGHT DISTANCE	MEAN	STD.DEV.
POOR SIGHT DISTANCE	9.5	7.8
AASHTO CRITERIA SIGHT DISTANCE	9.5	5.59
GOOD SIGHT DISTANCE	17.6	7.60

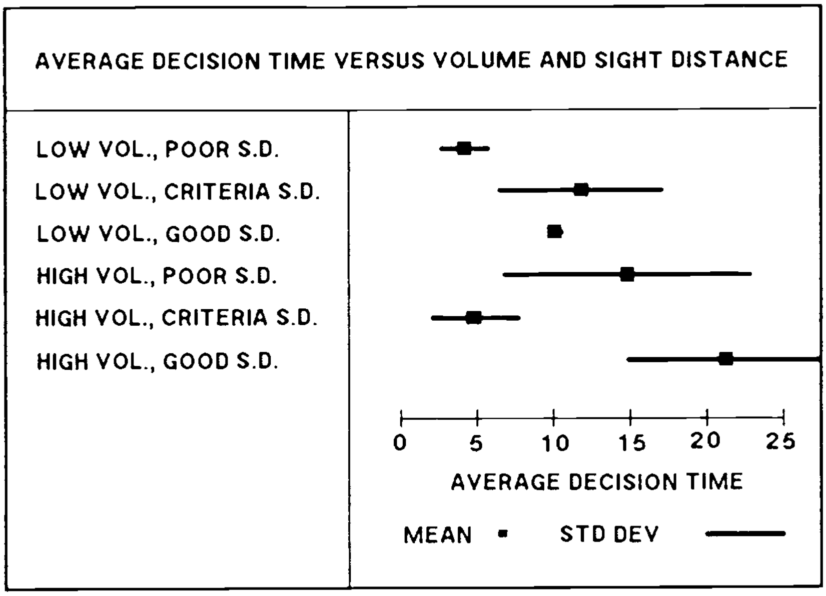

Figure 7-33 Average Decision Time Versus Volume and Sight Distance

TABLE 7-29 AVERAGE DECISION TIME (sec) VERSUS VOLUME AND SIGHT DISTANCE (p=0.08, C.V.=55.20)

VOLUME AND SIGHT DISTANCE	MEAN	STD.DEV.
LOW VOLUME, POOR SIGHT DISTANCE	4.19	1.49
LOW VOLUME, AASHTO CRITERIA SIGHT DISTANCE	11.83	5.26
LOW VOLUME, GOOD SIGHT DISTANCE	10.12	0.34
HIGH VOLUME, POOR SIGHT DISTANCE	14.88	8.00
HIGH VOLUME, AASHTO CRITERIA SIGHT DISTANCE	4.84	2.85
HIGH VOLUME, GOOD SIGHT DISTANCE	21.26	6.33

AASHTO criteria sight distance had low traffic volumes in the segments of video film. The relationship for decision time versus volume and sight distance was most strongly influenced by volume considerations.

The quality and width of field of the video tapes masked many of the sight distance effects. Many subjects were questioned about the sight distance at intersections with a sight distance of 150 feet or less. These subjects were unable to identify the sight distance as being significantly worse than other intersections where the sight distance met the AASHTO criteria distance, for example 550 feet. In actual driving situations, sight distance has a tremendous impact on intersection safety. This aspect of intersection design should not be overlooked. In the experimental situation the narrow focal width and foreshortening of the video cameras severely limited the impact of sight distance problems. These results clearly show the effect of traffic volume on gap acceptance, and intersection decision time (Blumenfeld et al, 1979).

7.1.4. Regression Analysis

Examination of the regression results in Appendix B shows the very high dispersion of data, with r^2 values ranging from (0.002 to 0.533). The r value is the correlation coefficient or coefficient of determination which is a measure of the degree of fit of the regression equation. This the percent of the total variation in the data that is explained by the regression. A good regression should have r^2 values of (0.8-0.99). Table 7-30 show the regression relationships for the intersection totals.

TABLE 7-30 REGRESSION ANALYSIS FOR TOTAL SUBJECTS AND INTERSECTIONS

	SLOPE	INTERCEPT	R^2
AVERAGE DECISION TIME	0.564 AVERAGE HEAD TURNS	9.150	0.138
AVERAGE DECISION TIME	0.041 AGE	9.701	0.025

On the totals, the relationship between average decision time and the average number of head turns has a positive slope of 0.564 and r^2 of 0.138. The relationship of average decision time versus age is relatively flat with a slope of only 0.041, and a correspondingly low r^2 of 0.025. These particular relationships hold for the individual intersection results as well.

Relationships of range of motion versus maximum angle for right and left respectively for the impaired group of subjects on the four intersections were also studied. Tables 7-31 to 7-34 contains the regression equations for the four intersection. The results are consistent across all intersections. Of the four intersections, the relationship between average decision time and the average number of head turns has a positive slope ranging from 0.328 to 2.230 and r^2 values ranging from 0.054 to 0.263. Of the four intersections, the relationship of average decision time versus age is relatively flat with a slope ranging from 0.048 to 0.062, and correspondingly low r^2 values ranging from 0.012 to 0.125. The right range of motion versus maximum right angle have positive slopes ranging from 0.119 to 0.203 and r^2 values of 0.032 to 0.107. The left range of motion versus maximum left angle have almost flat negative slopes ranging from -0.030 to -0.176, and correspondingly low r^2 values of 0.002 to 0.027. The low r^2 values and slopes indicate the weak relationships for average decision time versus age and range of motion versus maximum right and left angles. A stronger relationship exists between decision time and head turns.

TABLE 7-31 REGRESSION ANALYSIS FOR INTERSECTION: with Poor Sight Distance and Low Volume			
	SLOPE	INTERCEPT	R^2
AVERAGE DECISION TIME	0.628 AVERAGE HEAD TURNS	5.569	0.263
AVERAGE DECISION TIME	0.062 AGE	4.555	0.125
RIGHT R.O.M.*	0.147 MAX. RIGHT ANGLE	38.865	0.039
LEFT R.O.M.*	-0.091 MAX. LEFT ANGLE	43.400	0.008

* R.O.M.= Range Of Movement - impaired subjects only

TABLE 7-32 REGRESSION ANALYSIS FOR INTERSECTION: with Mixed Sight Distance and Low Volume			
	SLOPE	INTERCEPT	R^2
AVERAGE DECISION TIME	2.230 AVERAGE HEAD TURNS	-0.495	0.533
AVERAGE DECISION TIME	0.059 AGE	2.606	0.017
RIGHT R.O.M.*	0.203 MAX. RIGHT ANGLE	37.869	0.107
LEFT R.O.M.*	-0.176 MAX. LEFT ANGLE	45.096	0.027

* R.O.M.= Range Of Movement - impaired subjects only

TABLE 7-33 REGRESSION ANALYSIS FOR INTERSECTION: with Good Sight Distance and High Volume

	SLOPE	INTERCEPT	R^2
AVERAGE DECISION TIME	0.328 AVERAGE HEAD TURNS	23.866	0.054
AVERAGE DECISION TIME	0.052 AGE	24.028	0.012
RIGHT R.O.M.*	0.119 MAX. RIGHT ANGLE	39.238	0.032
LEFT R.O.M.*	-0.030 MAX. LEFT ANGLE	41.392	0.002

* R.O.M.= Range Of Movement - impaired subjects only

TABLE 7-34 REGRESSION ANALYSIS FOR INTERSECTION: with Good Sight Distance and Low Volume

	SLOPE	INTERCEPT	R^2
AVERAGE DECISION TIME	0.459 AVERAGE HEAD TURNS	8.294	0.085
AVERAGE DECISION TIME	0.048 AGE	7.782	0.041
RIGHT R.O.M.*	0.164 MAX. RIGHT ANGLE	38.651	0.041
LEFT R.O.M.*	-0.078 MAX. LEFT ANGLE	42.287	0.006

* R.O.M.= Range Of Movement - impaired subjects only

CHAPTER 8

DISCUSSION OF RESULTS

8.0 INTRODUCTION

The discussion of results identifies the most significant results and relates them to the literature and results from other sources. The experimental observations, which are included as part of the discussion of results, contain qualitative information that was gathered during conversations with the subjects as well as observations that were made during the data collection phase. The observations give further insight into the problems of drivers with diminished capacities at T-intersections.

8.1 TOTALS SUMMARY

The totals summary is the totals for all intersections and all subjects. A smaller decision time to turn left indicates that the subjects' driving performance is better because the driver has more of the "gap" time to accelerate to speed and thus maintain more uniform speed of the traffic stream. The most significant relationship is average decision time versus age, which is significant at the 4 percent level. The results show that the older drivers take longer to make a decision and are more inconsistent in their decision making than younger drivers. The larger standard deviation is a measure of the inconsistency in driver behavior. Both the longer decision time and inconsistency of the older driver support the hypothesis of this research that reaction times are influenced by age and are also suggested in the literature and a review of highway accident data (Brainin, Naughton, Breedlove, 1977; Yanik, 1986; and U.S. DOT Highway Statistics, 1980).

The relationship of average decision time versus functional level is significant at the 8 percent level. The definition of functional level is a combination of age and impairment level:

(a) functional level 1 = 30-50 years and no impairment,

(b) functional level 2 = 30-50 years and impairment,

(c) functional level 3 = 60-80 years and no impairment,

(d) functional level 4 = 60-80 years and impairment.

Impairment is defined by a combined static range of movement of the head and visual field of less that 285 degrees, whereas no impairment ranges from 285 to 360 degrees. There is no definitive definition of impairment level in the literature, therefore for this study, the choice of 284 degrees was arbitrarily based on the functional requirements for driving.

There is an increase in the mean decision time with functional level. The increase in standard deviation with impairment can be explained by the large diversity of severity of impairment and the less consistent driving behavior in this subject group. It is interesting to note that average decision time versus impairment is not significant ($p=0.85$). The implication of these results is that the younger impaired drivers are able to compensate in their driving behavior for their impairment, but the older drivers either impaired or unimpaired, are unable to make the necessary compensations.

There was no significant difference in decision time due to subject's sex, however, the relationship of average decision time versus age and sex was significant at the 15 percent level. In this study, younger males have a longer decision time than younger females, but older males have a shorter decision time than older females. The standard deviations increase with age, and young males show the most consistent behavior, while older males are the most inconsistent. The longer decision time taken by the older females is supported in the literature which suggests that the current generation of older female drivers lack the experience of their male counterparts, but the younger generation of female and male drivers are more equally matched in terms of driving experience (Grubb, 1986; Planck and Fowler, 1971).

8.2 INTERSECTION SUMMARY

Four intersections are examined separately since these intersections represent a cross section of difficulty, sight distance and traffic volume:

(i) Poor Sight Distance and Low Volume,

(ii) Mixed Sight Distance and Low Volume,

(iii) Good Sight Distance and High Volume,

(iv) Good Sight Distance and Low Volume.

Many of the other intersections have incomplete data sets and therefore have not been selected for the in-depth analysis. Intersection (i) has poor sight distance on the left and low traffic volume. Intersection (ii) has poor sight distance and no traffic on the left, and has good sight distance and low volume on the right. Intersection (iii) has good sight distance in both directions and high traffic volume. Intersection (iv) has good sight distance in both directions and low traffic volume.

8.2.1 Intersection with Poor Sight Distance and Low Volume

The average decision time versus functional level is significant at a zero percent level. Average decision time increases with increased functional level, that is increased age and impairment. The average decision time versus age is significant at the two percent level. It is clearly seen that age effects dominate and through the relationships of average decision time versus age and glasses, age and impairment, age, sex and impairment, and age and sex, which are all significant. These results are consistent with the totals summary and indicate the strong influence of age effects. The relationships for this intersection indicate that traffic volume has more of an impact than sight distance. This is due to the simulation and the deficiencies of the video cameras. In summary, the relationships for this intersection with poor sight distance and low volume show that there is more inconsistency among the older age group, the drivers with impairments, and male drivers. The significance levels are much lower than for the totals which indicates the greater sensitivity of analysis of individual intersections.

8.2.2. Intersection with Mixed Sight Distance and Low Volume

The results for this intersection also show a strong relation between average decision time and functional level which is significant at the 4 percent level. The influence of age effects are reflected in the relationship of average decision time versus age, sex, and medication. In general, the subjects not on medication had longer average decision times. The large inconsistency in behavior at this intersection is reflected in the large standard deviations, particularly for the 60-80 age males not on medication. The relationship of average decision time versus age, sex and medication shows significant interaction between age and medication (2 percent), and age, sex and medication (16 percent). There is an increase in inconsistency with age, and those drivers not on medication. Similarly, age effects are seen in the relationship of average decision time versus age and glasses, and age. Traffic volume had more of an influence on decision time than sight distance. This intersection is near the crest of a hill on the right and roadside obstacles such as utility poles obstruct the view on the left.

8.2.3. Intersection with Good Sight Distance and High Volume

This particular intersection had high traffic volume and as a result most of the subjects did not make a left turn which was an appropriate decision. The only relationship which was significant was average decision time versus subject's sex. The average decision time for females was less than males who were more inconsistent. Many of the older female drivers made inappropriate turning decisions at this intersection. The results at this intersection indicate that with good sight distance, i.e. good design, most people behave in the same manner at high volume intersections. This more consistent behavior supports the need for good design.

8.2.4. Intersection with Good Sight Distance and Low Volume

The relationships for this intersection show the influence of age effects. At intersections with good sight distance and low volume, younger drivers are able to determine when it is safe to proceed faster than older drivers. The younger drivers in general had faster and more agile head movements but often they were less cautious.

8.3 INTERSECTION GEOMETRICS

The intersection results are more sensitive than the totals results and show the strong influence of age effects and impairment. The relationships of average decision time and intersection volume and sight distance show that volume effects dominate. In general, the intersections with good sight distance also had very high volumes and therefore had long time intervals. However, the intersections with poor or standard sight distance had low traffic volumes in the segments of video film. The relationship for decision time versus volume and sight distance was most strongly influenced by volume considerations.

The quality and width of field of the video tapes masked many of the sight distance effects. Many subjects were questioned about the sight distance at intersections with sight distance of 150 feet or less. These subjects were unable to identify the sight distance as being significantly worse than other intersections where the sight distance was at standard, for example 550 feet. In actual driving situations, sight distance has a tremendous impact on intersection safety, and this aspect of intersection design should not be overlooked. In the experimental situation the narrow focal width and foreshortening of the video cameras severely limited the impact of sight distance problems. These results clearly show the effect of traffic volume on gap acceptance, and intersection decision time (Blumenfeld et al, 1979)

8.4. REGRESSION ANALYSIS

The regression analysis of average decision time versus head turns, and age indicates very weak relationships and low correlations. The sample size may have been a contributing factor, although the sample size was considered large for a human factors study. These results show that the number of head turns and the length of time a subject takes to decide are not strongly related. The relationships of average decision time versus age is poorly related. This is due to the dispersion of the data, however the analysis of variance on the grouped data shows that the age effects are significant. The relationships relating range of motion and maximum angle are also poorly correlated.

8.5 EXPERIMENTAL OBSERVATIONS

There were plenty of opportunities during the data collection phase for interaction and discussion with the test subjects. Many of the older subjects (60-80 age group) were married couples who came to be tested together. In general the husband did the majority of the driving when the couple travelled together and particularly on long trips. The wives usually did the driving on short trips and when they were not accompanied by their husbands. This observation is supported by the significant relationships of average decision time versus age and sex.

There were several couples where the husband's range of movement of the neck was severely restricted, and his driving capabilities were severely impaired. These couples were questioned about vehicle modifications, and driving behavior to compensate for their restricted head motion. The responses ranged from," my wife always looks to see if there are any cars coming", to " I only drive alone when I know I only have to use my mirrors and I do not need to turn my head", i.e. they are driving over familiar routes where they do not expect to have to turn their heads.

Several of the male subjects in the (60-80) age group had restricted range of movement of the neck that were due to whip lash injuries resulting from rear end collisions. There were several other common factors among this group of male subjects;

(a) they had been involved in one or more rear end collisions, "that had not been their fault!",

(b) their driving on the simulator was erratic and impetuous,

(c) they tended to make hasty and incorrect judgments, especially on gap lengths,

(d) in general they were divorcees and participated in the "singles" scene.

These subject's driving behavior on the simulator is clearly related to their accident involvement.

Many of the older subjects had difficulty judging the gap lengths, or when it was safe to proceed. The older drivers, in particular, made many more judgment errors on the simulator than the younger drivers.

Most of the older drivers would avoid driving in adverse weather conditions such as snow and ice. This was reflected in the large number of subjects whose test time had to be rescheduled due to the weather. These drivers also preferred late morning or early afternoon appointments in order to avoid the high traffic volumes at rush hour, or nighttime driving. Nearly all the older subjects mentioned that they would avoid nighttime driving as much as possible. This is consistent with the literature (Sivak, and Olson, 1982; Yanik 1986).

There are several very bad intersections near to the Turner Fairbank Highway Research Center, which prompted many of the subjects to comment on intersection design in general. Several of the older subjects mentioned that they had problems with skewed intersections, which are intersections that are not at 90 degrees, because they were forced to turn their heads and look over their shoulders which was painful or not possible. Some of these subjects mentioned that they would drive out of their way to avoid skewed intersections because they could not turn their head enough to judge gap length and approaching vehicle speed. These subjects were asked if they had any problems with merging on freeways and highways. The most frequent response was that they could always look ahead, and use their rear view mirrors or side mirrors when they were in the merge lane. It has been observed that the skewed intersection problem is accentuated due to the vehicle being stopped and the need for greater gap length in order to accelerate to speed. Often skewed intersections are complicated by poor sight distance conditions associated with the terrain or foliage.

Subjects from both age groups mentioned that they often felt that they had problems with gap length judgement and sight distance due to obstructions such as utility poles, street signs or foliage. These comments are consistent with the literature (Blumenfeld and Weiss, 1979).

CHAPTER 9

CONCLUSIONS and RECOMMENDATIONS

9.0 CONCLUSIONS

In general, older impaired drivers require longer to perceive and react to traffic conditions at T-intersections. The major specific conclusions of the study are:

1. Older drivers take longer to decide to make left turns at T-intersections and their driving behavior is much more inconsistent than younger drivers.

2. The relationship of decision time and functional level, which is a combination of age and impairment, shows that younger drivers with impairments are able to compensate in their driving behavior for their impairments. Older drivers, either with or without impairments, are not able to compensate in their driving behavior.

3. Younger male and female drivers are more evenly matched in their driving behavior, however there are differences in older male and female drivers which is most likely due to driving exposure and experience.

4. The effects of age overshadow the effects of glasses on decision time, but older drivers with glasses take longer to decide to make left turns at T-intersections.

5. Skewed intersections which require drivers to look over their shoulders to make a judgment of gap length cause the most difficulty for drivers with neck limitations.

6. Traffic volume has more of an effect on decision time than does sight distance, although subjects mentioned that a lack of sufficient sight distance is a major problem in judging gap length.

9.0.1 Implications of the Conclusions

The major conclusion of the study is that older drivers require longer time to perceive and react to traffic conditions at T-intersections. There are two main implications of this conclusion on traffic safety.

1. Older drivers need to change their driving behavior to account for the changes in their reaction time. Special driving education courses exist to help mature drivers learn more about their own driving needs as well as to account for changes in traffic and roadway design. Better incentives for mature driver education such as lower insurance rates and easier license renewal procedures would encourage more older drivers to participate in driver improvement programs.
2. Traffic engineers need to account for drivers with diminished capacities in the design of intersections and roadways. The perception reaction time factor in the sight distance calculation should be increased, particularly at complex intersections. Other factors such as increased legibility of signs and visibility of pavement markings should also be considered.

9.1 RECOMMENDATIONS

The results of the study have shown that there is an increase in average decision time with age, and also with age and impairment level. These findings are based on a laboratory study, however further studies both in the laboratory and in the field are required to validate the results. The experimental observations indicated that there is a significant problem that requires further study associated with skewed intersections and drivers with limited neck movement. Further study is required to determine if there is any significant relationship between medication and average decision time, particularly for medications which are known to affect reaction time such as allergy, beta blockers and seizure medication.

9.1.1 Validation Studies

9.1.1.1 Laboratory studies

There were limitations associated with the laboratory study which could have had an effect on the outcome of the results. Chapter 6 Experimental Procedure, discussed many of the problems associated with the equipment and the experimental technique. Modifications of the equipment and techniques are required in future laboratory studies. These studies should incorporate the following changes in equipment and experimental techniques:

1. A wider field of view of the intersection is required. This can be accomplished by either using cameras with wider lens angles or more

cameras. In any event, all cameras should function exactly the same and have the same speeds for their internal mechanisms.

2. Intersection filming should permit more flexibility in the degrees of freedom to accommodate variations in terrain and intersection geometry, such as those which are skewed. For example, the cameras should not be constrained to a horizontal platform and a straight ahead orientation. Protection should also be provided for the vehicle when it is filming the intersection.

3. There should be a procedure for editing and synchronizing the video tapes, and the video tape players should be of good quality so that they can all be synchronized. The video players should not be too heat sensitive to avoid distortion of the tapes which destroys synchronization.

4. Three point seat belt restraint systems should be incorporated into the driving simulator and their effect on driving performance of drivers with neck limitations should also be studied. The restraints will help with experimental control.

5. The data acquisition equipment should be adaptable enough to allow for repeated playback of intersection presentations when there are errors, automatic data tagging, minor real time data reduction, rapid scan rate for head turn measurements, both analog and digital data collection and consistency in data recording.

9.1.1.2 Field Studies

Field studies are required for validation of the experimental results and for the transfer of findings to the real world situation. The field studies should be conducted using an instrumented vehicle. The field studies would examine the effect of three point seat restraint systems, use and influence of rear and side mirrors on driving performance as well as the other variables which can not be studied in the laboratory.

9.1.1.3. Applications

Both the laboratory and field studies should establish base line data for drivers who are unimpaired and in three age segments; young (20-35), middle age (40-55) and older (60-75). Once the baseline information has been established then impaired drivers in the same age groups should be studied.

An application of both laboratory and field studies would be to compare the driving performance of subjects that are either impaired or unimpaired at intersections with 90 degree and skewed geometrics.

9.1.2. Medication Studies

The study of the effects of various medications on driving performance should be conducted in the laboratory due to the obvious risks of field study. The strategy and film scenarios which are developed for the validation studies can be applied for the medication study. Pharmacologists should be consulted and participate in the study. The medication study should be stratified with respect to age and should be structured to validate the current literature on the effects on driving performance of medication and age, with particular emphasis on drug interactions.

9.1.3 Closure

Further studies are required to validate the findings of this study, and to transfer these findings to "real world" applications. The skewed intersection problem is suggested as an application which requires further study. The literature suggests the need to examine the relationship of certain medications and age effects on driving performance.

BIBLIOGRAPHY

Aging America: Trends and Projections,(1985-86 ed.), U.S. Senate Special Commission on Aging, Washington, D.C.

Allen, R.W., Jex, H.R.,(1980) "Driving Simulation-Requirements, Mechanization and Application", SAE.Technical Paper Series, No.800448.

Alexander, G., Lunenfeld,H.A., (1977), Positive Guidance in Traffic Control, Federal Highway Administration, Washington, D.C., US Department of Transportation.

Blaauw, G.J.,(1982) "Driving Experience and Task Demands in Simulator and Instrumented Car: A Validation Study", Human Factors, Vol.24, No.4, p.473-486

Blumenfeld, D.E. and Weiss, G.H.,(1979) "The Effects of Gap Acceptance Criteria on Merging Delay and Capacity at an Uncontrolled Intersection", Traffic Engineering and Control, Vol. 20, No. 1. p.16-20.

Botwinick, J., Brinley, J.F. Birren, J.E,(1957) "Set in Relation to Age", Journal of Gerontology, Vol.12, No.3, p.300-305.

Brainin, P.A., Naughton, T.J., Breedlove, R.M.,(1977), Impact Study on Driving by Special Populations, Final Report, Volume 1 and Volume 2, National Highway Traffic Safety Administration, Washington D.C., Report No. DOT-HS-802 329.

Brainin, P.A.(1980), Safety and Mobility Issues in Licensing and Education of Older Drivers, National Highway Traffic Safety Administration, Washington, D.C.,Report No. DOT-HS-805-492

Burg, A.(1968),"Lateral Visual Field as related to Age and Sex", Journal of Applied Psychology, Vol.52, p10-15

Cooper, D.F., Storr, P.A., Wennell, J., (1977), "Traffic Studies at T-Junctions" Traffic Engineering and Control, Vol. 18, No. 3. p.110-112.

Cooper , D.F., Wennell, J., (1978),"Models of Gap Acceptance by Queues at intersections ", Traffic Engineering and Control, Vol. 19, No. 4.

David, N.A., Norman, J.R.,(1976), Motor Vehicle Accidents in Relation to Geometric and Traffic Features of Highway Intersections, Volume 1-3, Federal Highway Administration, Washington D.C., Report No. FHWA/76/128.

Freedman, M. Davit, P.S., Staplin, L.K., Breton, M.E.,(1985), Traffic Signal Brightness: An Examination of Nighttime Dimming, Federal Highway Administration, Washington D.C., Report No. FHWA/RD-85/005.

Gordon, D.A., McGee, H.W., Hooper, K.G.,(1984),"Driver Characteristics Impacting Highway Design and Operations", Public Roads, Vol.48, No.1, p.12-16.

Greenshields, B.D.(1965), "The Driver", The Traffic Engineering Handbook, Institute of Transportation Engineers, Washington, D.C., 3rd.ed.

Grubb, Monty,(1986) Driver Behavior at Intersections: An Analysis of Accident Related Variables,unpublished.

Hagen, R.E.(1975),"Sex Differences in Driving Performance", Human Factors, Vol.17, No.2, p.165-171.

Henderson, R.L.,ed,(1986) Driver Performance Data Book, National Highway Traffic Safety Administration, U.S. Department of Transportation, Washington D.C.

Hicks, T.G., Wierwille, W.W.,(1979),"Comparison of Five Mental Workload Assessment Procedures in a Moving Base Simulator", Human Factors, Vol. 21, No. 2, p.129-143.

Highway Capacity Manual, (1985), Transportation Research Board, Washington D.C.

Hooper, K. G.,McGee H.W.,(1983), "Driver Perception-Reaction Time: Are Revisions to Current Specification Values in Order?" Transportation Research Board, Washington D.C., Transportation Research Record, No. 904, p.21.

Hooper, K. G., McGee H.W.,(1983), "Corrections to Driver Characteristic Specifications and Standard Formulations for Intersection Sight Distance(Abridgement)", Transportation Research Board, Washington D.C., Transportation Research Record No. 904, p.30.

Hostetter, R.S., McGee, H.W., Crowley, K.W., Seguin, E.L., Dauber, G.W.,(1986), Improved Perception-Reaction Time Information for Intersection Sight Distance Volume 1 Report of Research, Federal Highway Administration Report No. FHWA/RD-86.

Hulbert, S.,(1961),"The Driving Simulator", Proceedings of the 13th California Street and Highway Conference, ITTE, University of California, Berkeley, January 26-28, 1961.

Hulbert, S.F., Burg, A.,(1970) "Human Factors in Transportation Systems", Systems Psychology, Kenyon B.DeGreene ed., New York, McGraw Hill.

Johansson, G., Rumar, K.(1971), "Driver's Brake Reaction Time", Human Factors, Vol.13, No.1, p.23-27.

Leonard, J.J., Wierwille, W.W.,(1975), "Human Performance Validation of Simulators: Theory and Experimental Verification", Proceedings Human Factors Society 19th Annual Meeting, Dallas, Texas, October 14-16, p. 446-456.

Malfetti, J.L. Ed.,(1985),"Drivers 55+: Needs and Problems of Older Drivers:Survey Results and Recommendations", Proceedings of the Older Drivers Colloquim,Orlando, Florida.

Mathewson, J. H.,(1958), "Some Potentials of a Driving Simulator", Proceedings of the 10th California Street and Highway Conference, ITTE, University of California, Los Angeles, January 29-31.

McGee, H.W., Moore, W., Knapp, B.G., Sanders, J.H.,(1978), Decision Sight Distance for Highway Design and Traffic Control Requirements,Federal Highway Administration, Washington D.C., Report No. FHWA/RD-78/78.

McGee, H.W., Hooper, K.G., Hughes, W.E., Benson, W.,(1983) Highway Design and Operations Standards Affected By Driver Characteristics, Volume 1: Final Technical Report, Federal Highway Administration, Washington D.C.,Report No.FHWA/RD-83/015.

Moore, R.L., Sedgley, I.P., Sabey, B.E.,(1982), "Ages of Car Drivers Involved in Accidents, with Special Reference to Junctions", Transport and Road Research Laboratory Supplementary Report No. 718, TRRL, Crowthorne, Berkshire, U.K.

Moraal, J., Kraiss, K.F., (1981) "Evaluating Simulator Validity", Manned Systems Design: Methods, Equipment, and Applications,Plenum Press, New York, p.411-426.

Panek, P.E., Barrett, G.V., Stearns, H.L., and Alexander, R.A.,(1977), "A review of age changes in perceptual information process ability with regard to driving", Experimental Aging Research, Vol.3., No.6, p.387-449.

Planck, T.W., Fowler, R.C., (1971), " Traffic Accident Problems and Exposure Characteristics of the Aging Driver", Journal of Gerontology, Vol.26, No.2., p.133-136.

A Policy on Geometric Design of Highways and Streets 1965, American Association of State Highway and Transportation Officials,Washington D.C.

A Policy on Geometric Design of Highways and Streets 1984, American Association of State Highway and Transportation Officials,Washington D.C.

Polus, A., (1983),"Gap Acceptance Characteristics at Unsignalized Urban Intersections", Traffic Engineering and Control, Vol. 24, No. 5, p.255-258.

Polus, A.,(1985)"Driver Behavior and Accident Records at Unsignalized urban intersections", Accident Analysis and Prevention, Vol.17, p.25-32.

Ratanaubol, U., Harvey, R.,(1985),"Accident and Violation Rate of Handicapped Drivers", Alabama Medicine, August 1985.

Rees, J.N., Botwinick, J.,(1971)," Detection and Decision Factors in Auditory Behavior of the Elderly", Journal of Gerontology, Vol. 26, No.2, p.133-136.

Sivak, M., Olson, P.L.,(1982),"Nighttime Legibility of Traffic Signs: conditions eliminating the effects of driver age and disability glare", Accident Analysis and Prevention, Vol.14, p.87-93.

Sivak, M., Olson, P.L., Pastalan, L.A.,(1981), "Effect of Drivers'Age on Nighttime Legibility of Highway Signs", Human Factors, Vol.23, No.1., p59-64.

Staplin, L.K., Breton, M.E., Haimo, S.F., Farber, E.I., and Byrnes, A.,(1986),"Age Related Diminished Capabilities and Driver Performance", A Working Paper Submitted to FHWA Contract No.DTFH61-86-C-00044.

U.S. Bureau of the Census, Decennial Census, 1980 and Projections of the Population of the United States by Sex and Race: 1983 to 2050, Series P-25, No. 952.

U.S. Department of Transportation,(1980), Highway Statistics.

Welford, A.T.,(1981), "Signal noise, performance and age", Human Factors, Vol 23, p.97-109.

Wennel, J., Cooper, D.F.,(1981), "Vehicle and Driver Effects on Junction Gap Acceptance", Traffic Engineering and Control, Vol. 22, No. 12., p.628-632.

Yanik, A.J.,(1985) "What Accident Data Reveal about Elderly Drivers", SAE Technical Paper Series N851688, September.

Yanik, A.J.,(1986) "Aging Factors that Affect the Driving Task", Fourth International Conference on Mobility and Transport for Elderly and Disabled Persons, Vancouver, 1986.

OTHER REFERENCES

Davis, B.T., Watts, J. M.(1970)"Further Investigations of Movement Time between Brake and Acceleration Pedal in Automobiles", Human Factors, Vol.12, No.6, p.559-561.

Glencross, D.J. Anderson, G.A.,(1976),"Operator Response Factors in the Location and Control of Foot Pedals", Ergonomics, Vol.19, p.399-408.

Knowles , W.B.,(1963), "Operator Loading Tasks",Human Factors, April, p.155-161.

Koppa, R.D., McDermott, M., Raab, C., Sexton, D.J., (1980), Human Factors Analysis of Automobile Adaptive Equipment for Disabled Drivers, National Highway Traffic Safety Administration, Washington, D.C.,Report No. DOT-HS-805-726.

Less, M., Colverd, E.G., Dillon, J.J.,Young,J.,(1977), Hand Controls and Assistive Devices for the Physically Disabled Driver, Human Resources Center, Albertson, New York.

Less, M., Colverd, E.G., DeMauro, G.E.,Young,J.,(1978), Evaluating Driving Potential of Persons with Physical Disabilites, Human Resources Center, Albertson, New York.

Mounce, J. M.,(1981)"Driver Compliance with Stop-Sign Control at Low-Volume Intersections", Transportation Research Board, Washington D.C., Research Record No.808, p.30.

Negri, D.B.,(1978), Accidents Involving Handicapped Drivers, U.S. Department of Transportation, Washington D.C.,Report No.DOT-HS-803 610.

Negri, B.D., Ibison, R.(1979),"Accidents Involving Handicapped Drivers", Journal of Traffic Medicine, Vol. 7, No.2, p.23-26.

Norton, C. P.,(1982), A Comparison of the Driving Skills of Paraplegic and Able-Bodied Individuals, Ph.D. Dissertation, University of Tennessee, Knoxville.

Rhoads, M.D.(1974),"Filling the Needs of the Handicapped Driver", Traffic Safety, Vol.74, No.2, p.26-7, 35-7.

Risk, H.F.,(1983) Force Capabilities of the Physically Handicapped at Selected Automobile Driving Controls, Ph. D. Dissertation, Southern Illinois University at Carbondale.

Rutley, K.S., Mace, D.G.W.,(1972)"Heart Rate as a Measure in Road Layout Design", Ergonomics, Vol.15, No.2, p.165-173.

Snyder, H.L., (1976),"Braking Movement Time and Accelerator and Brake Separation", Human Factors, Vol.18, p.201-204.

Summala, Heikki,(1981),"Driver/Vehicle Steering Response Latencies", Human Factors, Vol.23, No.6, p.683-692.

APPENDICES

APPENDIX A

INSTRUCTION SHEET

Hello, you are about to be shown a series of driving situations in which you will view the scene from the perspective of a driver in a vehicle stopped at a T-intersection. Please sit and hold the steering wheel as if you were driving and depress the brake pedal. The three screens in front of you will provide a wide field of view of intersections. As soon as the scene begins you will be faced with a decision about when to proceed to turn left. Release the brake pedal when you think you are ready to turn. Please respond only when there is sufficient time between vehicles to successfully complete your turning maneuver. There may be some intersections where there is never a sufficiently long gap to proceed. In that instance, just keep your foot on the brake.

After the intersection has been presented, the screens will go blank, during that time you will be asked to rate the intersection according to a rating scale concerning overall difficulty, sight distance and traffic volume. I will note your response. There will be time to relax while I am setting up the tapes for each intersection.

Before we begin with the actual study scenes we would like to provide you with two intersections. Do not worry about remembering all these instructions. By the time you have finished the two practice intersections you will be familiar with the tasks.

Thank you for volunteering and have fun!

RECORD OF INFORMED CONSENT

Part 46, Subtitle A to Title 45 of the Code of Federal Regulations relating to the Protection of Human Subjects in research requires your informed consent for participation in Federal Highway Administration driving studies. Section 46.103(c) gives the following definition: "Informed consent means the knowing consent of an individual or his legal authorized representative, so situated as to be able to exercise free legal power of choice, without undue inducement to any element of force, fraud, deceit, duress, or other form of constraint. " Your participation as a subject in a study to evaluate driving behavior at intersections is requested. Please consider the following elements of information in reaching your decision whether or not to consent.

1. You will be asked for biographical information necessary to the study. Your visual field, and static head movement will be measured. All information provided is confidential and the source of information will not be disclosed to the public.

2. You will drive a driving simulator, and will watch three video screens. You will be asked to wear a piece of equipment that will measure head movement. You will be given time to adjust to the equipment and practice intersections.

3. The test session will take about an hour. You will not be subjected to any risks.

4. You are free to decline consent, to withdraw consent and discontinue participation in the session at any time.

5. Upon completion of the session, you will be paid $25.00 for your participation. You must complete the entire session to receive full remuneration.

The basic elements of information have been presented and understood by me, and I consent to participate as a subject.

NAME:(Please Print)________________________________

SIGNATURE:______________________________

DATE:________________________

Subject Information Form

Subject Name______________________________ Code

Subject Number:_____ _____

Age:_____ _____

Age Code: 1 2 (1=30-50,2=60-80) _

Sex: 1 = M 2 = F _

Disability:______________________________
Disability Code: 1 2 (1=none, 2=some) _

Glasses: 1 = Yes, 2 = No _

Medication:______________________________
Medication Code: 1 = Yes 2 = No _

Reason
1 Heart & Circulation _
2 Arthritis
3 Depression etc.
4 Diabetes
5 Other ___________________________

Static ROM
Left_____
Right_____
Total_____ _____

Visual Field
Left_____
Right_____
Total_____ _____

Total of ROM and Visual Field _____ _____

Impairment Code: 1 > 285 2 < 284 _

Functional Level Code: _
1 = Age 30-50 No Impairment
2 = Age 30-50 Impairment
3 = Age 60-80 No Impairment
4 = Age 60-80 Impairment

APPENDIX B
STATISTICAL DATA

TOTAL FOR SUBJECTS AND INTERSECTIONS
ANOVA ANALYSIS

RELATIONSHIP: AVERAGE DECISION TIME VERSUS AGE CODE

SOURCE OF VARIATION	DEGREES OF FREEDOM	SUM OF SQUARES	MEAN SQUARE	F	C.V.	P
TOTAL	60	850.46				
AGE CODE	1	56.99	56.99	4.24	29.88	0.04
ERROR	59	793.47	13.45			

RELATIONSHIP: AVERAGE DECISION TIME VERSUS SEX

SOURCE OF VARIATION	DEGREES OF FREEDOM	SUM OF SQUARES	MEAN SQUARE	F	C.V.	P
TOTAL	60	850.46				
SEX	1	0.08	0.08	0.01	30.93	0.94
ERROR	59	850.38	14.41			

RELATIONSHIP: AVERAGE DECISION TIME VERSUS IMPAIRMENT CODE

SOURCE OF VARIATION	DEGREES OF FREEDOM	SUM OF SQUARES	MEAN SQUARE	F	C.V.	P
TOTAL	60	850.46				
IMPAIRMENT	1	0.53	0.54	0.04	30.92	0.85
ERROR	59	849.93	14.40			

RELATIONSHIP: AVERAGE DECISION TIME VERSUS GLASSES

SOURCE OF VARIATION	DEGREES OF FREEDOM	SUM OF SQUARES	MEAN SQUARE	F	C.V.	P
TOTAL	60	850.46				
GLASSES	1	3.92	3.92	0.27	30.86	0.60
ERROR	59	846.54	14.35			

INTERSECTION and SUBJECT TOTALS CONTINUED

RELATIONSHIP: AVERAGE DECISION TIME VERSUS MEDICATION

SOURCE OF VARIATION	DEGREES OF FREEDOM	SUM OF SQUARES	MEAN SQUARE	F	C.V.	P
TOTAL	60	850.46				
MEDICATION	1	29.18	29.18	2.10	30.40	0.15
ERROR	59	821.28	13.92			

RELATIONSHIP: AVERAGE DECISION TIME VERSUS FUNCTIONAL LEVEL

SOURCE OF VARIATION	DEGREES OF FREEDOM	SUM OF SQUARES	MEAN SQUARE	F	C.V.	P
TOTAL	60	850.46				
FUNCTION LV	3	95.12	31.71	2.39	29.66	0.08
ERROR	57	755.34	13.25			

RELATIONSHIP: AVERAGE DECISION TIME VERSUS AGE CODE AND SEX CODE

SOURCE OF VARIATION	DEGREES OF FREEDOM	SUM OF SQUARES	MEAN SQUARE	F	C.V.	P
TOTAL	60	850.46				
MODEL	3	75.68	25.22	1.86	30.04	0.15
ERROR	57	774.79	13.59			
SOURCE						
AGE	1	57.00		4.19		0.05
SEX	1	6.33		0.47		0.49
AGE+SEX	1	12.35		0.35		0.34

RELATIONSHIP: AVERAGE DECISION TIME VERSUS AGE CODE AND GLASSES

SOURCE OF VARIATION	DEGREES OF FREEDOM	SUM OF SQUARES	MEAN SQUARE	F	C.V.	P
TOTAL	60	850.46				
MODEL	3	73.07	24.36	1.79	30.09	0.16
ERROR	57	777.39	13.64			
SOURCE						
AGE CODE	1	56.99	56.99	4.17		0.045
GLASSES	1	0.35	0.35	0.03		0.87
AGE+GLASSES	1	15.73		1.15		0.29

INTERSECTION and SUBJECT TOTALS CONTINUED

RELATIONSHIP: AVERAGE DECISION TIME VERSUS AGE CODE AND IMPAIRMENT CODE

SOURCE OF VARIATION	DEGREES OF FREEDOM	SUM OF SQUARES	MEAN SQUARE	F	C.V.	P
TOTAL	60	850.46				
MODEL	3	63.45	21.15	1.53	30.27	0.22
ERROR	57	787.02	13.81			
SOURCE						
AGE	1	57.00		4.19		0.05
IMPAIRMENT	1	2.68		0.19		0.66
AGE+IMPAIRMENT	1	3.77		0.27		0.60

RELATIONSHIP: AVERAGE DECISION TIME VERSUS AGE CODE, SEX CODE AND MEDICATION CODE

SOURCE OF VARIATION	DEGREES OF FREEDOM	SUM OF SQUARES	MEAN SQUARE	F	C.V.	P
TOTAL	60	850.46				
MODEL	7	111.18	15.88	1.14	30.43	0.35
ERROR	53	739.27	13.95			
SOURCE						
AGE CODE	1	56.99		4.09		0.05
SEX CODE	1	6.33		0.45		0.50
AGE+SEX	1	12.35		0.89		0.35
MED CODE	1	33.76		2.42		0.13
AGE+MED	1	0.27		0.02		0.89
SEX+MED	1	1.45		0.10		0.75
AGE+SEX+MED	1	0.03		0.00		0.96

RELATIONSHIP: AVERAGE DECISION TIME VERSUS AGE CODE, SEX CODE AND IMPAIRMENT CODE

SOURCE OF VARIATION	DEGREES OF FREEDOM	SUM OF SQUARES	MEAN SQUARE	F	C.V.	P
TOTAL	60	850.46				
MODEL	7	79.46	11.35	0.78	31.07	0.61
ERROR	53	771.00	14.55			
SOURCE						
AGE CODE	1	56.99		3.92		0.05
SEX CODE	1	6.33		0.44		0.51
AGE+SEX	1	12.35		0.85		0.36
IMPAIRMENT	1	0.08		0.01		0.94
AGE+IMP	1	1.02		0.07		0.79
SEX+IMP	1	2.11		0.14		0.71
AGE+SEX+IMP	1	0.58		0.04		0.84

SUMMARY OF MEANS AND STANDARD DEVIATION TOTAL FOR SUBJECTS AND INTERSECTIONS

RELATIONSHIP: AVERAGE DECISION TIME VERSUS AGE

AVERAGE DECISION TIME	N	MEAN	STANDARD DEVIATION
30-50	31	11.324	3.45
60-80	30	13.257	3.88

RELATIONSHIP: AVERAGE DECISION TIME VERSUS SEX

AVERAGE DECISION TIME	N	MEAN	STANDARD DEVIATION
MALE	24	12.229	3.63
FEMALE	37	12.304	3.47

RELATIONSHIP: AVERAGE DECISION TIME VERSUS IMPAIRMENT

AVERAGE DECISION TIME	N	MEAN	STANDARD DEVIATION
NO IMPAIRMENT	26	12.283	3.36
SOME IMPAIRMENT	35	12.194	4.09

RELATIONSHIP: AVERAGE DECISION TIME VERSUS FUNCTIONAL LEVEL
(Functional level = age code, impairment code)

AVERAGE DECISION TIME	N	MEAN	STANDARD DEVIATION
1 30-50 NO IMPAIRMENT	16	11.296	2.87
2 30-50 IMPAIRMENT	15	11.353	4.09
3 60-80 NO IMPAIRMENT	15	12.130	3.08
4 60-80 IMPAIRMENT	15	14.384	4.35

RELATIONSHIP: AVERAGE DECISION TIME VERSUS GLASSES

AVERAGE DECISION TIME	N	MEAN	STANDARD DEVIATION
GLASSES	35	12.493	3.89
NO GLASSES	26	11.980	3.65

RELATIONSHIP: AVERAGE DECISION TIME VERSUS MEDICATION

AVERAGE DECISION TIME	N	MEAN	STANDARD DEVIATION
MEDICATION	26	11.472	3.71
NO MEDICATION	35	12.871	3.74

INTERSECTION and SUBJECT TOTALS CONTINUED

RELATIONSHIP: AVERAGE DECISION TIME VERSUS AGE AND SEX

AVERAGE DECISION TIME	N	MEAN	STANDARD DEVIATION
30-50, MALE	8	11.612	2.95
30-50, FEMALE	23	11.223	3.67
60-80, MALE	16	12.537	3.97
60-80, FEMALE	14	14.080	3.73

RELATIONSHIP: AVERAGE DECISION TIME VERSUS AGE AND GLASSES

AVERAGE DECISION TIME	N	MEAN	STANDARD DEVIATION
30-50, GLASSES	15	10.904	3.63
30-50, NO GLASSES	16	11.717	3.35
60-80, GLASSES	20	13.684	3.72
60-80, NO GLASSES	10	12.402	4.24

RELATIONSHIP: AVERAGE DECISION TIME VERSUS AGE AND IMPAIRMENT

AVERAGE DECISION TIME	N	MEAN	STANDARD DEVIATION
30-50, NO IMPAIRMENT	15	11.296	2.97
30-50, IMPAIRMENT	16	11.349	3.95
60-80, NO IMPAIRMENT	11	13.865	3.41
60-80, IMPAIRMENT	19	12.905	4.17

RELATIONSHIP: AVERAGE DECISION TIME VERSUS AGE, SEX, & MEDICATION

AVERAGE DECISION TIME	N	MEAN	STANDARD DEVIATION
30-50, MALE, MEDICATION	1	11.060	0.00
30-50, MALE, NO MEDICATION	7	11.691	3.17
30-50, FEMALE, MEDICATION	10	10.341	3.88
30-50, FEMALE, NO MEDICATION	13	11.902	3.50
60-80, MALE, MEDICATION	10	12.012	3.91
60-80, MALE, NO MEDICATION	6	13.412	4.28
60-80, FEMALE, MEDICATION	5	12.736	3.46
60-80, FEMALE, NO MEDICATION	9	14.827	3.86

INTERSECTION and SUBJECT TOTALS CONTINUED

RELATIONSHIP: AVERAGE DECISION TIME VERSUS AGE, SEX, & IMPAIRMENT

AVERAGE DECISION TIME	N	MEAN	STANDARD DEVIATION
30-50, MALE, NO IMPAIRMENT	6	11.493	2.56
30-50, MALE, IMPAIRMENT	2	11.970	5.26
30-50, FEMALE, NO IMPAIRMENT	9	11.164	3.35
30-50, FEMALE, IMPAIRMENT	14	11.260	3.97
60-80, MALE, NO IMPAIRMENT	3	12.220	0.73
60-80, MALE, IMPAIRMENT	13	12.610	4.43
60-80, FEMALE, NO IMPAIRMENT	8	14.483	3.86
60-80, FEMALE, IMPAIRMENT	6	13.543	3.84

ANOVA ANALYSIS FOR INTERSECTION WITH POOR SIGHT DISTANCE AND LOW VOLUME

RELATIONSHIP: AVERAGE DECISION TIME VERSUS AGE CODE

SOURCE OF VARIATION	DEGREES OF FREEDOM	SUM OF SQUARES	MEAN SQUARE	F	C.V.	P
TOTAL	60	410.17				
AGE CODE	1	38.34	38.34	6.08	31.96	0.02
ERROR	59	371.83	6.30			

RELATIONSHIP: AVERAGE DECISION TIME VERSUS SEX

SOURCE OF VARIATION	DEGREES OF FREEDOM	SUM OF SQUARES	MEAN SQUARE	F	C.V.	P
TOTAL	60	410.17				
SEX	1	15.87	15.87	2.38	32.91	0.13
ERROR	59	394.30	6.68			

RELATIONSHIP: AVERAGE DECISION TIME VERSUS IMPAIRMENT CODE

SOURCE OF VARIATION	DEGREES OF FREEDOM	SUM OF SQUARES	MEAN SQUARE	F	C.V.	P
TOTAL	60	410.17				
IMPAIRMENT	1	19.85	19.85	3.00	32.75	0.08
ERROR	59	390.33	6.62			

RELATIONSHIP: AVERAGE DECISION TIME VERSUS GLASSES

SOURCE OF VARIATION	DEGREES OF FREEDOM	SUM OF SQUARES	MEAN SQUARE	F	C.V.	P
TOTAL	60	410.17				
GLASSES	1	18.26	18.26	2.75	32.81	0.10
ERROR	59	391.91	6.64			

RELATIONSHIP: AVERAGE DECISION TIME VERSUS MEDICATION

SOURCE OF VARIATION	DEGREES OF FREEDOM	SUM OF SQUARES	MEAN SQUARE	F	C.V.	P
TOTAL	60	410.17				
MEDICATION	1	7.97	7.97	1.17	33.24	0.28
ERROR	59	402.20	6.82			

INTERSECTION WITH POOR SIGHT DISTANCE AND LOW VOLUME CONTINUED

RELATIONSHIP: AVERAGE DECISION TIME VERSUS FUNCTIONAL LEVEL

SOURCE OF VARIATION	DEGREES OF FREEDOM	SUM OF SQUARES	MEAN SQUARE	F	C.V.	P
TOTAL	60	410.17				
FUNCTION LV	3	84.66	28.22	4.94	30.43	0.00
ERROR	57	755.34	13.25			

RELATIONSHIP: AVERAGE DECISION TIME VERSUS AGE CODE AND SEX CODE

SOURCE OF VARIATION	DEGREES OF FREEDOM	SUM OF SQUARES	MEAN SQUARE	F	C.V.	P
TOTAL	60	410.17				
MODEL	3	46.55	15.52	2.43	32.16	0.07
ERROR	57	363.62	6.38			
SOURCE						
AGE	1	38.34		6.01		0.02
SEX	1	5.45		0.85		0.36
AGE+SEX	1	2.76		0.43		0.51

RELATIONSHIP: AVERAGE DECISION TIME VERSUS AGE CODE AND GLASSES

SOURCE OF VARIATION	DEGREES OF FREEDOM	SUM OF SQUARES	MEAN SQUARE	F	C.V.	P
TOTAL	60	410.17				
MODEL	3	58.22	19.41	3.14	31.64	0.03
ERROR	57	351.95	6.17			
SOURCE						
AGE CODE	1	38.34		6.21		0.015
GLASSES	1	10.14		1.64		0.21
AGE+GLASSES	1	9.74		1.58		0.21

RELATIONSHIP: AVERAGE DECISION TIME VERSUS AGE CODE AND IMPAIRMENT CODE

SOURCE OF VARIATION	DEGREES OF FREEDOM	SUM OF SQUARES	MEAN SQUARE	F	C.V.	P
TOTAL	60	410.17				
MODEL	3	58.29	19.43	3.15	31.63	0.03
ERROR	57	351.88	6.17			
SOURCE						
AGE	1	38.34		6.21		0.02
IMPAIRMENT	1	14.04		2.28		0.14
AGE+IMPAIRMENT	1	5.90		0.96		0.33

INTERSECTION WITH POOR SIGHT DISTANCE AND LOW VOLUME CONTIUNED

RELATIONSHIP: AVERAGE DECISION TIME VERSUS AGE CODE, SEX CODE AND MEDICATION CODE

SOURCE OF VARIATION	DEGREES OF FREEDOM	SUM OF SQUARES	MEAN SQUARE	F	C.V.	P
TOTAL	60	410.17				
MODEL	7	77.48	11.07	1.76	31.89	0.11
ERROR	53	332.69	6.27			
SOURCE						
AGE CODE	1	38.34		6.11		0.02
SEX CODE	1	5.45		0.87		0.36
AGE+SEX	1	2.76		0.44		0.51
MED CODE	1	12.09		1.93		0.17
AGE+MED	1	13.61		2.17		0.15
SEX+MED	1	4.10		0.65		0.42
AGE+SEX+MED	1	1.12		0.18		0.67

RELATIONSHIP: AVERAGE DECISION TIME VERSUS AGE CODE, SEX CODE AND IMPAIRMENT CODE

SOURCE OF VARIATION	DEGREES OF FREEDOM	SUM OF SQUARES	MEAN SQUARE	F	C.V.	P
TOTAL	60	410.17				
MODEL	7	85.91	12.27	2.01	31.49	0.07
ERROR	53	324.26	6.11			
SOURCE						
AGE CODE	1	38.34		6.27		0.02
SEX CODE	1	5.45		0.89		0.35
AGE+SEX	1	2.76		0.45		0.50
IMPAIRMENT	1	20.29		3.32		0.07
AGE+IMP	1	3.66		0.60		0.44
SEX+IMP	1	3.51		0.57		0.45
AGE+SEX+IMP	1	11.88		1.94		0.17

SUMMARY OF MEANS AND STANDARD DEVIATION FOR INTERSECTION WITH POOR SIGHT DISTANCE AND LOW VOLUME

RELATIONSHIP: TOTAL DECISION TIME VERSUS AGE

TOTAL DECISION TIME	N	MEAN	STANDARD DEVIATION
30-50	31	7.074	1.85
60-80	30	8.660	3.04

INTERSECTION WITH POOR SIGHT DISTANCE AND LOW VOLUME CONTINUED

RELATIONSHIP: TOTAL DECISION TIME VERSUS SEX

TOTAL DECISION TIME	N	MEAN	STANDARD DEVIATION
MALE	24	8.487	3.17
FEMALE	37	7.444	2.13

RELATIONSHIP: TOTAL DECISION TIME VERSUS IMPAIRMENT

TOTAL DECISION TIME	N	MEAN	STANDARD DEVIATION
NO IMPAIRMENT	26	7.192	2.30
SOME IMPAIRMENT	35	8.346	2.75

RELATIONSHIP: TOTAL DECISION TIME VERSUS FUNCTIONAL LEVEL
(Functional level = age code, impairment code)

TOTAL DECISION TIME	N	MEAN	STANDARD DEVIATION
1 30-50 NO IMPAIRMENT	16	6.818	2.00
2 30-50 IMPAIRMENT	15	7.346	1.70
3 60-80 NO IMPAIRMENT	15	7.446	2.27
4 60-80 IMPAIRMENT	15	9.873	3.30

RELATIONSHIP: TOTAL DECISION TIME VERSUS GLASSES

TOTAL DECISION TIME	N	MEAN	STANDARD DEVIATION
GLASSES	35	8.325	2.96
NO GLASSES	26	7.219	1.92

RELATIONSHIP: TOTAL DECISION TIME VERSUS MEDICATION

TOTAL DECISION TIME	N	MEAN	STANDARD DEVIATION
MEDICATION	26	7.435	2.02
NO MEDICATION	35	8.165	2.97

RELATIONSHIP: AVERAGE DECISION TIME VERSUS AGE AND SEX

AVERAGE DECISION TIME	N	MEAN	STANDARD DEVIATION
30-50, MALE	8	7.925	2.15
30-50, FEMALE	23	6.778	1.68
60-80, MALE	16	8.768	3.60
60-80, FEMALE	14	8.535	2.38

INTERSECTION WITH POOR SIGHT DISTANCE AND LOW VOLUME CONTINUED

RELATIONSHIP: AVERAGE DECISION TIME VERSUS AGE AND GLASSES

AVERAGE DECISION TIME	N	MEAN	STANDARD DEVIATION
30-50, GLASSES	15	7.113	1.89
30-50, NO GLASSES	16	7.037	1.87
60-80, GLASSES	20	9.235	3.33
60-80, NO GLASSES	10	7.510	2.06

RELATIONSHIP: AVERAGE DECISION TIME VERSUS AGE AND IMPAIRMENT

AVERAGE DECISION TIME	N	MEAN	STANDARD DEVIATION
30-50, NO IMPAIRMENT	15	6.880	2.05
30-50, IMPAIRMENT	16	7.256	1.68
60-80, NO IMPAIRMENT	11	7.618	2.64
60-80, IMPAIRMENT	19	9.263	3.16

RELATIONSHIP: AVERAGE DECISION TIME VERSUS AGE, SEX, & MEDICATION

AVERAGE DECISION TIME	N	MEAN	STANDARD DEVIATION
30-50, MALE, MEDICATION	1	7.800	0.00
30-50, MALE, NO MEDICATION	7	7.943	2.33
30-50, FEMALE, MEDICATION	10	6.850	2.21
30-50, FEMALE, NO MEDICATION	13	6.723	1.23
60-80, MALE, MEDICATION	10	7.750	1.76
60-80, MALE, NO MEDICATION	6	10.466	5.27
60-80, FEMALE, MEDICATION	5	7.900	2.47
60-80, FEMALE, NO MEDICATION	9	8.888	2.41

RELATIONSHIP: AVERAGE DECISION TIME VERSUS AGE, SEX, & IMPAIRMENT

AVERAGE DECISION TIME	N	MEAN	STANDARD DEVIATION
30-50, MALE, NO IMPAIRMENT	6	7.966	2.43
30-50, MALE, IMPAIRMENT	2	7.800	1.69
30-50, FEMALE, NO IMPAIRMENT	9	6.155	1.48
30-50, FEMALE, IMPAIRMENT	14	7.178	1.73
60-80, MALE, NO IMPAIRMENT	3	5.800	1.83
60-80, MALE, IMPAIRMENT	13	9.453	3.60
60-80, FEMALE, NO IMPAIRMENT	8	8.300	2.66
60-80, FEMALE, IMPAIRMENT	6	8.850	2.15

ANOVA ANALYSIS FOR INTERSECTION INTERSECTION WITH MIXED SIGHT DISTANCE AND LOW VOLUME

RELATIONSHIP: AVERAGE DECISION TIME VERSUS AGE CODE

SOURCE OF VARIATION	DEGREES OF FREEDOM	SUM OF SQUARES	MEAN SQUARE	F	C.V.	P
TOTAL	60	2771.64				
AGE CODE	1	85.94	85.94	1.89	116.46	0.18
ERROR	59	2685.70	45.52			

RELATIONSHIP: AVERAGE DECISION TIME VERSUS SEX

SOURCE OF VARIATION	DEGREES OF FREEDOM	SUM OF SQUARES	MEAN SQUARE	F	C.V.	P
TOTAL	60	2771.64				
SEX	1	29.31	29.31	0.63	117.68	0.43
ERROR	59	2742.32	46.48			

RELATIONSHIP: AVERAGE DECISION TIME VERSUS IMPAIRMENT CODE

SOURCE OF VARIATION	DEGREES OF FREEDOM	SUM OF SQUARES	MEAN SQUARE	F	C.V.	P
TOTAL	60	2771.64				
IMPAIRMENT	1	37.75	37.75	0.81	117.50	0.37
ERROR	59	2733.89	46.34			

RELATIONSHIP: AVERAGE DECISION TIME VERSUS GLASSES

SOURCE OF VARIATION	DEGREES OF FREEDOM	SUM OF SQUARES	MEAN SQUARE	F	C.V.	P
TOTAL	60	2771.64				
GLASSES	1	12.45	12.45	0.27	118.04	0.61
ERROR	59	2759.19	46.77			

RELATIONSHIP: AVERAGE DECISION TIME VERSUS MEDICATION

SOURCE OF VARIATION	DEGREES OF FREEDOM	SUM OF SQUARES	MEAN SQUARE	F	C.V.	P
TOTAL	60	2771.64				
MEDICATION	1	65.38	65.38	1.43	116.90	0.24
ERROR	59	2706.26	45.87			

INTERSECTION WITH MIXED SIGHT DISTANCE AND LOW VOLUME CONTINUED

RELATIONSHIP: AVERAGE DECISION TIME VERSUS FUNCTIONAL LEVEL

SOURCE OF VARIATION	DEGREES OF FREEDOM	SUM OF SQUARES	MEAN SQUARE	F	C.V.	P
TOTAL	60	2771.64				
FUNCTION LV	3	368.72	122.91	2.92	112.07	0.04
ERROR	57	2402.91	42.16			

RELATIONSHIP: AVERAGE DECISION TIME VERSUS AGE CODE AND SEX CODE

SOURCE OF VARIATION	DEGREES OF FREEDOM	SUM OF SQUARES	MEAN SQUARE	F	C.V.	P
TOTAL	60	2771.64				
MODEL	3	94.64	31.55	0.67	118.29	0.57
ERROR	57	2677.00	46.97			
SOURCE						
AGE	1	85.93		1.83		0.18
SEX	1	8.53		0.18		0.67
AGE+SEX	1	0.16		0.00		0.95

RELATIONSHIP: AVERAGE DECISION TIME VERSUS AGE CODE AND GLASSES

SOURCE OF VARIATION	DEGREES OF FREEDOM	SUM OF SQUARES	MEAN SQUARE	F	C.V.	P
TOTAL	60	2771.64				
MODEL	3	256.31	85.44	1.94	114.66	0.13
ERROR	57	2515.33	44.13			
SOURCE						
AGE CODE	1	85.94		1.95		0.17
GLASSES	1	3.41		0.08		0.78
AGE+GLASSES	1	166.96		3.78		0.05

RELATIONSHIP: AVERAGE DECISION TIME VERSUS AGE CODE AND IMPAIRMENT CODE

SOURCE OF VARIATION	DEGREES OF FREEDOM	SUM OF SQUARES	MEAN SQUARE	F	C.V.	P
TOTAL	60	2771.64				
MODEL	3	131.78	43.93	0.95	117.47	0.42
ERROR	57	2639.85	46.31			
SOURCE						
AGE	1	85.94		1.86		0.18
IMPAIRMENT	1	25.82		0.56		0.46
AGE+IMPAIRMENT	1	20.03		0.43		0.51

INTERSECTION WITH MIXED SIGHT DISTANCE AND LOW VOLUME CONTINUED

RELATIONSHIP: AVERAGE DECISION TIME VERSUS AGE CODE, SEX CODE AND MEDICATION CODE

SOURCE OF VARIATION	DEGREES OF FREEDOM	SUM OF SQUARES	MEAN SQUARE	F	C.V.	P
TOTAL	60	2771.64				
MODEL	7	547.61	78.23	1.86	111.81	0.09
ERROR	53	2224.02	41.96			
SOURCE						
AGE CODE	1	85.94		2.05		0.16
SEX CODE	1	8.53		0.20		0.65
AGE+SEX	1	0.16		0.00		0.95
MED CODE	1	101.69		2.42		0.13
AGE+MED	1	263.10		6.27		0.02
SEX+MED	1	2.56		0.06		0.80
AGE+SEX+MED	1	85.61		2.04		0.16

RELATIONSHIP: AVERAGE DECISION TIME VERSUS AGE CODE, SEX CODE AND IMPAIRMENT CODE

SOURCE OF VARIATION	DEGREES OF FREEDOM	SUM OF SQUARES	MEAN SQUARE	F	C.V.	P
TOTAL	60	2771.64				
MODEL	7	193.11	27.59	0.57	120.40	0.78
ERROR	53	2578.53	48.65			
SOURCE						
AGE CODE	1	85.94		1.77		0.19
SEX CODE	1	8.53		0.18		0.67
AGE+SEX	1	0.16		0.00		0.95
IMPAIRMENT	1	26.21		0.54		0.47
AGE+IMP	1	14.72		0.30		0.58
SEX+IMP	1	0.85		0.02		0.90
AGE+SEX+IMP	1	56.69		1.17		0.29

SUMMARY OF MEANS AND STANDARD DEVIATION
FOR INTERSECTION WITH MIXED SIGHT DISTANCE AND LOW VOLUME

RELATIONSHIP: TOTAL DECISION TIME VERSUS AGE

TOTAL DECISION TIME	N	MEAN	STANDARD DEVIATION
30-50	31	4.625	4.32
60-80	30	7.000	8.56

INTERSECTION WITH MIXED SIGHT DISTANCE AND LOW VOLUME CONTINUED

RELATIONSHIP: TOTAL DECISION TIME VERSUS SEX

TOTAL DECISION TIME	N	MEAN	STANDARD DEVIATION
MALE	24	6.654	9.23
FEMALE	37	5.235	4.66

RELATIONSHIP: TOTAL DECISION TIME VERSUS IMPAIRMENT

TOTAL DECISION TIME	N	MEAN	STANDARD DEVIATION
NO IMPAIRMENT	26	4.880	4.66
SOME IMPAIRMENT	35	6.471	8.03

RELATIONSHIP: TOTAL DECISION TIME VERSUS FUNCTIONAL LEVEL
(Functional level = age code, impairment code)

TOTAL DECISION TIME	N	MEAN	STANDARD DEVIATION
1 30-50 NO IMPAIRMENT	16	4.387	4.57
2 30-50 IMPAIRMENT	15	4.880	4.17
3 60-80 NO IMPAIRMENT	15	3.940	2.79
4 60-80 IMPAIRMENT	15	10.060	11.13

RELATIONSHIP: TOTAL DECISION TIME VERSUS GLASSES

TOTAL DECISION TIME	N	MEAN	STANDARD DEVIATION
GLASSES	35	6.182	8.17
NO GLASSES	26	5.269	4.42

RELATIONSHIP: TOTAL DECISION TIME VERSUS MEDICATION

TOTAL DECISION TIME	N	MEAN	STANDARD DEVIATION
MEDICATION	26	4.592	3.88
NO MEDICATION	35	6.685	8.28

RELATIONSHIP: AVERAGE DECISION TIME VERSUS AGE AND SEX

AVERAGE DECISION TIME	N	MEAN	STANDARD DEVIATION
30-50, MALE	8	5.125	5.13
30-50, FEMALE	23	4.452	4.12
60-80, MALE	16	7.418	10.79
60-80, FEMALE	14	6.521	5.35

INTERSECTION WITH MIXED SIGHT DISTANCE AND LOW VOLUME CONTINUED

RELATIONSHIP: AVERAGE DECISION TIME VERSUS AGE AND GLASSES

AVERAGE DECISION TIME	N	MEAN	STANDARD DEVIATION
30-50, GLASSES	15	3.246	3.19
30-50, NO GLASSES	16	5.918	4.91
60-80, GLASSES	20	8.385	10.00
60-80, NO GLASSES	10	4.230	3.47

RELATIONSHIP: AVERAGE DECISION TIME VERSUS AGE AND IMPAIRMENT

AVERAGE DECISION TIME	N	MEAN	STANDARD DEVIATION
30-50, NO IMPAIRMENT	15	4.513	4.71
30-50, IMPAIRMENT	16	4.731	4.08
60-80, NO IMPAIRMENT	11	5.381	4.78
60-80, IMPAIRMENT	19	7.937	10.14

RELATIONSHIP: AVERAGE DECISION TIME VERSUS AGE, SEX, & MEDICATION

AVERAGE DECISION TIME	N	MEAN	STANDARD DEVIATION
30-50, MALE, MEDICATION	1	14.200	0.00
30-50, MALE, NO MEDICATION	7	3.828	3.87
30-50, FEMALE, MEDICATION	10	4.730	4.35
30-50, FEMALE, NO MEDICATION	13	4.238	4.10
60-80, MALE, MEDICATION	10	4.290	3.29
60-80, MALE, NO MEDICATION	6	12.633	16.66
60-80, FEMALE, MEDICATION	5	3.000	0.81
60-80, FEMALE, NO MEDICATION	9	8.477	5.84

RELATIONSHIP: AVERAGE DECISION TIME VERSUS AGE, SEX, & IMPAIRMENT

AVERAGE DECISION TIME	N	MEAN	STANDARD DEVIATION
30-50, MALE, NO IMPAIRMENT	6	6.133	5.61
30-50, MALE, IMPAIRMENT	2	2.100	1.55
30-50, FEMALE, NO IMPAIRMENT	9	3.433	3.98
30-50, FEMALE, IMPAIRMENT	14	5.107	4.21
60-80, MALE, NO IMPAIRMENT	3	3.566	0.85
60-80, MALE, IMPAIRMENT	13	8.307	11.87
60-80, FEMALE, NO IMPAIRMENT	8	6.063	5.53
60-80, FEMALE, IMPAIRMENT	6	7.133	5.55

ANOVA ANALYSIS FOR INTERSECTION WITH GOOD SIGHT DISTANCE AND HIGH VOLUME

RELATIONSHIP: AVERAGE DECISION TIME VERSUS AGE CODE

SOURCE OF VARIATION	DEGREES OF FREEDOM	SUM OF SQUARES	MEAN SQUARE	F	C.V.	P
TOTAL	60	2895.63				
AGE CODE	1	53.09	53.09	1.10	25.90	0.30
ERROR	59	2842.54	48.18			

RELATIONSHIP: AVERAGE DECISION TIME VERSUS SEX

SOURCE OF VARIATION	DEGREES OF FREEDOM	SUM OF SQUARES	MEAN SQUARE	F	C.V.	P
TOTAL	60	2895.63				
SEX	1	183.89	183.89	4.00	25.30	0.05
ERROR	59	2711.74	45.96			

RELATIONSHIP: AVERAGE DECISION TIME VERSUS IMPAIRMENT CODE

SOURCE OF VARIATION	DEGREES OF FREEDOM	SUM OF SQUARES	MEAN SQUARE	F	C.V.	P
TOTAL	60	2895.63				
IMPAIRMENT	1	0.18	0.18	0.00	26.14	0.95
ERROR	59	2895.45	49.07			

RELATIONSHIP: AVERAGE DECISION TIME VERSUS GLASSES

SOURCE OF VARIATION	DEGREES OF FREEDOM	SUM OF SQUARES	MEAN SQUARE	F	C.V.	P
TOTAL	60	2895.63				
GLASSES	1	1.91	1.91	0.04	26.13	0.84
ERROR	59	2893.71	49.05			

RELATIONSHIP: AVERAGE DECISION TIME VERSUS MEDICATION

SOURCE OF VARIATION	DEGREES OF FREEDOM	SUM OF SQUARES	MEAN SQUARE	F	C.V.	P
TOTAL	60	2895.63				
MEDICATION	1	58.56	58.56	1.22	25.87	0.27
ERROR	59	2837.07	48.08			

INTERSECTION WITH GOOD SIGHT DISTANCE AND HIGH VOLUME CONTINUED

RELATIONSHIP: AVERAGE DECISION TIME VERSUS FUNCTIONAL LEVEL

SOURCE OF VARIATION	DEGREES OF FREEDOM	SUM OF SQUARES	MEAN SQUARE	F	C.V.	P
TOTAL	60	2895.63				
FUNCTION LV	3	128.68	42.89	0.88	25.99	0.45
ERROR	57	2766.95	48.54			

SUMMARY OF MEANS AND STANDARD DEVIATION
FOR INTERSECTION WITH GOOD SIGHT DISTANCE AND HIGH VOLUME

RELATIONSHIP: TOTAL DECISION TIME VERSUS AGE

TOTAL DECISION TIME	N	MEAN	STANDARD DEVIATION
30-50	31	25.880	8.89
60-80	30	27.746	4.02

RELATIONSHIP: TOTAL DECISION TIME VERSUS SEX

TOTAL DECISION TIME	N	MEAN	STANDARD DEVIATION
MALE	24	28.954	7.33
FEMALE	37	25.400	6.40

RELATIONSHIP: TOTAL DECISION TIME VERSUS IMPAIRMENT

TOTAL DECISION TIME	N	MEAN	STANDARD DEVIATION
NO IMPAIRMENT	26	26.734	4.07
SOME IMPAIRMENT	35	26.845	8.54

RELATIONSHIP: TOTAL DECISION TIME VERSUS FUNCTIONAL LEVEL
(Functional level = age code, impairment code)

TOTAL DECISION TIME	N	MEAN	STANDARD DEVIATION
1 30-50 NO IMPAIRMENT	16	26.581	4.28
2 30-50 IMPAIRMENT	15	25.133	12.20
3 60-80 NO IMPAIRMENT	15	26.340	3.37
4 60-80 IMPAIRMENT	15	29.153	3.89

INTERSECTION WITH GOOD SIGHT DISTANCE AND HIGH VOLUME CONTINUED

RELATIONSHIP: TOTAL DECISION TIME VERSUS GLASSES

TOTAL DECISION TIME	N	MEAN	STANDARD DEVIATION
GLASSES	35	26.645	6.29
NO GLASSES	26	27.003	7.86

RELATIONSHIP: TOTAL DECISION TIME VERSUS MEDICATION

TOTAL DECISION TIME	N	MEAN	STANDARD DEVIATION
MEDICATION	26	25.661	7.69
NO MEDICATION	35	27.642	6.32

ANOVA ANALYSIS FOR INTERSECTION WITH GOOD SIGHT DISTANCE AND LOW VOLUME

RELATIONSHIP: AVERAGE DECISION TIME VERSUS AGE CODE

SOURCE OF VARIATION	DEGREES OF FREEDOM	SUM OF SQUARES	MEAN SQUARE	F	C.V.	P
TOTAL	60	756.85				
AGE CODE	1	32.41	32.41	2.64	33.84	0.11
ERROR	59	724.44	12.27			

RELATIONSHIP: AVERAGE DECISION TIME VERSUS SEX

SOURCE OF VARIATION	DEGREES OF FREEDOM	SUM OF SQUARES	MEAN SQUARE	F	C.V.	P
TOTAL	60	756.85				
SEX	1	0.42	0.42	0.03	34.58	0.86
ERROR	59	756.43	12.82			

RELATIONSHIP: AVERAGE DECISION TIME VERSUS IMPAIRMENT CODE

SOURCE OF VARIATION	DEGREES OF FREEDOM	SUM OF SQUARES	MEAN SQUARE	F	C.V.	P
TOTAL	60	756.85				
IMPAIRMENT	1	0.05	0.05	0.00	30.58	0.95
ERROR	59	756.80	12.83			

RELATIONSHIP: AVERAGE DECISION TIME VERSUS GLASSES

SOURCE OF VARIATION	DEGREES OF FREEDOM	SUM OF SQUARES	MEAN SQUARE	F	C.V.	P
TOTAL	60	756.85				
GLASSES	1	16.84	16.84	1.34	34.20	0.25
ERROR	59	740.01	12.54			

RELATIONSHIP: AVERAGE DECISION TIME VERSUS MEDICATION

SOURCE OF VARIATION	DEGREES OF FREEDOM	SUM OF SQUARES	MEAN SQUARE	F	C.V.	P
TOTAL	60	756.85				
MEDICATION	1	1.78	1.78	0.14	34.54	0.71
ERROR	59	755.07	12.80			

INTERSECTION WITH GOOD SIGHT DISTANCE AND LOW VOLUME CONTINUED

RELATIONSHIP: AVERAGE DECISION TIME VERSUS FUNCTIONAL LEVEL

SOURCE OF VARIATION	DEGREES OF FREEDOM	SUM OF SQUARES	MEAN SQUARE	F	C.V.	P
TOTAL	60	756.85				
FUNCTION LV	3	42.56	14.19	1.13	34.18	0.34
ERROR	57	714.29	12.53			

RELATIONSHIP: AVERAGE DECISION TIME VERSUS AGE CODE AND SEX CODE

SOURCE OF VARIATION	DEGREES OF FREEDOM	SUM OF SQUARES	MEAN SQUARE	F	C.V.	P
TOTAL	60	756.85				
MODEL	3	36.14	12.05	0.95	34.34	0.42
ERROR	57	720.71	12.64			
SOURCE						
AGE	1	32.41		2.56		0.11
SEX	1	0.99		0.08		0.78
AGE+SEX	1	2.74		0.22		0.64

RELATIONSHIP: AVERAGE DECISION TIME VERSUS AGE CODE AND GLASSES

SOURCE OF VARIATION	DEGREES OF FREEDOM	SUM OF SQUARES	MEAN SQUARE	F	C.V.	P
TOTAL	60	756.85				
MODEL	3	66.12	22.04	1.82	33.62	0.15
ERROR	57	690.73	12.12			
SOURCE						
AGE CODE	1	32.41		2.67		0.11
GLASSES	1	9.64		0.08		0.38
AGE+GLASSES	1	24.07		1.99		0.16

RELATIONSHIP: AVERAGE DECISION TIME VERSUS AGE CODE AND IMPAIRMENT CODE

SOURCE OF VARIATION	DEGREES OF FREEDOM	SUM OF SQUARES	MEAN SQUARE	F	C.V.	P
TOTAL	60	756.85				
MODEL	3	35.25	11.75	0.93	34.36	0.43
ERROR	57	721.60	12.66			
SOURCE						
AGE	1	32.41		2.56		0.11
IMPAIRMENT	1	0.21		0.02		0.89
AGE+IMPAIRMENT	1	2.63		0.21		0.65

INTERSECTION WITH GOOD SIGHT DISTANCE AND HIGH VOLUME CONTINUED

RELATIONSHIP: AVERAGE DECISION TIME VERSUS AGE CODE, SEX CODE AND MEDICATION CODE

SOURCE OF VARIATION	DEGREES OF FREEDOM	SUM OF SQUARES	MEAN SQUARE	F	C.V.	P
TOTAL	60	756.85				
MODEL	7	43.69	6.24	0.46	35.42	0.85
ERROR	53	713.15	13.45			
SOURCE						
AGE CODE	1	32.41		2.41		0.13
SEX CODE	1	0.99		0.07		0.79
AGE+SEX	1	2.74		0.20		0.65
MED CODE	1	3.22		0.24		0.63
AGE+MED	1	2.32		0.17		0.68
SEX+MED	1	1.83		0.14		0.71
AGE+SEX+MED	1	0.18		0.01		0.91

RELATIONSHIP: AVERAGE DECISION TIME VERSUS AGE CODE, SEX CODE AND IMPAIRMENT CODE

SOURCE OF VARIATION	DEGREES OF FREEDOM	SUM OF SQUARES	MEAN SQUARE	F	C.V.	P
TOTAL	60	756.85				
MODEL	7	39.79	5.68	0.42	35.52	0.88
ERROR	53	717.06	14.55			
SOURCE						
AGE CODE	1	32.41		2.40		0.13
SEX CODE	1	0.99		0.07		0.79
AGE+SEX	1	2.74		0.20		0.65
IMPAIRMENT	1	0.04		0.00		0.96
AGE+IMP	1	1.67		0.12		0.73
SEX+IMP	1	1.74		0.13		0.72
AGE+SEX+IMP	1	0.20		0.01		0.90

SUMMARY OF MEANS AND STANDARD DEVIATION FOR INTERSECTION WITH GOOD SIGHT DISTANCE AND HIGH VOLUME

RELATIONSHIP: TOTAL DECISION TIME VERSUS AGE

TOTAL DECISION TIME	N	MEAN	STANDARD DEVIATION
30-50	31	9.638	3.39
60-80	30	11.096	3.62

RELATIONSHIP: TOTAL DECISION TIME VERSUS SEX

TOTAL DECISION TIME	N	MEAN	STANDARD DEVIATION
MALE	24	10.458	4.65
FEMALE	37	10.289	2.68

RELATIONSHIP: TOTAL DECISION TIME VERSUS IMPAIRMENT

TOTAL DECISION TIME	N	MEAN	STANDARD DEVIATION
NO IMPAIRMENT	26	10.323	3.20
SOME IMPAIRMENT	35	10.380	3.83

RELATIONSHIP: TOTAL DECISION TIME VERSUS FUNCTIONAL LEVEL
(Functional level = age code, impairment code)

TOTAL DECISION TIME	N	MEAN	STANDARD DEVIATION
1 30-50 NO IMPAIRMENT	16	9.500	3.55
2 30-50 IMPAIRMENT	15	9.786	3.31
3 60-80 NO IMPAIRMENT	15	10.533	3.12
4 60-80 IMPAIRMENT	15	11.660	4.09

RELATIONSHIP: TOTAL DECISION TIME VERSUS GLASSES

TOTAL DECISION TIME	N	MEAN	STANDARD DEVIATION
GLASSES	35	10.808	2.61
NO GLASSES	26	9.746	4.51

RELATIONSHIP: TOTAL DECISION TIME VERSUS MEDICATION

TOTAL DECISION TIME	N	MEAN	STANDARD DEVIATION
MEDICATION	26	10.157	4.35
NO MEDICATION	35	10.302	2.87

INTERSECTION WITH GOOD SIGHT DISTANCE AND HIGH VOLUME CONTINUED

RELATIONSHIP: AVERAGE DECISION TIME VERSUS AGE AND SEX

AVERAGE DECISION TIME	N	MEAN	STANDARD DEVIATION
30-50, MALE	8	9.812	4.80
30-50, FEMALE	23	9.578	2.87
60-80, MALE	16	10.781	4.70
60-80, FEMALE	14	11.457	1.86

RELATIONSHIP: AVERAGE DECISION TIME VERSUS AGE AND GLASSES

AVERAGE DECISION TIME	N	MEAN	STANDARD DEVIATION
30-50, GLASSES	15	10.680	3.40
30-50, NO GLASSES	16	8.662	3.16
60-80, GLASSES	20	10.905	1.89
60-80, NO GLASSES	10	11.480	5.87

RELATIONSHIP: AVERAGE DECISION TIME VERSUS AGE AND IMPAIRMENT

AVERAGE DECISION TIME	N	MEAN	STANDARD DEVIATION
30-50, NO IMPAIRMENT	15	9.493	3.68
30-50, IMPAIRMENT	16	9.775	3.20
60-80, NO IMPAIRMENT	11	11.454	2.05
60-80, IMPAIRMENT	19	10.889	4.32

RELATIONSHIP: AVERAGE DECISION TIME VERSUS AGE, SEX, & MEDICATION

AVERAGE DECISION TIME	N	MEAN	STANDARD DEVIATION
30-50, MALE, MEDICATION	1	8.800	0.00
30-50, MALE, NO MEDICATION	7	9.957	5.17
30-50, FEMALE, MEDICATION	10	9.640	4.04
30-50, FEMALE, NO MEDICATION	13	9.531	1.71
60-80, MALE, MEDICATION	10	10.330	5.83
60-80, MALE, NO MEDICATION	6	11.533	1.99
60-80, FEMALE, MEDICATION	5	11.120	1.74
60-80, FEMALE, NO MEDICATION	9	11.644	2.00

INTERSECTION WITH GOOD SIGHT DISTANCE AND HIGH VOLUME CONTINUED

RELATIONSHIP: AVERAGE DECISION TIME VERSUS AGE, SEX, & IMPAIRMENT

AVERAGE DECISION TIME	N	MEAN	STANDARD DEVIATION
30-50, MALE, NO IMPAIRMENT	6	9.816	5.65
30-50, MALE, IMPAIRMENT	2	9.800	1.41
30-50, FEMALE, NO IMPAIRMENT	9	9.277	1.91
30-50, FEMALE, IMPAIRMENT	14	9.771	3.42
60-80, MALE, NO IMPAIRMENT	3	11.566	2.04
60-80, MALE, IMPAIRMENT	13	10.600	5.17
60-80, FEMALE, NO IMPAIRMENT	8	11.413	2.19
60-80, FEMALE, IMPAIRMENT	6	11.516	1.50

INTERSECTION DATA ANALYSIS

SUMMARY OF DECISION TIMES

INTERSECTION	N	MEAN	STANDARD DEVIATION	VOLUME	SIGHT DISTANCE
1	57	23.82	7.74	HIGH	GOOD
2	55	23.59	27.56	HIGH	POOR
3	51	2.85	2.35	LOW	POOR
4	61	14.53	4.70	LOW	CODE
5	61	7.85	2.61	HIGH	POOR
6	53	2.82	1.52	HIGH	CODE
7	57	5.92	2.62	LOW	CODE
8	59	13.19	16.19	HIGH	POOR
9	61	5.79	6.80	LOW	POOR
10	57	9.20	4.19	LOW	CODE
11	61	9.87	8.21	LOW	GOOD
12	61	26.80	6.95	HIGH	GOOD
13	61	6.85	5.13	HIGH	CODE
14	61	12.24	4.13	HIGH	GOOD
15	61	17.66	11.30	LOW	CODE
16	61	10.36	3.55	LOW	GOOD
17	57	3.93	4.09	LOW	POOR
18	59	22.60	16.62	HIGH	GOOD

ANOVA ANALYSIS
INTERSECTION DATA

RELATIONSHIP: AVERAGE DECISION TIME VERSUS VOLUME

SOURCE OF VARIATION	DEGREES OF FREEDOM	SUM OF SQUARES	MEAN SQUARE	F	C.V.	P
TOTAL	17	1011.94				
VOLUME	1	197.65	197.65	3.88	58.40	.066
ERROR	16	814.29	50.89			

RELATIONSHIP: AVERAGE DECISION TIME VERSUS SIGHT DISTANCE

SOURCE OF VARIATION	DEGREES OF FREEDOM	SUM OF SQUARES	MEAN SQUARE	F	C.V.	P
TOTAL	17	1011.94				
SIGHT DIST	2	262.32	131.16	2.62	57.87	0.11
ERROR	15	749.62	49.97			

INTERSECTION DATA ANALYSIS CONTINUED

RELATIONSHIP: AVERAGE DECISION TIME VOLUME AND SIGHT DISTANCE

SOURCE OF VARIATION	DEGREES OF FREEDOM	SUM OF SQUARES	MEAN SQUARE	F	C.V.	P
TOTAL	17	1011.94				
VOL+ST DIST	3	375.39	125.13	2.75	55.20	0.08
ERROR	14	636.55	45.47			
SOURCE						
VOLUME	1	197.65		4.35		0.06
SIGHT DIST	1	177.74		1.95		0.18

SUMMARY OF MEANS AND STANDARD DEVIATION FOR INTERSECTION DATA ANALYSIS

RELATIONSHIP: AVERAGE DECISION TIME VERSUS VOLUME

AVERAGE DECISION TIME	N	MEAN	STANDARD DEVIATION
LOW VOLUME	9	8.90	4.89
HIGH VOLUME	9	15.53	8.82

RELATIONSHIP: AVERAGE DECISION TIME VERSUS SIGHT DISTANCE

AVERAGE DECISION TIME	N	MEAN	STANDARD DEVIATION
POOR SIGHT DIST.	6	9.54	7.80
CODE SIGHT DIST.	6	9.50	5.59
GOOD SIGHT DIST.	6	17.61	7.60

RELATIONSHIP: AVERAGE DECISION TIME VERSUS VOLUME AND SIGHT DISTANCE

AVERAGE DECISION TIME	N	MEAN	STANDARD DEVIATION
LOW VOL, POOR SIGHT DIST	3	4.19	1.49
LOW VOL, CODE SIGHT DIST	4	11.83	5.26
LOW VOL, GOOD SIGHT DIST	2	10.12	0.34
HIGH VOL, POOR SIGHT DIST	3	14.88	8.00
HIGH VOL, CODE SIGHT DIST	2	4.84	2.85
HIGH VOL, GOOD SIGHT DIST	4	21.36	6.33

REGRESSION ANALYSIS

TOTAL FOR SUBJECTS AND INTERSECTIONS

RELATIONSHIP: AVERAGE DECISION TIME VERSUS AVERAGE NUMBER OF HEAD TURNS

AVERAGE DECISION TIME = 0.564 AVERAGE HEAD TURNS + 9.150
R-SQUARE = 0.138

RELATIONSHIP: AVERAGE DECISION TIME VERSUS AGE

AVERAGE DECISION TIME = 0.041 AGE + 9.701
R-SQUARE = 0.025

TOTALS FOR FOUR EXAMPLE INTERSECTIONS

INTERSECTION WITH POOR SIGHT DISTANCE AND LOW VOLUME

RELATIONSHIP: AVERAGE DECISION TIME VERSUS AVERAGE NUMBER OF HEAD TURNS

AVERAGE DECISION TIME = 0.628 AVERAGE HEAD TURNS + 5.569
R-SQUARE = 0.263

RELATIONSHIP: AVERAGE DECISION TIME VERSUS AGE

AVERAGE DECISION TIME = 0.062 AGE + 4.555
R-SQUARE = 0.125

RELATIONSHIP: RIGHT RANGE OF MOTION VERSUS MAXIMUM RIGHT ANGLE (IMPAIRED GROUP)

RIGHT R.O.M.= 0.147 MAX RIGHT ANGLE + 38.865
R-SQUARE = 0.039

RELATIONSHIP: LEFT RANGE OF MOTION VERSUS MAXIMUM LEFT ANGLE (IMPAIRED GROUP)

LEFT R.O.M.=-0.091 MAX LEFT ANGLE + 43.400
R-SQUARE = 0.008

INTERSECTION WITH MIXED SIGHT DISTANCE AND LOW VOLUME

RELATIONSHIP: AVERAGE DECISION TIME VERSUS AVERAGE NUMBER OF HEAD TURNS

AVERAGE DECISION TIME = 2.230 AVERAGE HEAD TURNS - 0.495
R-SQUARE = 0.533

RELATIONSHIP: AVERAGE DECISION TIME VERSUS AGE

AVERAGE DECISION TIME = 0.059 AGE + 2.606
R-SQUARE = 0.017

RELATIONSHIP: RIGHT RANGE OF MOTION VERSUS MAXIMUM RIGHT ANGLE (IMPAIRED GROUP)

RIGHT R.O.M.= 0.203 MAX RIGHT ANGLE + 37.869
R-SQUARE = 0.107

RELATIONSHIP: LEFT RANGE OF MOTION VERSUS MAXIMUM LEFT ANGLE (IMPAIRED GROUP)

LEFT R.O.M.=-0.176 MAX LEFT ANGLE + 45.096
R-SQUARE = 0.027

INTERSECTION WITH GOOD SIGHT DISTANCE AND HIGH VOLUME

RELATIONSHIP: AVERAGE DECISION TIME VERSUS AVERAGE NUMBER OF HEAD TURNS

AVERAGE DECISION TIME = 0.328 AVERAGE HEAD TURNS + 23.866
R-SQUARE = 0.054

RELATIONSHIP: AVERAGE DECISION TIME VERSUS AGE

AVERAGE DECISION TIME = 0.052 AGE + 24.028
R-SQUARE = 0.012

INTERSECTION WITH GOOD SIGHT DISTANCE AND HIGH VOLUME CONTINUED

RELATIONSHIP: RIGHT RANGE OF MOTION VERSUS MAXIMUM RIGHT ANGLE (IMPAIRED GROUP)

RIGHT R.O.M.= 0.119 MAX RIGHT ANGLE + 39.238
R-SQUARE = 0.032

INTERSECTION WITH GOOD SIGHT DISTANCE AND HIGH VOLUME CONTINUED

RELATIONSHIP: LEFT RANGE OF MOTION VERSUS MAXIMUM LEFT ANGLE (IMPAIRED GROUP)

LEFT R.O.M.=-0.030 MAX LEFT ANGLE + 41.392
R-SQUARE = 0.002

INTERSECTION WITH GOOD SIGHT DISTANCE AND LOW VOLUME

RELATIONSHIP: AVERAGE DECISION TIME VERSUS AVERAGE NUMBER OF HEAD TURNS

AVERAGE DECISION TIME = 0.459 AVERAGE HEAD TURNS + 8.294
R-SQUARE = 0.085

RELATIONSHIP: AVERAGE DECISION TIME VERSUS AGE

AVERAGE DECISION TIME = 0.048 AGE + 7.782
R-SQUARE = 0.041

RELATIONSHIP: RIGHT RANGE OF MOTION VERSUS MAXIMUM RIGHT ANGLE (IMPAIRED GROUP)

RIGHT R.O.M.= 0.164 MAX RIGHT ANGLE + 38.651
R-SQUARE = 0.041

RELATIONSHIP: LEFT RANGE OF MOTION VERSUS MAXIMUM LEFT ANGLE (IMPAIRED GROUP)

LEFT R.O.M.=-0.078 MAX LEFT ANGLE + 42.287
R-SQUARE = 0.006