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16. Abstract

Driving accidents among the elderly are suspected to be related to visual information processing of briefly presented objects in the periphery. The primary purpose of this research was to determine if simple laboratory tests of visual information processing would predict driver visual processing performance in driving through an intersection. Brief field of view (BFOV) was measured in both the laboratory and the field with a sample of 20 young and 20 older drivers both in the laboratory and under field conditions. No significant correlations were found between laboratory and field measures of brief field of view. Young drivers scored significantly higher on all measures than their elderly counterparts. However, older drivers improved in visual performance from the laboratory to the field study whereas younger driver performance deteriorated in the field as compared to their laboratory performance.

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Brief Field of View and Elderly Drivers

A Research Study
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April 1993

ABSTRACT

Driving accidents among the elderly are suspected to be related to visual information processing of briefly presented objects in the periphery. The primary purpose of this research was to determine if simple laboratory tests of visual information processing would predict driver visual processing performance in driving through an intersection. If so, then simple tests could be recommended for licensing of elderly drivers.

A secondary objective was to compare young and old drivers on the same set of tests to determine the degree to which visual processing skills degrade over the years, if at all. Brief field of view (BFOV) was measured in both the laboratory and the field with a sample of 20 young (mean age 26 years) and 20 older drivers (mean age 73 years).

The laboratory tests consisted of BFOV under two central vision task conditions, as well as tests of static and dynamic visual acuity. The controlled field study, conducted under closed course conditions, simulated a traffic intersection. Drivers reported briefly presented traffic signal configurations (colors in each lane) at designated distances while they were driving a vehicle toward those signals.

No significant correlations were found between laboratory and field measures of brief field of view. Young drivers scored significantly higher on all measures than their elderly counterparts. However, older drivers improved in visual performance from the laboratory to the field study whereas younger driver performance deteriorated in the field as compared to their laboratory performance.

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INTRODUCTION

The elderly population is increasing in the United States both in absolute terms and as a portion of the total population. From 1980 to 1990 the overall population in the United States of America increased by 9.8 % while the segment of the population age 65 years old and older increased by 22 % (U.S. Bureau of the Census, 1992). In addition, the rate of growth of the seniors in our population should increase as the baby boomers reach age 65. The elderly population is getting older as the benefits of both improved medical care and nutrition increase longevity. A child born in 1985 has every expectation of living to age 74.7 years which is 27 years longer than a person born in 1900 (American Association of Retired Persons, 1986).

Contrary to popular belief, the elderly do not typically live in nursing homes. More often, they live in the same places where they raised their families. A person over 64 years old is less likely to live in a metropolitan area in 1980 than is a younger person (American Association of Retired Persons, 1986). In 1980, over 57% of the population over age 65 in the United States had a license to drive (Brain, 1980). Because of the growth of this segment of the population, the performance of the older motorist is becoming more of a concern to highway engineers, transportation officials, and the motoring public.

Elderly people lead an increasingly active life. In all areas of life they expect and demand a higher quality of life than preceding generations. This implies an increasing continued use of the driver license and access to private automobiles after age 65 (Kroj, 1987, Smith, 1990). An examination of the life-style characteristics of retirement communities shows a high level of mobility for the residents. The trip profiles show a need for shopping, dining out, medical and entertainment purposes (Witkowski and Buick, 1985).

The elderly of the future will be as heterogeneous, affluent, educated, dispersed in a variety of living environments, and more likely to drive than the elderly of the past or of the present (Wachs, 1979). The older motorist has access to independence, social activities, medical care, and grocery shopping denied those without transportation (Elder and Holly, 1975).

The United States lacks the public transportation infrastructure to provide for the needs of the growing population of seniors. This country needs older people to be motorist to provide for their own needs and transportation. If the federal or state government attempts to provide these services the cost will be enormous. One estimate of the cost is $174 trillion annually (Rosenbloom, 1988) given parity in the number of trips. The benefit group would be elders without driver licenses and the comparison group would be elders with driver licenses.

Characteristics of the Older Motorist

Many older motorists are aware of their behavioral deficits and have changed their driving patterns in an attempt to adopt compensatory behavioral strategies (Society of Automotive Engineers, 1988). Driving is, however, a social activity. Older drivers do not exist in a vacuum and their behavior has an influence on the safety and efficiency of other motorists in the area.

Older motorists drive more slowly, take shorter trips, stay on familiar roads, avoid rush hours, avoid bad weather, and drive with deliberate maneuvers. Unfortunately, these are some of the complaints lodged against them by others on the road. Most elderly drivers drive less than 7,000 miles per year and do not drive on a daily basis. Most trips occur between the hours of 12 and 6 pm (52%).

Drivers as a whole are over confident of their ability to avoid accidents. The actual chance of an accident in one year is 1:7. Forty-two percent of a survey rated the chances as 1:500 while more than 50% of those over 50 years of age rated chances as 1:1000 (Overend, 1985).

Malfetti and Winter (1987) used the critical incident technique to survey the driving practices of older drivers, categorized as Driving Practices. They sum up the older driver in the following way.

> " After reading and analyzing the hundreds of critical behaviors collected in this study, the investigators have concluded that drivers over age 55 are pretty much like all other drivers--there are some safe ones and unsafe ones at all age levels. - - - - - For drivers over 55, especially at the upper reaches, Driving Practices are loaded toward the unsafe."

In the same report, the older motorists confirm that they see most of the same behaviors in themselves as others report. However, the older driver has a much different interpretation of these behaviors. They see themselves as courteous and non-competitive. Safe driving means operating within their limitations and differing to others. Others view this as impeding the flow of traffic and failing to conform to the understood protocols. Older drivers reduce speed to increase time to find signs, read signs, and maneuver but it is better for traffic flow and safety to maintain a uniform speed (Hauer, 1971).

Expectation heavily influences the process of human perception. Some older motorists drive in a manner that is markedly different from the expectations of those on the road with them. This mismatch causes many of the problems in their interaction with the other vehicles sharing the road with them. Seldom is a driver alone on the road. All drivers expect the driving event to be predictable within certain constraints. The most obvious constraints are the traffic laws. Supplementing the laws are the signs and markings on the pavement, curbs and roadside. Beyond this is an expectation that the others on the road will behave in a predictable manner. That is to say that an individual vehicle will travel at a speed similar to the traffic flow, change lanes in a manner like other lane changers, and stop at the locations and in the manner of other vehicles of the same type. These protocols arise from past experience. The unpredictable driver is a hazard.

Performance of the Older Driver

On an absolute basis, motor vehicle crashes are not a significant cause of death for older persons (Cerrelli, 1989). The total number of accidents involving older drivers are small. Teenagers have 23 times the number of crashes involving 80 year old drivers (Cerrelli, 1989). There is little difference in the severity of accidents based on age as seen in Figure 1.

Adjusting these figures for population percentages, the picture changes. Now teens have only 5.4 times the number of accidents involving 80 year old drivers. The picture changes even more drastically when vehicle miles of travel are considered. Crash involvement rates based on Vehicle Miles Traveled (VMT) follows a U-shaped curve, illustrated in Figure 1. This figure shows much higher rates of occurrence for critical events for the very young and very old (Cerrelli, 1989).

Accident records reveal that the elderly driver has more accidents per miles driven than would be expected if all else were equal (Cerrelli, 1989). The consequences of these accidents are much worse for the older driver, given the same severity of accident, than they would be for a younger or middle aged driver (Cerrelli, 1989; Partyka, 1983). The consequences can be seen in Figure 1 by noting the increased rate of fatalities compared with the rate of serious injuries at and beyond age 73. This is because of the frailty of the older driver. They are not able to

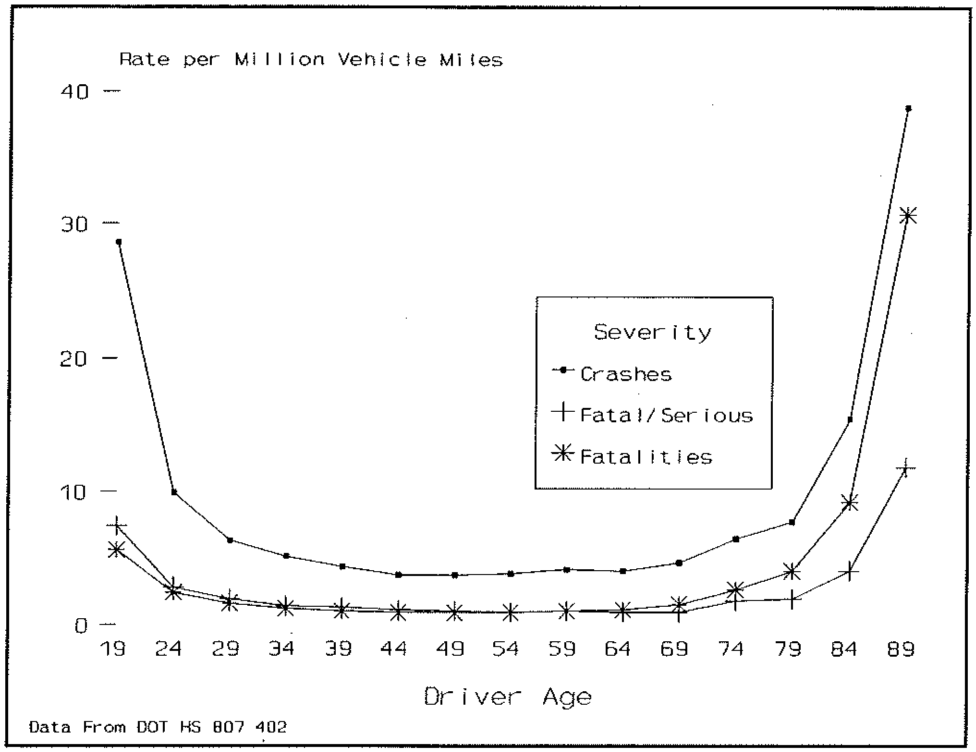

Figure 1. *Crash involvements and crash severity by age (5 state files).*

recover from the trauma of the accident in the same way a younger person can (Mackay, 1988).

The older motorist has a higher probability of being in a fatal crash with a younger driver than with one of his own age and is most likely to be the one to die (Partyka, 1983). She asserts that the juxtaposition of the high speed characteristics of the younger driver and the low speed style of the older driver is the source for this increased probability of a fatal crash.

The older driver is exposed to the greatest risk of any member if the driving public. Risk is a term used by safety professionals to describe not only hazard but also the probability of the occurrence of a loss event associated with that hazard and the consequences of that event (Brauer, 1990). When compared to the young, adult, or middle aged driver, the older driver has an elevated hazard, probability of loss, or both (Cerrelli, 1989).

When the rate of accidents per million vehicle miles traveled (VMT) is considered, the driver over 65 years old has a rate comparable to that of the 25 years and under driver. This rate translates into a probability of loss higher than the adult or middle aged driver and as high as the young driver.

At approximately age 72, and beyond, the rate of fatalities matches then exceeds the rate of injuries. The loss of life is considered a greater hazard than injury. Older drivers are not able to recover from the trauma of the accident in the same way a younger person can (Mackay, 1988).
When the accident records for drivers are examined across age, a pattern of accident types appears for the older driver. These drivers are not involved in high speed or reckless driving accidents. Many elderly drivers are involved in accidents occurring in parking lots. Intersection and night driving accidents figure highly in the profile of the older motorist (Society of Automotive Engineers, 1988). The older driver is most often ticketed for the following:

* failure to yield
* changing directions unsafely
* failure to obey traffic signs and signals
* careless intersection crossings
* improper and inaccurate turns
* careless and improper lane changes
* careless merging
* careless backing (Society of Automotive Engineers, 1988).

The older motorist has problems with right of way decisions, passing, left turns, reading signs, and entering expressways (Fox, 1989). The most common type of accidents for the elderly driver are, according to the Society of Automotive Engineers (1988):

* rear end collisions (27.5%)
* traffic signals (19%)
* stop/yield signs (14%)
* loss of control (13.5%)
* backing in driveways (9.5%)
* changing lanes (9%)
* non-intersection turns (7.5%).

The fatal accident the older driver experiences is more likely to be from a crossing collision (left-hand turn) or a head-on collision when compared with the 15 year old to 64 year old age group. In the case of injury, treatment and rehabilitation takes much longer and is more costly for the elderly driver (Mackay, 1988).

Over the adult life of the driver physical attributes and skills change. When compared with their youth, the older driver is weaker, shorter, less flexible, and may have arthritis (Society of Automotive Engineers, 1988). Fibromyalgia can cause drivers to steer needlessly wide on turns or when pulling into parking spaces. Sudden reactions to the unexpected may be painful and thus delayed.

The fatal accident the older driver experiences is more likely to be from a crossing collision (left-hand turn) or a head-on collision when compared with the 15 years old to 64 years old age group.

A general behavioral slowing is reported with age. This is not just associated with reaction time. The term "behavioral slowing" is meant to describe both overt behavior and cognitive processing in the face of increasing complexity (Birren, Woods, and Williams, 1980). Age related functional deficits cause a greater disruption to central mental processes than to the peripheral functions (*Physical Fitness and the Aging Driver*, 1988).

Information processing becomes more difficult with age. Botwinick (1978) reports that the ability to focus attention decreases as age increases. This statement is supported by both Kausler (1982) and Staplin, Benton, Haimo, Sarber, and Byrnes, (1987) who state that ease of distraction increases with age. Staplin et al. (1987) also suggests that the performance of older people declines on complex multifactored tests.

Visual Abilities

The relationship of vision and good driving seems clear and obvious. Blind persons are not licensed to drive. The connection between vision, age, and driver ability has been investigated for years (Burg, 1966, Burg and Hulbert, 1961, Hulbert, Burg, Knoll and Mathewson, 1958).

The older driver has reduced visual acuity, loses the ability to focus on static or moving objects and has increased sensitivity to glare (Bailey and Sheedy, 1989; Weale, 1963; Wolfe, 1960). Both the total visual field and dynamic visual acuity decrease as age increases (Johnson and Keltner, 1983; Reading, 1968). However, none of the measures of visual function show a high correlation with traffic accidents. A small, although significant, correlation between dynamic visual acuity (DVA) and accidents was reported by Burg (1966).

Simple clinical measures of visual function have not proved to be predictive nor explanatory of traffic accidents. Researchers have sought explanations in more complex areas of visual behavior.

Eye Fixation and Age

A study by Rackoff and Mourant (1979) shows that the older motorist exhibits different eye fixation behavior than does the young motorist. They noted that the older driver had longer mean eye travel distances when compared with younger drivers. Rackoff and Mourant (1979) suggest the explanation for this difference in eye travel is due to younger drivers having better peripheral vision than older drivers. If the younger driver is able to use peripheral vision to acquire information and the older driver must use only foveal vision to acquire the same information, then the younger driver can cover a given scene with shorter excursions. Only the most stressful driving conditions brought these differences to light.

Larger standard deviation in the length of eye travel for older drivers was reported. This implies some individual older drivers had peripheral acuity equal to the peripheral acuity of some individual young drivers.

Rackoff and Mourant (1979) subjected the drivers to both day and night driving under conditions of open (low stress) and car-following (high stress) requirements.

Rackoff and Mourant (1979) state that older drivers require more time to acquire the minimum information required for vehicle control. It may be that the older motorist needs more time for:

1. finding particular cues
2. extracting information from the cues available
3. looking for additional cues.

In an associated embedded figures test, Rackoff and Mourant (1979) report that aged drivers took seven times longer than young drivers to find the embedded figures.

Participants shut their eyes as often and as long as possible while driving. Older motorists had longer eye open and eye closed times than did the young motorists.

In summary, for the older driver, a significant difference between young and older drivers in both mean eye travel and the standard deviation of eye travel was noted under the high stress condition.

Rackoff and Mourant (1979) found that older drivers had greater eye travel distance, a larger standard deviation in length of eye travel, a need to keep their eyes open longer, and a willingness to keep their eyes closed longer while driving.

They suggest that long eye travel and eye open time for the older driver hints at one or both of the following:

1. A diminished rate of information processing requiring more time to acquire information.
2. The older driver is simply more cautious than the young driver and wishes to collect more information before making a decision (Rackoff and Mourant, 1979).

Variation in glare recovery is associated with increasing age. In terms of efficiency, these changes mean that the 55 year old takes eight times as long to recover from glare as the 16 year old. If the target is of low contrast, the older person requires twice the illumination of a younger person to detect the target. The optical train darkens and becomes cluttered as we age. To illustrate the extent of this deterioration, the retina of 20 year old person receives three times the light reaching the retina of a 60 year old given equal external illumination. Required illumination doubles for every 13 years to get the equivalent level of accuracy on a test task (Fox, 1989).

The term Field of View (FOV) describes the total visual field that can be seen with the eyes relaxed and looking forward at a point. It has both vertical and horizontal dimensions but the horizontal dimension is most often reported alone. The FOV has two major sections, the foveal field and the peripheral field.

The foveal field is that area of the visual field projected on the cones in the fovea of the eye. Foveal vision shows the greatest acuity. Rods, and few cones as compared with the macular area, are the source of vision in the remaining area of the field of view, the peripheral field. The peripheral field is most sensitive to light and motion. Targets that move at a high rate of speed and for short distances in the periphery are conspicuous.

Fox (1989) reports that peripheral vision declines with age. The field of view is about 170 degrees at age 35 years but decreases to 140 degrees by age 50 years.

As a person ages the sensitive of the peripheral retina decreases at a greater rate than the rate of deterioration of the fovea.

Visual Information Processing

Interest in recent years has moved from tests of visual function to the pursuit of visual information processing. Sperling (1960) did landmark work in the area of visual information processing, particularly in Sensory Information Storage (SIS).

Sperling (1960) reports a difference in Immediate Memory versus Available Information. Immediate Memory is that information about a briefly presented visual stimulus array which can be reported as soon as the stimulus ceases. After the stimulus is withdrawn, a probe is made in the form of a request for a report of a portion of the array.

The size of Available Information is a calculated from the results of repeated Immediate Memory trials. The average number of correct responses to the probes is multiplied by the number of equiprobable partial reports. This value is considered to be the amount of Available Information in short term memory.

Immediate Memory can be no larger than Available Information and usually is smaller. Sperling (1960) reports that the size of Immediate Memory is invariant in his subjects. The size of Immediate Memory appears to be governed by the rate of decay in sensory information storage (Lindsay and Norman, 1972). The size of Available Information is 100% given an immediate probe and decays to the size of Immediate Memory as the probe is delayed.

The size of the stimulus used by Sperling (1960) is not reported in terms of visual angle. However, an estimate based on his report indicates a stimulus that is 10 degrees by 10 degrees.

The influence of a cluttered field on the report of briefly presented targets was investigated by Engel (1974). He found that as the characteristics, size and luminance, of the test-object were varied in relation to the background the perceptibility of the test disk, in eccentric vision, varied. The area of perceptibility was called the Conspicuity Area (CA). The greater the similarity of the test disk to the clutter in the field the smaller the size of the CA.

The impact of CA on visual search attracted the attention of Kraiss and Knäeuper (1982). They investigated the effect of the size of Visual Lobe (VL) on search time. Kraiss and Knäeuper (1982) describe VL as "The visual lobe area is defined as the peripheral area around the central fixation point from which specific information can be extracted in a single glance." The larger the VA, given equal eye movement times, the less time required to search a given area.

Williams (1982) was interested in the influence of a central task workload on Mackworth's (1965) Useful Field of View (UFOV). Mackworth (1965) describes UFOV as ". . . the area around the fixation point from which information is being briefly stored and read out during a visual task."

Williams (1982) manipulated the work load of the central task and observed the shrinkage of the UFOV in relation to the difficulty of the central task. He called this resulting area the Functional Field of View (FFOV). The more difficult the center task the smaller the FFOV.

UFOV and Accidents

A recent report by Owsley, Ball, Sloane, Roenker, and Bruni (1991) shows a high correlation between UFOV and accidents in the older driver. UFOV is "the total visual field area in which useful information can be acquired without eye and head movements."(Ball, Beard, Roenker, Miller and Griggs, 1988)

In the study by Owsley et al.(1991) older drivers (mean age = 70) were evaluated on a number of visual and cognitive tests. Three of these tests are considered to be measures of the components which comprise UFOV. The components of UFOV are:

1. Speed of visual information processing
2. Ability to ignore distractors in the visual field
3. Ability to divide attention (Owsley et al., 1991).

The visual tests had two main tasks. The central task and the peripheral task.

Based on the results of the above tests, participants were divided into two groups, pass and fail. The pass group was made up of persons who had passed at least one of the UFOV tests. The Fail group was comprised of persons who had not passed any of the UFOV tests.

Accident reports from the Alabama Department of Public Safety were used as the dependent variable. The number of persons failing the UFOV test was 26. An examination of the accidents records of the persons who failed UFOV yield some interesting information.

A significant zero-order correlation between failure on the UFOV test and accidents was reported. People in the fail group experienced 4.2 times the number of accidents of the members of the pass group. The types of accidents experienced by these people appears to present a pattern. Most of the accidents in the sample were intersection accidents (67%). An intersection accident is characterized by the failure of a driver to yield the right of way and/or failure to notice another vehicle in the intersection according to the police officer at the scene. Persons who failed UFOV were responsible for 15 of the 16 intersection accidents.

Not only did the persons who passed the UFOV tests have fewer accidents, but their accidents presented a different pattern. Five persons in the pass group of UFOV had accidents. Three were struck from behind while stopped. One lost control on wet pavement and another backed into another car.

If UFOV is restricted, a greater number of fixations would be required to cover the same visual field. It is also reported that the rate of extraction of information from briefly presented visual stimuli is significantly lower for older adults (Welsandt, Zupnick, and Meyer, 1973). Either or both of these conditions would increase the time to cover a given field for the older driver.

A UFOV of less than 10 degrees would appear to be analogous to viewing the world through a tube. A restriction of this type would require more time to view a given visual world. Conversely, with a fixed time the size of the scanned field would be reduced.

In a dynamic situation, the amount of data for a given number of fixations per unit time would be reduced if the UFOV is restricted. Faced with these constraints on the volume of data that can be captured, a motorist could reduce his scan to only the area of perceived greatest risk. If the area of perceived risk does not coincide with the area of risk, safety will be jeopardized. In some situations he can reduce his speed in order to reduce the rate at which his environment changes.

However, in other situations the motorist cannot reduce speed. If his UFOV is reduced, speed is held constant, and visual field is held constant he must operate with less visual data. Information results from the integration of legitimate data with a reliable schema. Information is that which reduces uncertainty. Therefore, reduction of UFOV may increase uncertainty. The driver can become more risky in his decisions. Beyond a certain point, uncertainty increases to a level where performance suffers. The modern driving environment, with good roads, wide shoulders, and well defined routes can provide a margin of safety to compensate for poor performance.

Older drivers can be very choosy about the times and places in which they are willing to drive. As noted above they tend to use familiar routes and choose off-peak hours. The older motorist is less seen at night and tends to avoid high traffic areas.

Brief Field of View

In this study the term Brief Field of View (BFOV) will be used to describe the measure of visual information processing. This rubric is used to emphasize the ephemeral nature of the characteristic under investigation and to stress the indispensable dimension of duration not just panorama.

The efficacy with which visual information is processed was at the heart of the studies of Conspicuity Area, Visual Lobe, Useful Field Of View, and Functional Field Of View. The brevity with which the stimulus is presented is integral to these investigations yet the rubrics applied to these variables do not reflect this.

If an infinite amount of time were available for the detection of the target in Engel's (1974) Conspicuity Area study the Conspicuity Area could be the size of the visual world. Visual Lobe is defined in terms of a single glance. The duration of a single glance is, although variable, brief indeed.

Useful Field Of View is defined in terms of an area in which "information is briefly stored." The relationship of workload to the size of this area in which "information is briefly stored" is at the heart of Williams' (1982) Functional Field Of View study. Brevity of presentation relates these studies to the work done by Sperling (1960) around the issue of Immediate Memory versus Available Information.

The term Brief Field of View (BFOV) was used in this study to couple the characteristics of duration and panorama inherent in dynamic environment of vehicle operation. BFOV will have the following characteristics:

1. Brief Presentation of Information
2. Simultaneous Tasks
3. Cluttered Visual Field.

It should be noted that these characteristics are similar to the components of UFOV stated by Owsley et al. (1991).

A stimulus duration of 110 ms. is chosen for BFOV to insure that the information is present for only one eye fixation. Russo (1978) writes that the complete eye cycle for voluntary saccadic eye movements which are initiated by cognitive processes typically require 230 ms. The stimulus in transmitted from retina to optical area in 60 ms. An additional 60 ms. are required to decode the stimulus. Cognition requires 50 ms. to determine the location of the next fixation. Transmission of the movement command and actual movement of the eye requires an additional 60 ms.

Holding the stimulus duration to 110 ms. insures that the participant is unable to search for the peripheral target because the stimulus is extinguished before eye movement can be initiated. Vision is only available during fixation and is suppressed during saccades (Volkmann, 1974). This duration fills the requirement of Brief Presentation of Information. The ability to divide attention will be assessed by the requirement that both a central task and a peripheral task will be presented simultaneously. A visual field cluttered with distractors insures that the participant must have a robust intention to find the target.

Purpose of the Study

The above study (Owsley et al.,1991) suggests that failure on all three aspects of visual information processing,

1. Speed of visual information processing
2. Ability to ignore distractors in the visual field
3. Ability to divide attention,

has a relationship to the type of accident, failure to yield at an intersection, most characteristic of the older driver. If a conveniently administered test of visual information processing had a strong relationship to a measure of driver performance, this test could be used to evaluate drivers.

The use of accidents as the dependent variable poses some difficulties. Accidents by their very nature are rare events and this can cause difficulties in collecting sufficient data for analysis and conclusions. The measurement of driver performance in a task having a high level of verisimilitude to a common driving task would be superior to the use of accidents as a dependent measure.

In this study driver performance in an accident avoidance simulator was used as the dependent measure. An analog of the BFOV task was presented to the driver at a simulated intersection. What relationship exists between visual information processing as measured in a laboratory setting and visual information processing measured in a controlled field study? A comparison of Brief Field of View (BFOV) and visual performance in a simulated intersection could shed light on similarities and differences in information processing across settings.

What relationship exists between measures of visual function, static visual acuity or dynamic visual acuity, and BFOV, as measured in a laboratory setting, or driver performance in a simulated intersection? If there is a strong correlation between a well established driver vision screening test, static visual acuity, and BFOV this would lend credibility to the new test and relate BFOV to past studies. The finding of a firm correlation between dynamic visual acuity, which has face validity to a driving vision task, and has also been shown to have a significant correlation with accidents could bolster confidence in BFOV. If the laboratory measure of BFOV is solidly related to the field measure of BFOV then the predictive value of the laboratory test will be substantiated.

Experimental Hypotheses

All hypotheses will be tested at $\alpha = 0.001$.

1. Young drivers will have significantly better static visual acuity than older drivers.
2. Young drivers will have significantly better dynamic visual acuity than older drivers.

3. Young drivers will correctly locate significantly more peripheral targets than older drivers while correctly performing the central task under Laboratory BFOV test conditions.
4. Young drivers will correctly identify the Signal Light Configuration significantly more often than older drivers while safely driving through the simulated intersection at the Hazard Avoidance Facility.
5. There will exist a significant correlation between the performance on the Laboratory BFOV test and performance in the simulated intersection.

ASSESSMENT OF VISUAL CAPABILITIES

Participants

Forty drivers participated in all sections of this study. All were licensed drivers in the State of Texas. The participants were divided into two cohorts, Old and Young, based on age. Those requiring corrective lenses wore them for all tests. The characteristics of the participants are summarized in Table 1.

The persons in the Old cohort were paid $10 per hour for both laboratory sessions and driving sessions. The Young cohort was made up of graduate and undergraduate students. The students were given class credit for participation. These sessions were conducted on different days and required roughly two hours total time for each participant.

Static Visual Acuity

Rationale

The only visual test common to all 50 states is Static Visual Acuity (SVA). A new method of evaluating driver vision should have a sound relationship to this established method. Bailey and Sheedy (1989) report that SVA remains relatively constant until age 50 years and begins a rapid decline. SVA was assessed in this sample to rule out any gross vision impairment and to provide a standard from which to evaluate the efficacy of BFOV. The inferences about the population from which this sample is drawn are strengthened by establishing that the level of SVA in the sample is within the required SVA for drivers in the State of Texas (Snellen 20/40).

Materials and Apparatus

A Bausch & Lomb Modified Ortho-Rater (Model #71213102, Bausch & Lomb, Rochester, NY 14602) with slide Test F-3 (Acuity Both Eyes - Far) installed was placed on a counter in the Human Factors Engineering Laboratory, Zachry Engineering Building, at Texas A & M University.

Procedure

The participant adjusted the position of the eyepiece of the Modified Ortho-Rater to a comfortable position. Test Slide F3 was inserted into the holder and it was observed that the light bulb turns on and that the slide is illuminated. The research participant was requested to look through the eye piece while wearing any correction normally used while driving.

TABLE 1
Summary of Participant Characteristics by Cohort

Cohort	*Gender*		*Age(Years)*		*Driving Experience (Years)*	
	Male	*Female*	*Mean*	*Range*	*Mean*	*Range*
Old	11	9	73.1	65 - 86	58.4	50 - 65
Young	11	9	26.0	21 - 35	10.3	4 - 21

The following instructions were read:

> "In the big sign at the top, the Number 1 sign, do you see a large black checkerboard on your right? (Wait for an affirmative response.) In the Number 2 sign where is the checkerboard? Number 3? ...."(Bausch & Lomb, 1974)

The participant was prompted to continue until two consecutive signs are missed.

The last correct test item was considered to be a measure of the participant's static visual acuity (SVA). This value was scored in accordance with the table in the instruction manual for the Modified Ortho-Rater (Bausch & Lomb, 1974).

Dynamic Visual Acuity

Rationale

As noted earlier, a small, although significant, correlation between dynamic visual acuity (DVA) and accidents was reported by Burg (1966). Driving is a task that requires vision while in motion. Either the driver or his targets of interest or both are in motion. DVA is a measure of a person's ability to resolve targets while they are in motion. This measure of acuity appears to be more relevant to driving than SVA. Burg (1967) has shown that DVA decreases with increasing age. UFOV has been shown to decrease with age also. An assessment of DVA and visual information processing in the same individuals could be useful in leading to a fuller understanding of the function of vision in driving.

Materials and Apparatus

A Large Dynamic Visual Acuity Test Station was constructed in the environmental test chamber of the Human Factors Engineering Laboratory. This apparatus consisted of a Focal Point Stand and a high reflectance semi-circular screen (see Figure 2).

The Focal Point Stand held a plane, front surfaced mirror (10 in. x 10 in.)(25.4 cm x 25.4 cm) mounted vertically upon the rotating table of a Photoelectric Rotary Pursuit Device (Model 30014 Lafayette Instrument Co., Lafayette, Ind. TAMU #O714084).

A Kodak Ectagraphic 35mm slide projector (Model AF-2, Eastman Kodak Co., Rochester, NY) with remote control was positioned on the Focal Point Stand to project an image onto the front surface mirror. The slide tray on the projector was filled with sets of stimulus slides. These stimuli consisted of Landolt rings, white on

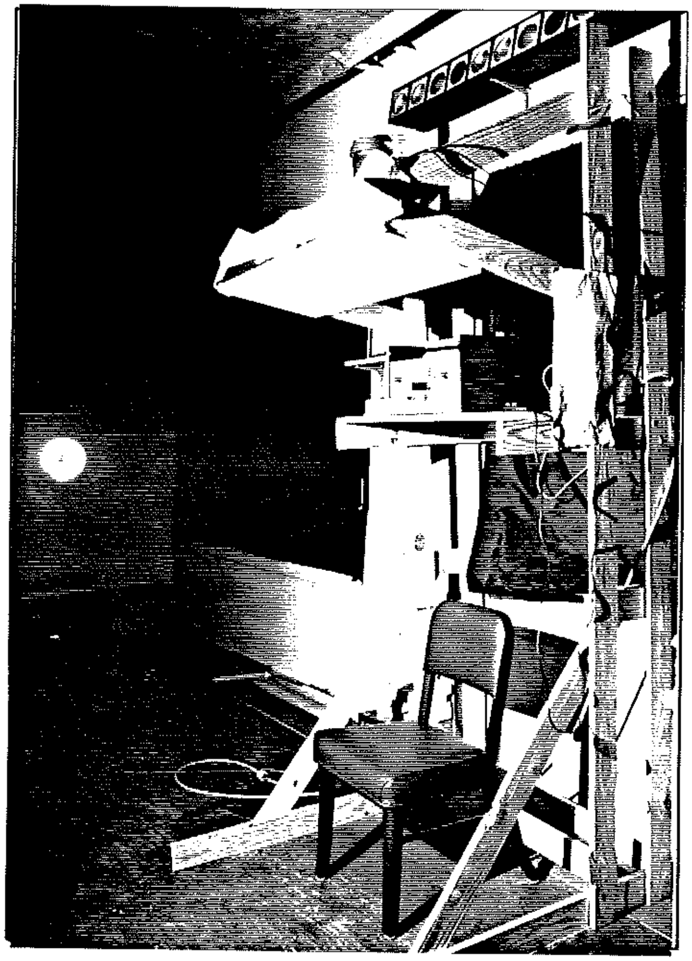

Figure 2. *Dynamic visual acuity test station showing focal point stand, participant position, and typical target on the semi-circular screen.*

black, of graduated sizes. A typical slide is presented in Figure 3. The dimensions of the Landolt ring are as follows: the gap is one unit, the stroke is one unit, and the outside diameter is five units.

Besides the stimulus slides, one Instruction slide and one Combined slide were used. The image on the Instruction slide was that of a large Landolt ring with the gap and direction conventions labeled in yellow (see Figure 4). The purpose of the Instruction slide was to familiarize the participants with all possible locations of the gap in the stimulus rings.

The Combined slide held the images of eight different Landolt rings of graduated sizes (see Figure 5). The Combined slide presented a series of Landolt rings. All possible gap sizes were present on this slide. The gaps were located in randomly selected locations. This slide served two purposes. First, this slide gave a demonstration of the possible gap locations as a follow-up to the instruction slide. Secondly, by presenting this slide under motionless conditions, static visual acuity of the participants in the Dynamic Visual Acuity test stand was assessed.

The image of the Landolt ring was reflected from the front surface mirror upon the semi-circular screen. The Focal Point Stand was constructed so that the research participant could sit in a straight backed office chair underneath the shelf holding the rotating mirror and associated apparatus (see Figure 6). This allowed the axis of rotation of the mirror to be concentric with the axis of rotation of the head of the participant. This configuration, the relationship between the rotating mirror and participant, insured that the perceived angular velocity of the Landolt ring image is the same as the angular velocity of the Photoelectric Rotary Pursuit Device. The screen was made of white polyester fabric stretched over curved plywood form. The curves of the plywood held the screen in a semi-circle of radius 10 feet (3.05 m). The center of curvature was the axis of rotation of front surface mirror located on the Focal Point Stand.

In order to reduce light backscatter, a neutral density filter was placed in front of the projection lens of the slide projector to reduce the brightness of the stimulus image to 7.5 fL (25.7 cd/m^2). The contrast ratio of the stimulus to background was 99 percent. The apparent size of the gaps in Landolt rings, in Minutes of Arc (MOA), were as follows: 2, 4, 8, 14, 22, 29, 36, 50, and 57.

The slide tray held three different sets of stimulus slides. The orientation of the gaps in the slides was randomly assigned. The slide sets to be used for the 60

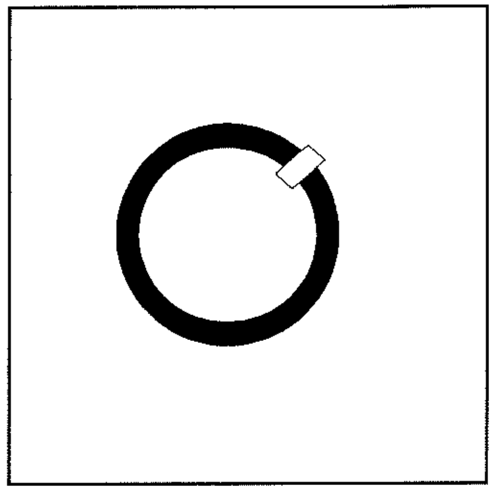

Figure 3. *An example of a typical landolt ring used as a stimulus in the dynamic visual acuity test.*

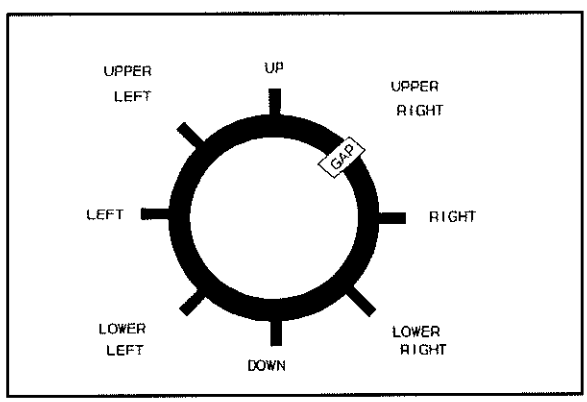

Figure 4. *Training slide used to teach the participants the directional conventions used to report the gap location during the dynamic visual acuity test.*

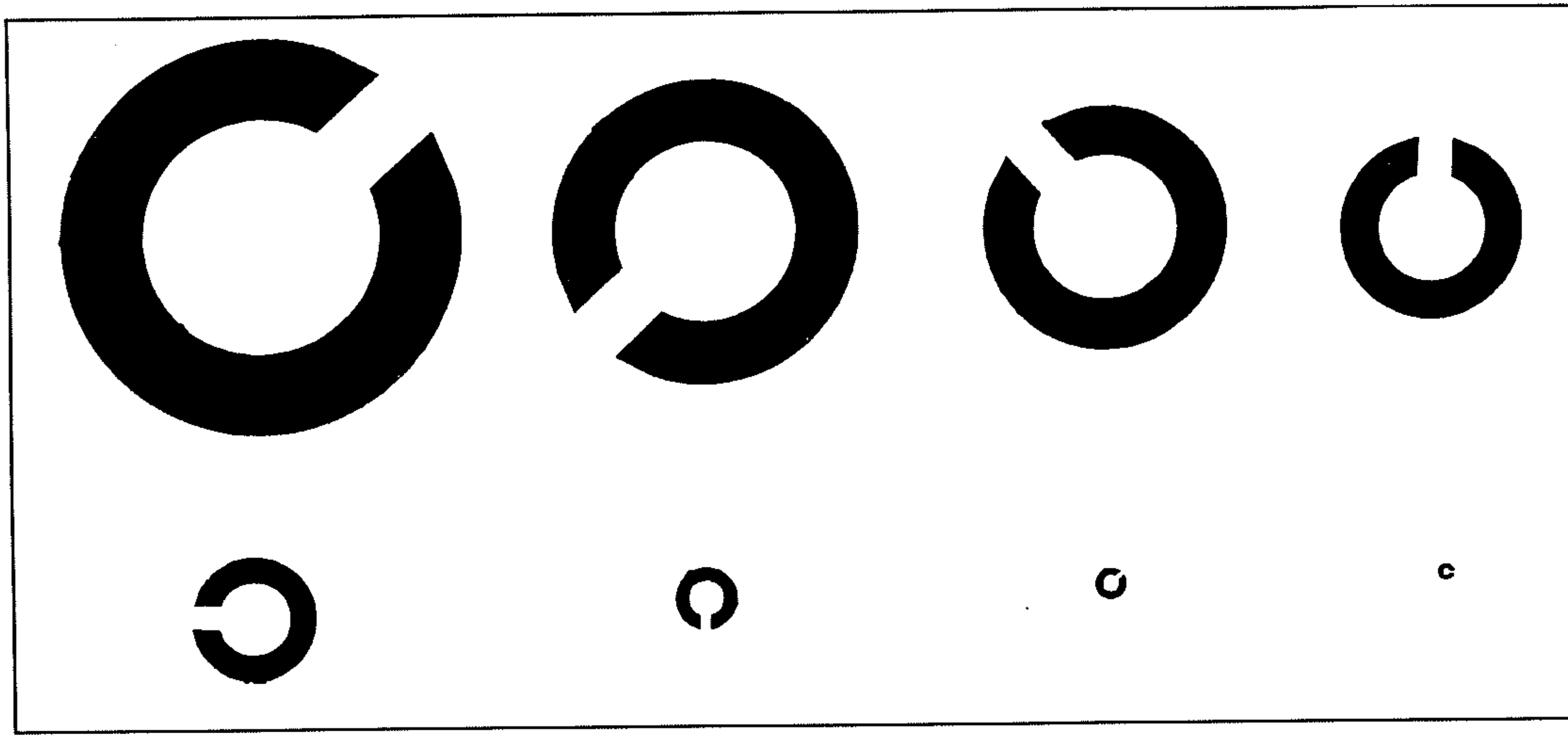

Figure 5. *Combined landolt ring slide showing eight rings of graduated sizes used for assessing dynamic visual acuity at an angular velocity of zero.*

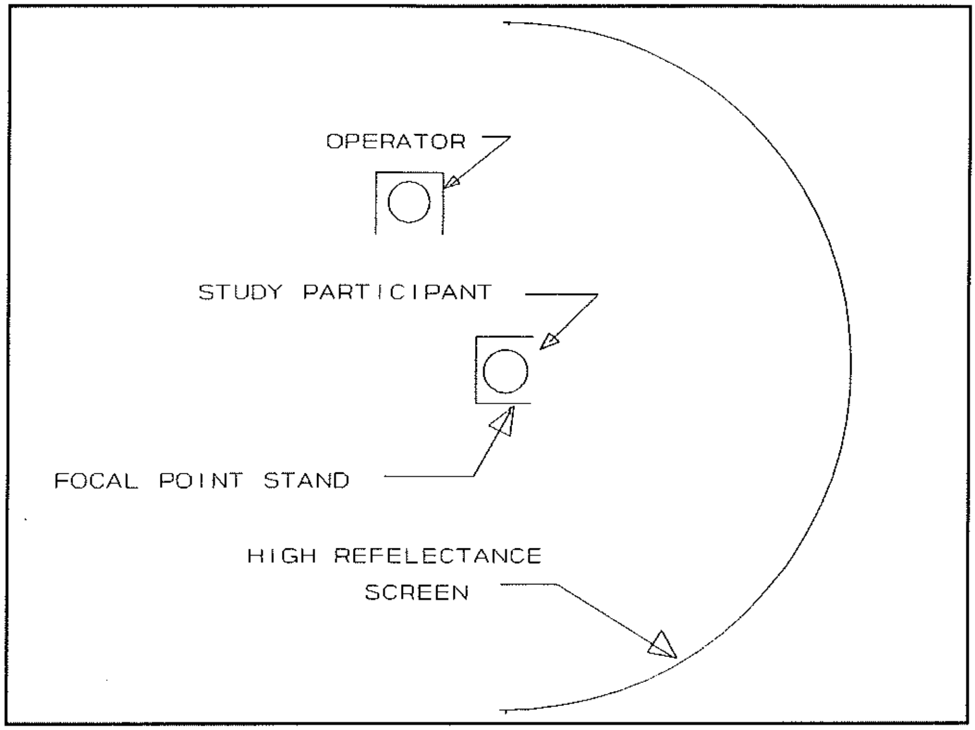

Figure 6. *Plan view of the dynamic visual acuity test station showing the location of the participant and operator during testing.*

degrees/second (1.05 rad/sec) and 90 degree/second (1.57 rad/sec) angular velocities had gaps of 2, 4, 8, 14, 22, 29, 36, and 50 MOA. The slide set for 120 degrees/second (2.09 rad/sec) angular velocity had gaps of 4, 8, 14, 22, 29, 36, 50, and 57 MOA. A pilot study suggested that few persons could see a small gap of 4 MOA, and none could see 2 MOA, at an angular velocity of 120 degree/second. In contrast, some persons could not see a large gap of 50 MOA at 120 degrees/second.

Procedure

Research participants were seated in the chair under the Focal Point Stand in the darkened environmental test chamber for five minutes to allow their eyes to adapt. The participants were given individual instructions (see Appendices) and practice before DVA was measured. DVA was assessed at four levels of ascending angular velocity.

Laboratory Brief Field of View

Rationale

Driving is a task that requires rapid information processing. The study by Owsley et al. (1991) reported earlier shows a correlation between a measure of information processing and a specific set of accidents. Part of the information processing task is the focusing of attention and the pursuit of a goal in the face of distractors. In the laboratory BFOV test the participant was required to obtain information from the center of a briefly presented visual array while simultaneously detecting a peripheral target. Both the information from the central vision task and the location of the peripheral target were reported immediately. The central vision task had the highest priority and its location was conspicuous and constant. The peripheral task was secondary and the target location was obscured by analogous shapes.

A comparison of Brief Field of View performance in both a laboratory setting and in an intersection could shed light on similarities and differences in information processing across settings and prove useful in evaluating drivers.

Materials and Apparatus

The Brief Field of View Test Station consisted of a rear projection screen, two Kodak 35mm slide projectors, stimulus and training slides, a projection tachistoscope (Projection Tachistoscope Model 15-5-C, Marietta Apparatus Co., Marietta, OH), a chin rest with interlock and a participant's chair (see Figure 7). The chin rest with interlock was made with local material. The stimulus and training slides were designed and made by the experimenter.

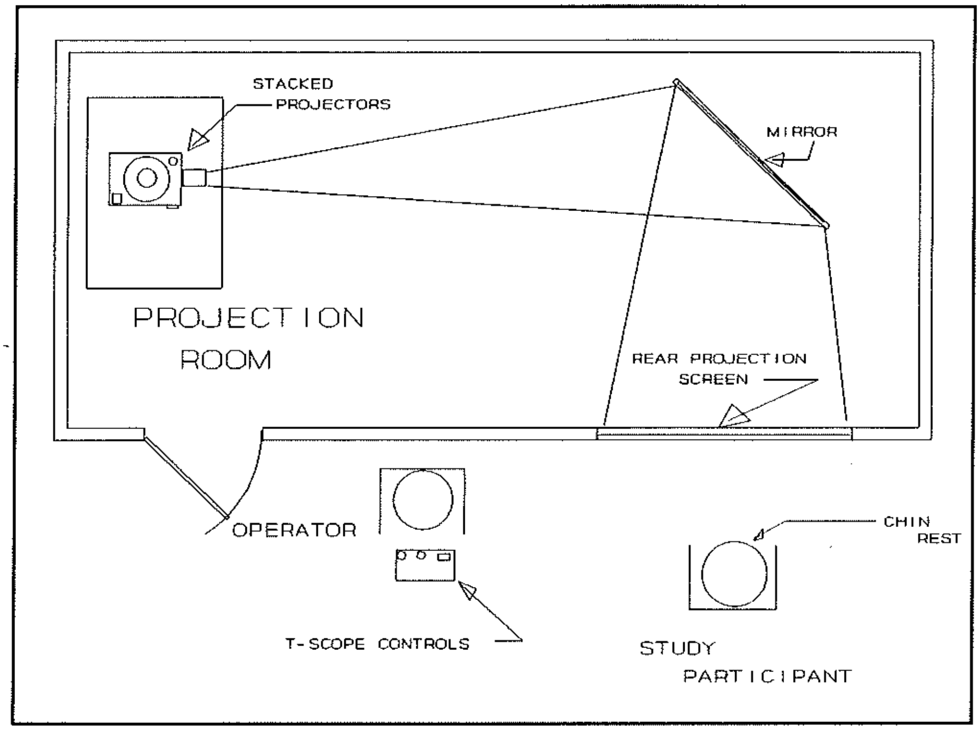

Figure 7. *Plan view of the brief field of view test station showing the location of the participant, the operator, and the light path of the stimulus image during testing.*

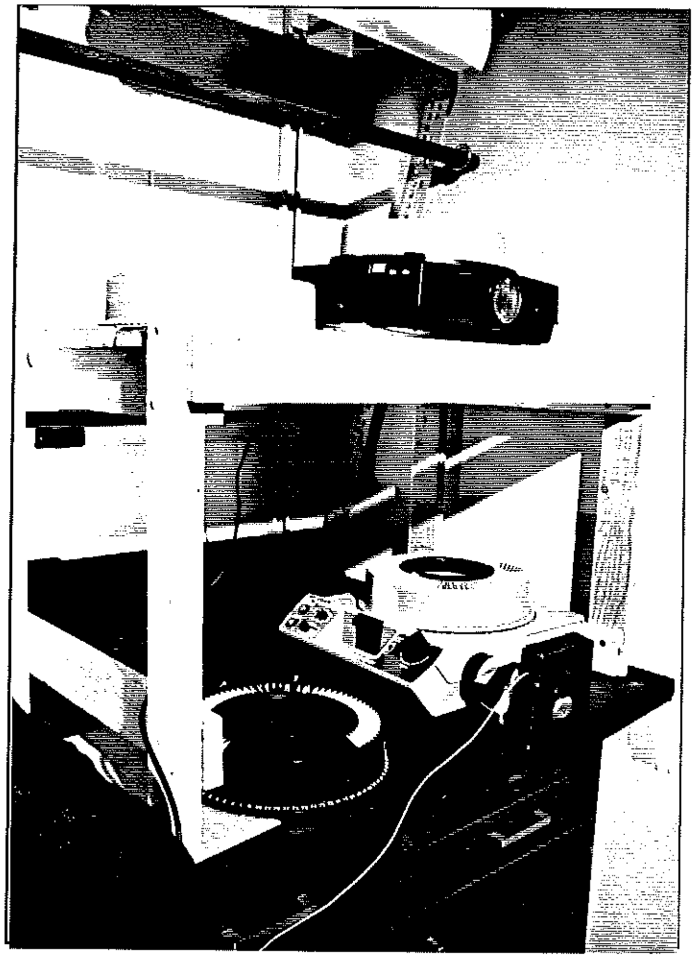

Figure 8. *Slide projectors used in the laboratory BFOV experiment showing the tachistoscope shutter open on the stimulus projector.*

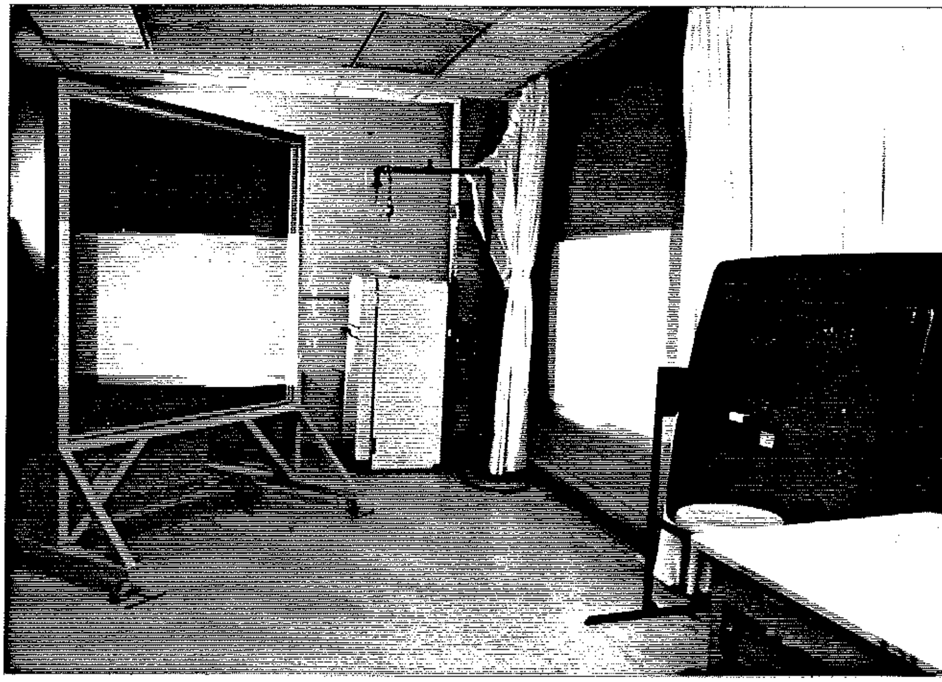

Figure 9. *View of the plane mirror and rear projection screen, showing a typical stimulus slide, from the position of the slide projectors.*

A rear projection screen is built into one wall of the environmental test chamber located in the Human Factors Engineering Laboratory in the Zachry Engineering Building of Texas A & M University. Stimulus slides were projected upon this screen for the BFOV experiment. Two 35mm Kodak slide projectors, a fixation projector (Ectagraphic Model AF-2, Eastman Kodak Co., Rochester, NY) and a stimulus projector (Ectagraphic III Model ATS, Eastman Kodak Co., Rochester, NY), were placed in a stand in the projection room behind the rear projection screen (see Figure 8). The fixation projector was placed above the stimulus projector. The light paths from the projectors to the screen were bent by a large (6 ft(1.8 m) x 6 ft(1.8 m)) plane mirror (see Figure 9). The projectors were positioned such that their images were concentric at the screen. One of the slide projectors was used to hold a fixation point slide and to project that fixation point upon the screen at a location directly in front of the seated participant and 30 in. (76.2 cm) above the floor. The fixation point appeared as a white spot upon a dark blue background and both the fixation point and the blue background were constantly visible. The stimulus images were white and were projected on the dark blue background (see Figure 10). All room lighting was extinguished. The only ambient illumination came from the blue background whose brightness was 0.05 fL (0.171 cd/m^2).

The lines used to form the center box, dummy boxes, and the target hexagon subtended an angle of 16′ (0.0047 rad). The lines used to form the letters in the center box subtended an angle of 47′ (0.0137 rad). The stop sign shaped target had letters made up of lines which subtended an angle of 8′ (0.0023 rad).

Two sets (24 each) of Stimulus Array slides were placed in the carousel tray of the stimulus projector. In addition, the carousel tray held a set of training slides. A projection tachistoscope shutter was placed on the lens of the stimulus projector and a 10 percent neutral density filter was affixed to the shutter opening. A summary of the characteristics of the projected images is presented in Table 2.

The chin rest was located at a distance of 40 in. (1.02 m) orthogonal to the center of the plane of the projected image. The participants chair was placed in a position that would allow the person to sit comfortably with their chin in position on the chin rest while regarding the projected image. The projected image was masked to a size of 51.5 in. x 40.5 in. (1.31 m x 1.03 m).

The weight of the person's chin closed an interlock switch located in the shutter actuation circuit of the projection tachistoscope. The purpose of this interlock was to insure that the participant's head was in a known location. A typical stimulus slide is presented in Figure 11.

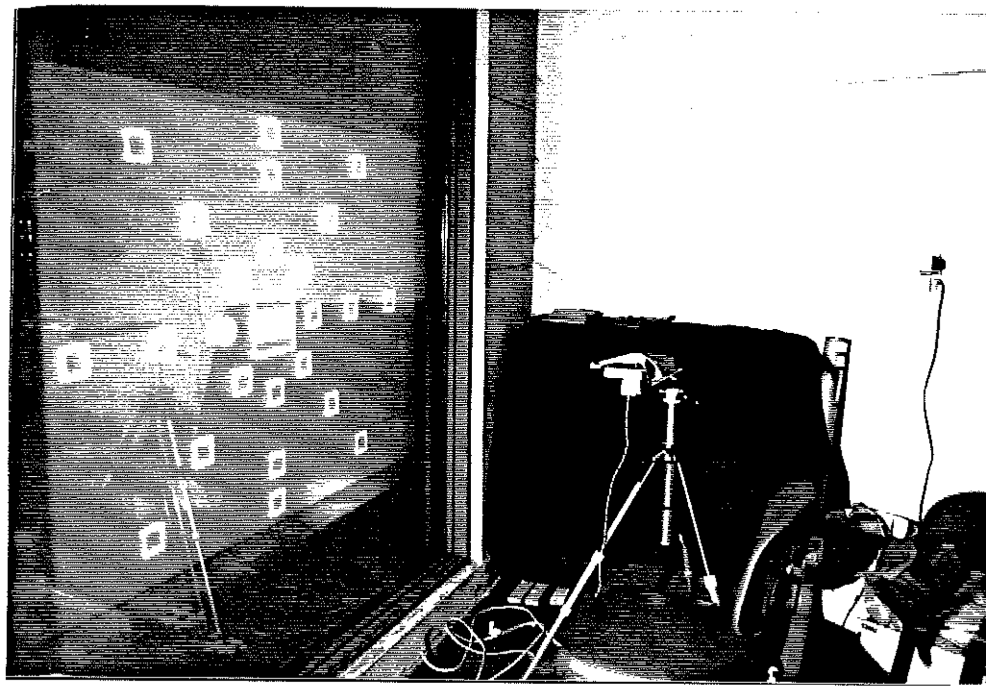

Figure 10. *View of the participant position in the laboratory BFOV test station showing chair, chin rest, and typical stimulus image.*

TABLE 2
Apparent Size, Shape, and Photometric Values for the Parts of the Stimulus Images

Image type	*Shape*	*Position in the field*	*Size (Deg) (Rad)*	*Brightness (fL) (cd/m^2)*	*Luminance Contrast*
Fixation Point	Point	Center	1 (0.017)	0.20 (0.69)	75%
Center Box	Rectangle	Center	9 x 8 (0.16 x 0.14)	0.91 (3.12)	95%
Letter Pair	Letters	Center	5 x 5 (0.09 x 0.09)	0.91 (3.12)	95%
Dummy Boxes	Square	On Grid	3 x 3 (0.05 x 0.05)	0.91 (3.12)	95%
Target	Hexagon	On Grid	3 x 3 (0.05 x 0.05)	0.91 (3.12)	95%

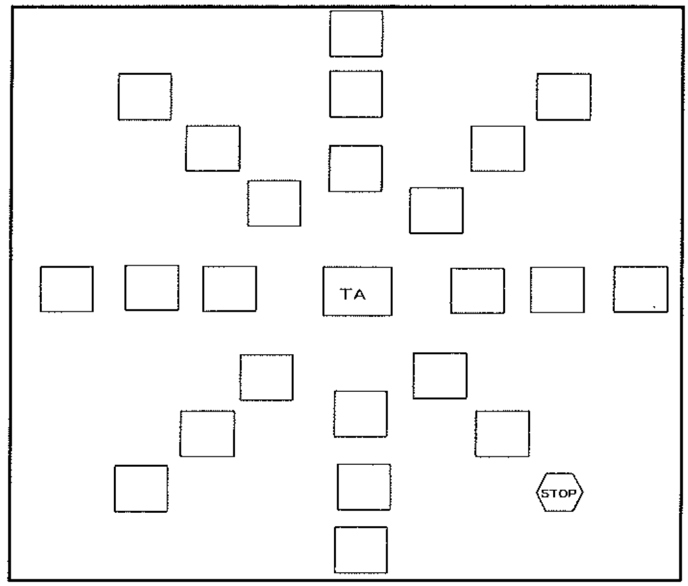

Figure 11. *Typical stimulus slide used in the laboratory brief field of view test.*

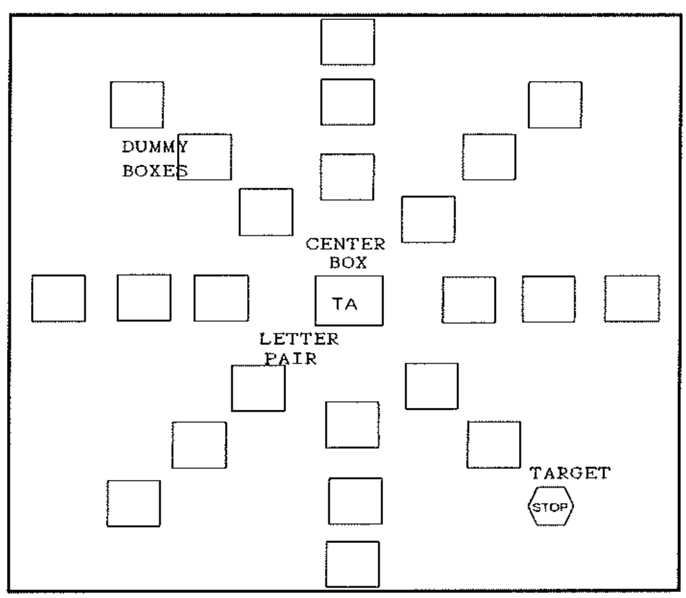

Figure 12. *Laboratory BFOV training slide with components labeled.*

The image has two classes of stimuli based on size, center box and peripheral images. The center box was located in the center of the slide and its image, when projected tachistoscopicly, surrounded the image of the fixation point. The function of the center box was to provide a distinct location for the central vision task. The center box contained a randomly selected letter pair formed from the letters A,E,M,O,T, or X. Surrounding the center box was an array of 23 distractors (dummy boxes) and 1 target (see Figure 12). The target was a hexagon with the word "STOP" in the middle. This shape was chosen because it resembles a common traffic sign and was different from the distractors. Within a Stimulus Slide Set, the target appeared only once at each of the 24 intersections of rings and axis. The function of the distractors was to increase the difficulty of the target location task.

All of these images were positioned on an imaginary polar coordinate grid whose origin was located at the center of the center box. This grid had eight axis: Up, Down, Left, Right, Upper Right, Lower Right, Lower Left and Upper Left. The rings of this grid were located eccentric to the pole at 10° (0.175 rad), 20° (0.349 rad), 25° (0.436 rad) and 30° (0.524 rad). The 25° (0.436 rad) ring was only used forthe Up and Down Axis. These axes and the 24 intersections of the axes with the rings which defined the locations for the center of the small stimuli are indicated in Figure 13.

Procedure

The participants were seated in position in front of the rear projection screen and the chin rest was adjusted to a comfortable height. The fixation point was indicated and the participants received instructions and training in the tasks (see Appendices).

The participants were told that they would be shown, very briefly, a slide with letters, boxes, and stop sign shapes on it. The training slides were used to familiarize the participants with the nature of the stimuli and the directional conventions used. The primary task for the participants was to read the letters in the center box then, if possible, the location of the target, the stop sign shape, was to be reported. The central vision task was given the higher priority in the instructions in order to insure that the gaze was anchored at a know location. The purpose of this was to allow inferences about the extent of the visual field to be made. For the peripheral target detection task, an indication of the axis upon which the target was located was sufficient and the degree of eccentricity was not asked.

The participants were told that the target could appear on any axis and at any eccentricity. They were told that any failure to correctly report the letters in the center box, the central vision task, would cause that trial to be discarded.

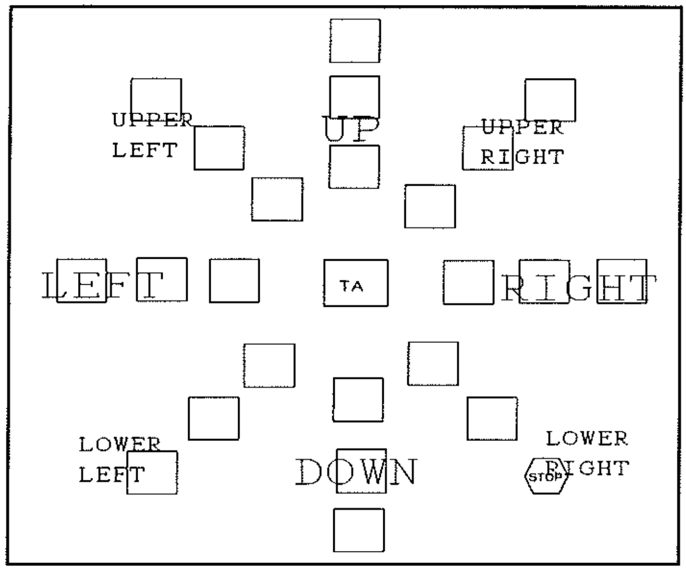

Figure 13. *Laboratory brief field of view slide showing the directional conventions used by the participant to report the location on the peripheral target.*

Training in the central vision task and peripheral target detection task was given to insure the task was understood and to develop confidence in the participant. After the slide was presented and a response was made, the slide was presented for an extended period of study by the participant. Four task training slides were presented at durations of 800 ms, 500 ms, 400 ms, and 300 ms.

A set of five speed training slides were presented before the 24 measurement slides. One slide was presented at each of the following four durations: 700 ms, 500 ms, 500 ms, 400 ms, 300 ms. For each slide the participant was given a preparatory warning of "Ready" after which, within one second, the stimulus slide was presented. The participant immediately identified the letter pair and, if possible, the direction of the target. This information was recorded and the preparatory warning for the next slide was given.

The responses to the speed training slides were not analyzed. The sixth slide was the first of the measured stimuli and was presented, as were all subsequent slides, for 110 ms. duration. The 24 measurement slides were presented in the same randomly determined order for all participants, such that each target location was presented only once.

Upon completion of the training and with the participants willingness, BFOV was assessed under two central vision task conditions, identification and matching.

The order of the central vision task was randomized and balanced. A rest period of roughly 3 minutes, based on participant stated willingness to continue, was provided between the different tasks assessments.

Figure 14. *View of test vehicle and signal light array (showing configuration - green center) from near trip wire one.*

Driving Brief Field of View

Rationale

Measurement of BFOV driving performance was an attempt to obtain data related to visual information processing under controlled field study conditions. An accident avoidance simulator was chosen as the venue for this controlled field study. The accident avoidance simulator is a well known device for assessing driver performance.

The participant's tasks were to drive in a lane under an array of three traffic signals and to correctly report a change in the color of the signal lights. The duration of the change was brief and occurred when the vehicle was passing known,but randomly selected, locations.

Material and Apparatus

A 1991 Ford Taurus Station Wagon (TTI Vehicle #637) with automatic transmission, power brakes, six-way power driver seat, and air conditioning was used as the experimental vehicle in this study (see Figure 14). The Hazard Avoidance Facility (HAF) located on Runway 17L (see Figure 15) in the Proving Grounds Area of the Texas A&M University Riverside Campus was used as the driving range by all participants. The HAF consists of approach and departure lanes, traffic signals, a Signal Control Unit, suspension masts and cables, five external trigger switches with cables, and a 110 volt AC generator.

The HAF is a 600 ft(183 m) x 120 ft(14.4 m) portion of a former aircraft runway. Three standard traffic signals are suspended over three simulated traffic lanes each 12 ft(3.7 m) wide. The lanes are designated Left, Center, and Right. At its lowest point, the center of the signal light over the center lane was 10 ft(3.05 m) above the pavement.

The outboard edges of the signal lights in both the left and right lanes were 17 ft(5.2 m) from the center of the signal above the center lane.

These signal lights were viewed against the southern sky. All testing was conducted during fair weather conditions. The sky was partly cloudy to clear and ranged in brightness from approximately 500 fL(1 713 cd/m^2) to 3500 fL(11 991 cd/m^2) Tests were conducted no earlier than 9:00 AM and all participants completed their runs by 1 hr. 30 min. before sunset. The luminance of the signal lights in footlamberts are listed in Table 3.

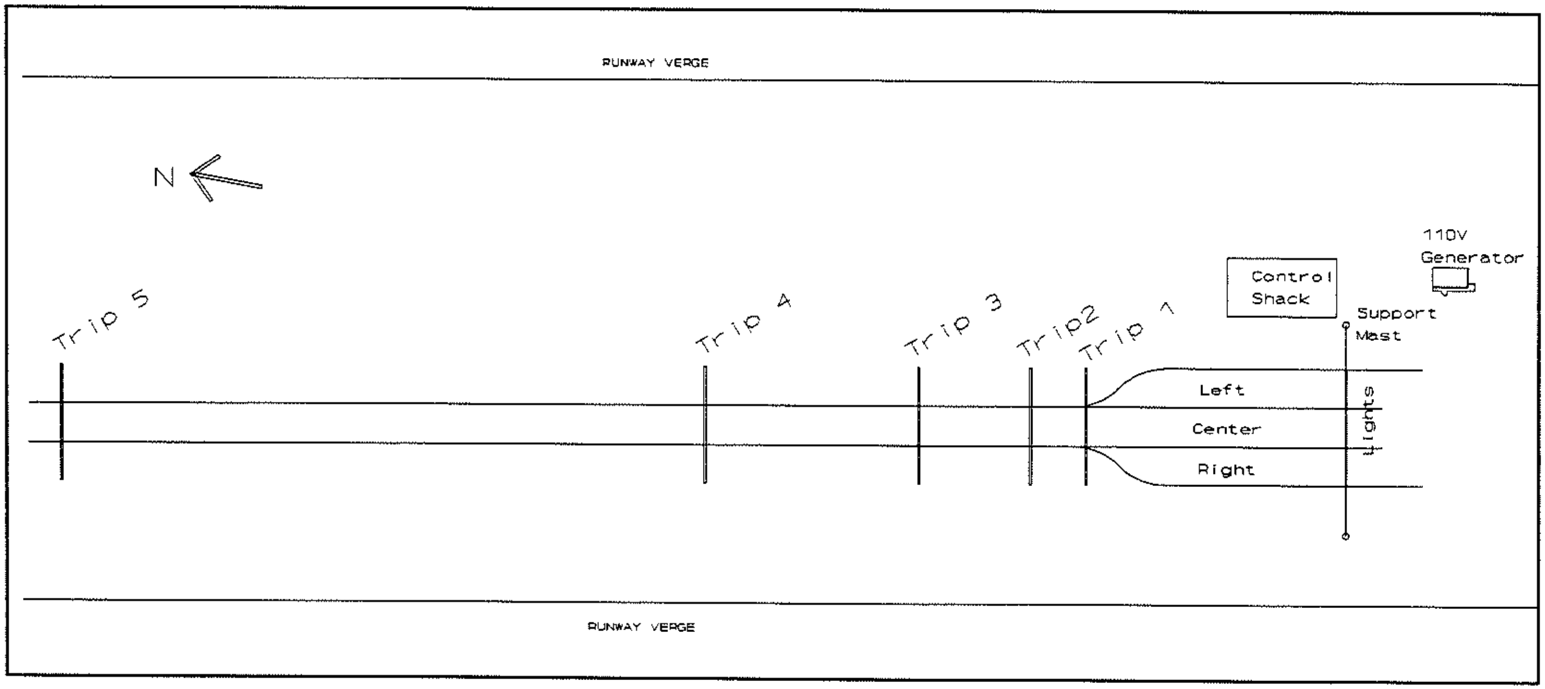

Figure 15. *Plan view of the Hazard Avoidance Facility showing entrance lane with trip wire locations, position of the signal light array and auxiliary equipment.*

TABLE 3
Signal Light Luminance by Color and Lane

Color	*Brightness (fL) (cd/m²)*		
	Left	*Center*	*Right*
Red	1100 (3 769)	825 (2 827)	525 (1 799)
Yellow	2250 (7 709)	2750 (9 422)	2490 (8 531)
Green	500 (1 713)	660 (2 261)	550 (1 884)

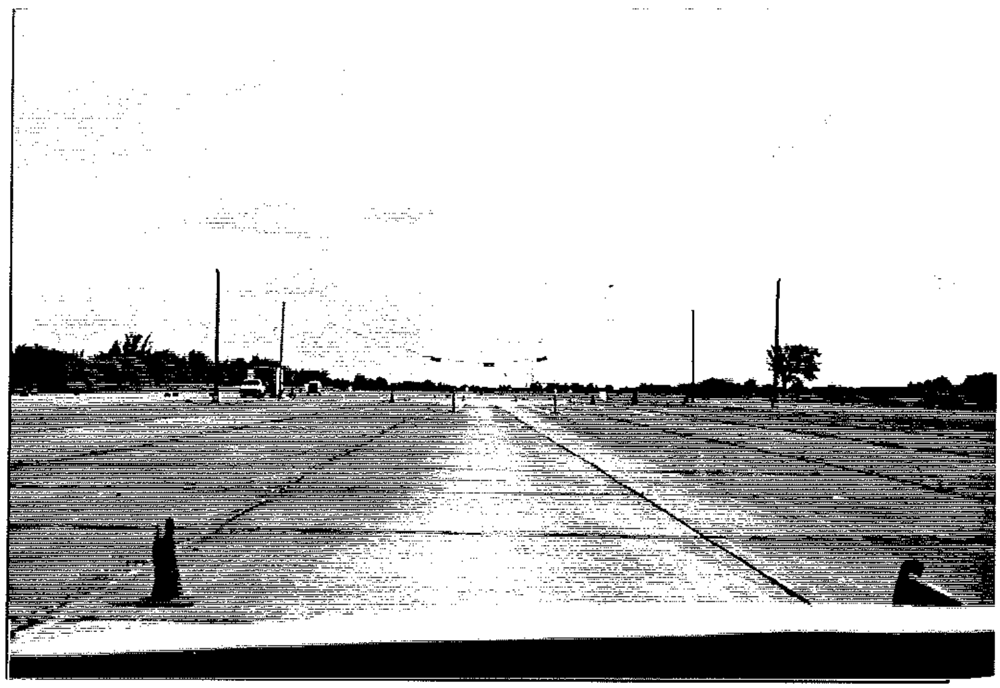

Figure 16. *View of HAF taken with a normal lens from the driver's seat of the test vehicle stopped at trip wire five showing the approach lane and signal light array (configuration neutral).*

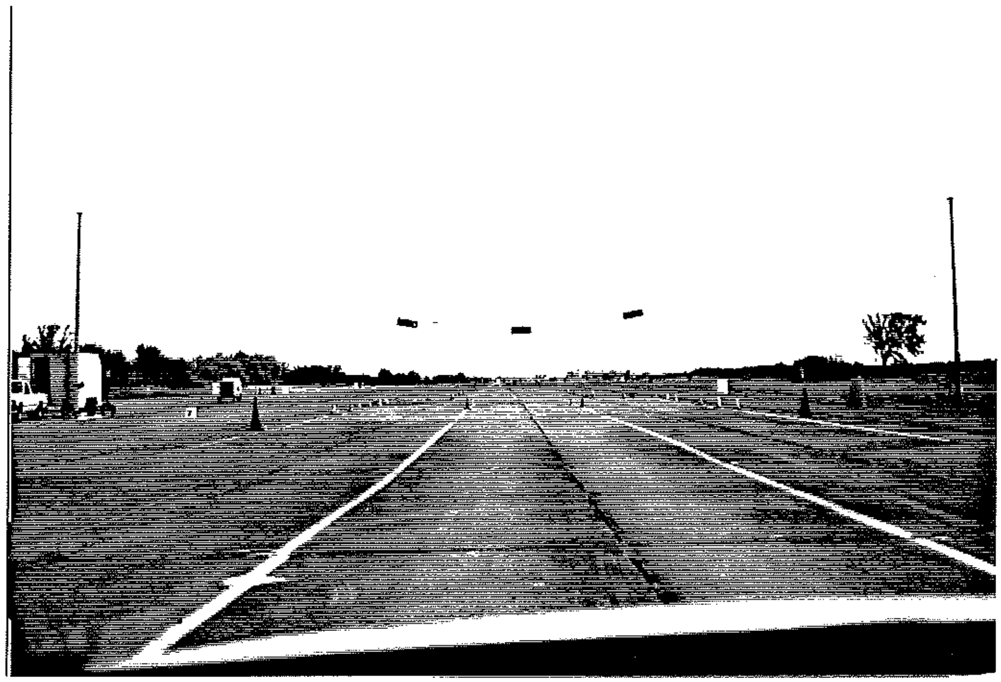

Figure 17. *View of the signal light array (configuration green left) from the driver's seat at trip wire four.*

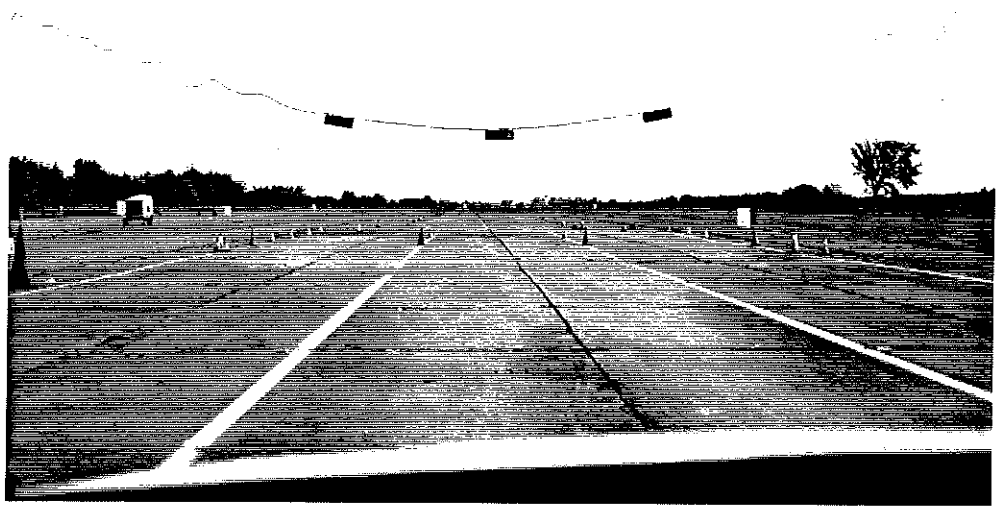

Figure 18. *Signal light array showing configuration green center as seen by the driver at trip wire three.*

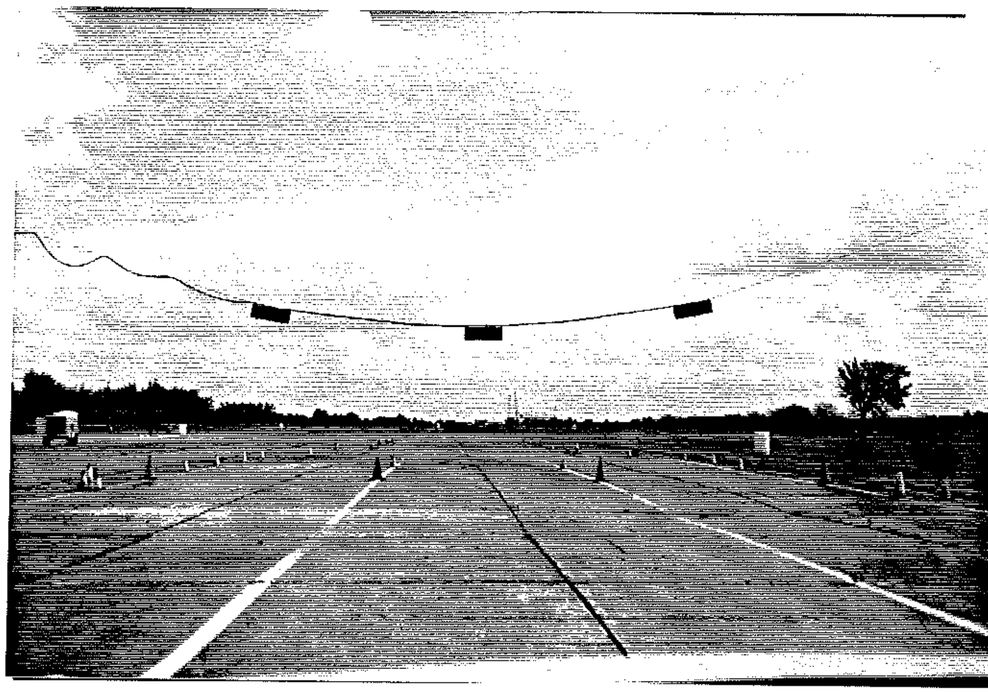

Figure 19. *Green right configuration of signal lights seen against a typical southern sky by the driver.*

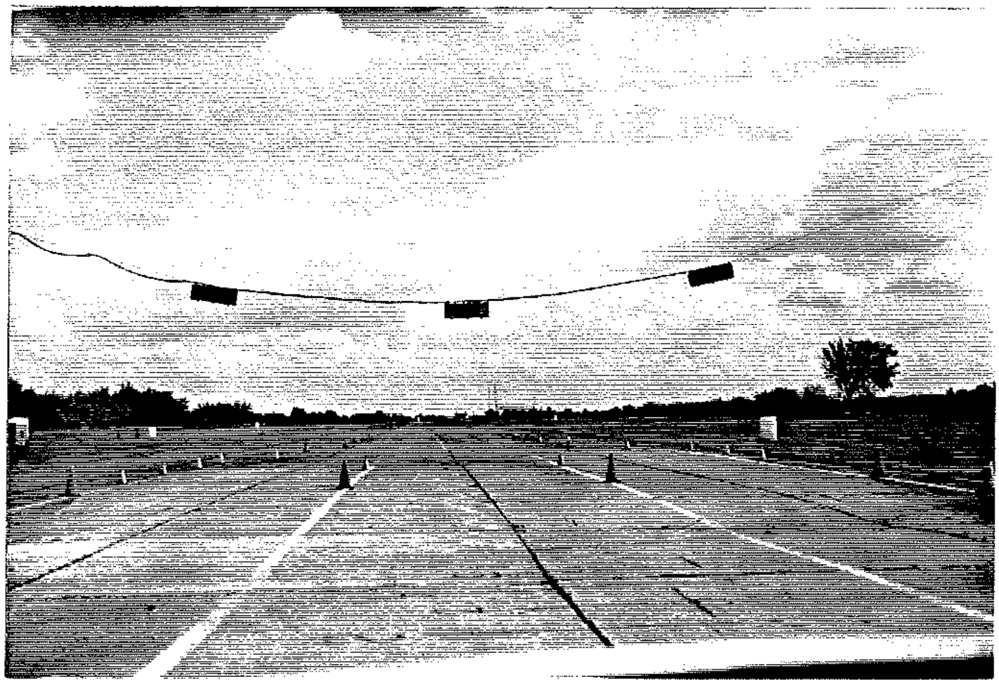

Figure 20. *Driver's view of green center configuration with the vehicle at trip wire one.*

The HAF Signal Control Unit controls the duration and configuration of signal lights located over the lanes. Five flat tape switches (Trip 1 through Trip 5) were placed in the tire path of the center approach lane at distances of 76 ft. (23.2 m), 96 ft. (29.3 m), 130 ft. (39.6 m), 195 ft. (59.4 m), and 390 ft. (118.9 m) from the signal lights.

At these distances, the three signal light array subtended a cone of 5° , 10°, 15°, 20°, and 25° respectively (see Figures 16 - 20). In terms of eccentricity from the centerlane signal light, the outboard edges of the signal lights in both the left and right lanes were 2.5°, 5°, 7.5°, 10°, and 12.5° eccentric, respectively, from the center light. Figures 16 - 20 illustrate the change in eccentricity of the outboard lights in relation to the center light as the participants drove from trip wire five to trip wire one.

Four Signal Light Configurations were selected as test stimuli for the BFOV Driving Performance Test. These configurations along with the neutral condition are listed in Table 4.

It is to be noted that the maximum eccentricity of the outboard signal lights with regard to the center of the array is half of the maximum eccentricity of the target (25 degrees) with regard to the Center Box in the Laboratory BFOV test. A pilot study using eccentricities greater than 12.5° for the driver performance task resulted in driver performance scores on the order of random chance, reports of driver discomfort, and an unwillingness of participants to continue.

Procedure

The research participants were met at the Texas Transportation Institute, Proving Grounds Office located on the Riverside Campus of Texas A & M University. They were driven in the experimental vehicle roughly one mile to the HAF. The research participants were driven through the course at least twice to familiarize them with the physical layout of the HAF. Then the participant was invited to take the drivers position while the experimenter was seated in the front passenger seat. After the participant adjusted the seat and controls to their comfort, they drove through the HAF at least

TABLE 4
Signal Light Configurations Used in BFOV Driving Performance Experiment by Lane

Configuration	*Lane*		
	Left	*Center*	*Right*
Neutral	Yellow	Yellow	Yellow
All Red	Red	Red	Red
Green Left	Green	Red	Red
Green Center	Red	Green	Red
Green Right	Red	Red	Green

three times. The purpose of these trips was to insure the participants comfort with the car and their familiarity with the facility.

The participants were given instructions and training (see Appendices) in the BFOV driving task. The car was parked at Trip 5. All four of the possible signal light configurations were presented, in a random order, for a duration of two seconds as a demonstration and to screen the participants. A failure on the part of a participant to correctly report the configuration would disqualify the participant. None of the participants failed this screening.

Speed training consisted of presenting one trial of all light configurations for durations of 1.5 seconds and 500 ms, two trials at a duration of 200 ms, and three trials at 110 ms. The order of presentation of the signal light configurations was randomized. The failure of a participant to correctly report at least one presentation of the green light over the center lane at a duration of 110 ms would disqualify the participant. All participants passed this screening.

On order to familiarize the participants with the location of the trip switches, they drove the car through the HAF five times with the trip switches activated and the light duration set at 800 ms. Upon completion of training the participants were told that the test would be similar to the training and would consist of 24 trials. They were told that the duration of the presentations could change and that they would be required to guess at an answer even if they were not sure of the correct answer.

When the participant indicated willingness to begin BFOV Driving Performance was assessed (see Figure 21). All participants were exposed to the same order of presentation. The participant was instructed to drive through the HAF at approximately 30 mph. The duration of the signal presentation was set at 110 ms for all test trips. The participant was required to report the configuration of the signal lights after passing under the signal light array. A response was required for each trial. A complete evaluation consisted of 24 trips through the HAF although the responses on only 20 trips were scored. On four of the trips (6, 10, 16, and 21) the signal light duration was increased to 500 ms. These trials were made easier in order to maintain participant motivation in the face of a difficult task. The order of the presentation of the various signal light configurations and the location of the active trip wire were randomized within the constraint that all four configurations were presented at each of the trip wire locations. The configurations on the motivational trials were as follows: All Red, Green Right, All Red, and Green Left.

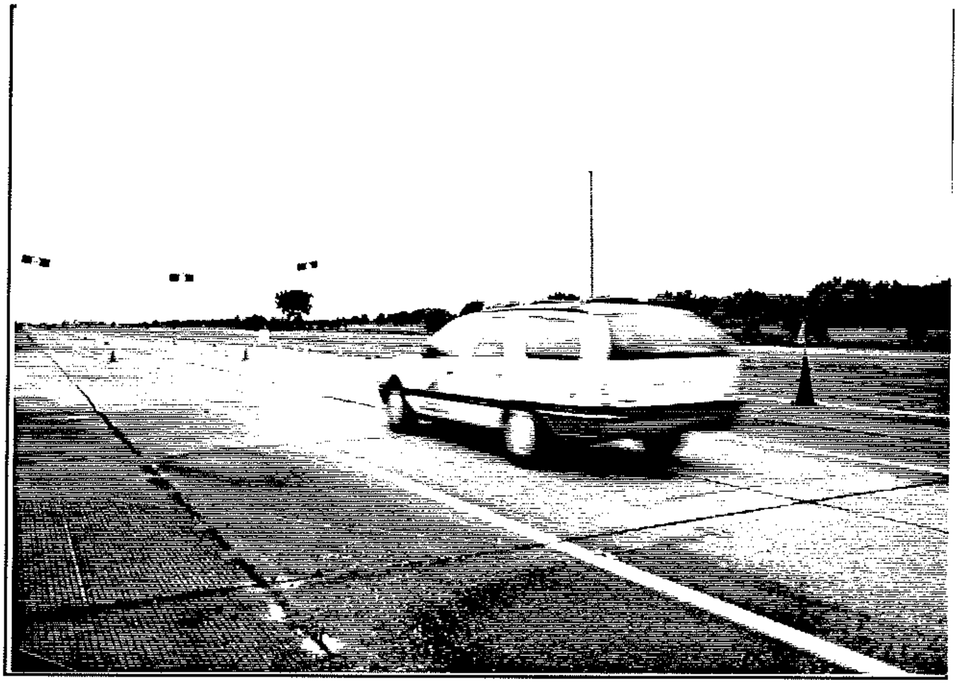

Figure 21. *Test vehicle approaching trip wire one at speed while signal light array is in the neutral configuration.*

RESULTS

The data was collected in two separate sessions due to the distance between test locations and the amount of time needed to complete the tests. The location of the Human Factors Engineering Laboratory is in the Zachry Engineering Center on the main campus of Texas A&M University and the Hazard Avoidance Facility is at the Riverside Campus. This distance is 13 miles (20.9 km). The BFOV Driving Performance test required 45 to 70 minutes, all of the other experiments were completed in one hour total. The order of testing, laboratory or runway, was controlled by weather conditions and availability of facilities. Thirteen members of the Old Cohort and eleven members of the Young Cohort participated in the BFOV Driving Performance test prior to being examined in the laboratory. All tests, laboratory and runway, were completed within 21 days of initial data collection for all participants.

Statistical analysis of the data collected during all experiments was conducted utilizing the SAS® System Release 6.03 (SAS Institute Inc., Cary, NC, 1988) running on a microcomputer platform.

Static Visual Acuity

Static acuity was assessed prior to all other laboratory tests. Visual acuity is the ability of the eye to discriminate fine details. The test used in this study to evaluate static acuity was a test of minimum separable acuity. The targets are ranked in terms of size based on visual angle (VA). Visual angle was measured in minutes of arc (MOA). Acuity is considered to be the reciprocal of visual angle (Sanders, and McCormick, 1987).

The smallest sign correctly discriminated on Test Slide F-3 in the Bausch & Lomb Modified Ortho-Rater (Model #71213102, Bausch & Lomb, Rochester, NY 14602) was considered to be the participants best effort for static acuity. The visual angle and decimal acuity value for this sign was displayed in a table in the instruction manual for the Modified Ortho-Rater. This value was recorded as the participants score.

The mean static acuity scores for both Cohorts were within the requirements for drivers in the State of Texas (Decimal acuity 0.5 or Snellen score 20/40). These values are presented in Table 5. The average static acuity for the Young Cohort was very close to Snellen score of 20/20. The Old Cohort static acuity was equivalent to a little better than 20/26. The young people were able to see smaller targets than the older participants. The static acuity of the Young cohort was significantly better than that of the Old cohort.

TABLE 5
Summary of Static Acuity by Age Group

	Static Acuity		
Cohort	*Mean*	*Standard deviation*	*t(38)*
Old	0.7601 (20/26)	0.2070	
Young	1.001 (20/20)	0.1669	4.0524*

* $p < 0.002$

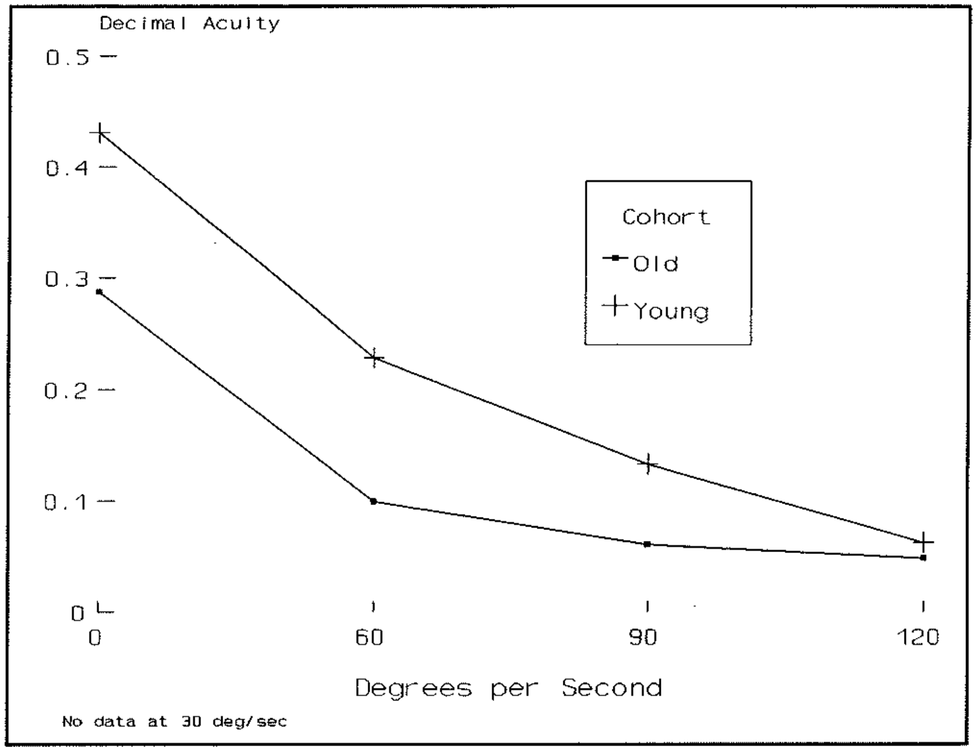

Figure 22. *Dynamic visual acuity for both cohorts at four levels of angular velocity.*

Drivers have a need to read guide signs. If the average member of the young cohort was able to read a sign at 300 feet, the average member of the old cohort must be at 228 feet to read the same sign. The worst sighted individual in the young group could read the sign at 210 feet but the worst member of the old cohort could not read the sign at a distance further than 90 feet. On the other hand, the best individual in both groups could read the sign at 362 feet.

All participants in this study passed a vision test requiring 0.500 (20/40) vision when they last renewed their driver licenses. A person with 0.500 (20/40) could read the hypothetical sign at 150 feet.

Dynamic Visual Acuity

The data obtained during the DVA test was analyzed using the Analysis of Variance Procedure (PROC ANOVA) of the SAS statistical package(see APPENDIX K). DVA is similar to SVA in that both are measures of the ability to see fine details. However, in the case of DVA, the target was moving. Four levels of angular velocity were assessed in this experiment. These speeds, in degrees per second, were 0, 60, 90, and 120. The detail to be discriminated was the gap in the Landolt ring. The smaller the visual angle of the gap discriminated the better the DVA. A graphical presentation of dynamic visual acuity and the relationship of Cohort and Velocity is found in Figure 22.

Age by itself had an effect on the participants ability to discriminate the moving targets. In addition, the rate of speed of the targets by itself had a significant effect on how well the participants scored. Furthermore, the rate of speed of the targets had a different effect on the score depending upon which age group the participant belonged too. A summary of the analysis of the results of the DVA test is presented in Table 6.

The mean DVA for the Young Cohort was 0.2140 ($\approx$20/93) overall angular velocities. This was significantly better than the mean DVA for the Old Cohort (0.1243, $\approx$20/161). Not surprisingly, over all the best DVA was at an angular velocity of 0 degrees per second, 0.3594 ($\approx$20/56). At the two highest speeds, 90 and 120 degrees per second, the DVA's were not significantly different, 0.0971 ($\approx$20/206) and 0.0561 ($\approx$20/357) respectively. The mean DVA of 0.1640 ($\approx$20/122) for an angular velocity of 60 degrees per second was significantly different than both 0 degrees per second and the two higher velocities (Tukey's HSD ($T(114) = 4.815$, $p < 0.005$).

TABLE 6
ANOVA Summary Table for the Dynamic Visual Acuity Test

Source	*Sum of squares*	*Degrees of freedom*	*Mean square*	*F*
Between subjects				
Cohort	0.3221	1	0.3221	34.08*
Subject(Cohort)	0.3591	38		0.0095
Within subjects				
Speed	2.1679	3	0.7226	204.16*
Cohort x Speed	0.1057	3	0.0352	9.96*
Speed x Subject(Cohort)	0.4035	114	0.0035	
Total	3.3584	159		

* $p < 0.0001$

The mean value of acuity collapsed over all levels of angular velocity for all members of each cohort was considered a figure of merit for overall dynamic visual. This value was designated DYNAM. If it is assumed that the figure of merit, DYNAM, relates to some general measure of the ability to discriminate moving targets, then this score can be used to compare the two cohorts. While riding in a moving vehicle stationary objects appear, to the rider, to be moving with some combination of liner and angular velocity. Neglecting the linear component of apparent motion, if a person with a DYNAM ability equal to that of the average member of the young cohort were able to read a sign with letters 12 in. (30 cm) high at some angular velocity, what size must the letters be for the average member of the old cohort to read the sign?

If all other pertinent variables are considered to be equal, the letters in the sign must be roughly 21 in. (53 cm.) high for the average old driver to read the sign. The person with the worst DYNAM in the old cohort requires a sign with letters 30 in. (76 cm) high. A sign with letters roughly 11 in. (28 cm) high is acceptable for the member of the old cohort with the best DYNAM. In the young cohort, the person with the worst value of DYNAM could read the sign if the letters are at least 29 in. (74 cm) high. This worst young person has a requirement in letter size nearly the same as the best old participant. The young driver with the best value of DYNAM can read this hypothetical sign with letters as small as 9 in. (23 cm) high.

The range of letter sizes covered in this hypothetical situation goes from a minimum of 9 in. (23 cm) to a maximum of 30 in. (76 cm). Drivers can not control the size of the letters in the guide sign with which they are presented. However, drivers can control the apparent angular velocity of the signs, while remaining in the roadway, by changing the speed of their vehicle.

Laboratory Brief Field of View

The data collected during laboratory BFOV was made up of the count of correct reports on both the Center Task and Peripheral Task. The count of the number of correct responses was converted into a ratio of the number correct out of the total number of opportunities, a proportion.

Data in the form of a proportion violates the assumptions of the Analysis of Variance. The data can be transformed (Lentener, and Bishop, 1986; Collyer and Enns, 1988) and analyzed. The recommended transformation (Lentener and Bishop, 1986) is as follows:

TABLE 8
Summary of Central Vision Performance by Task and Cohort

Task	*Cohort*	*Mean proportion correct*	*Standard deviation*	*t(19)*
Identify	Old	0.9563	0.1043	0.6649
	Young	0.9729	0.0411	
Match	Old	0.9666	0.0613	0.1678
	Young	0.9625	0.0923	

$$XFORM = \arcsin\sqrt{(PROPORTION)}$$

Both the transformed data set and the untransformed data were analyzed using PROC ANOVA from the SAS statistical package (see Appendix).

At $\alpha = 0.005$ the analysis of either data set supports the same conclusions. Because the concept of a proportion is relatively simpler than the concept of transformed data, the results of the analysis of the proportion data set will be presented in this paper.

The Center Task was given the higher priority in the instructions in order to insure that the gaze was anchored at a know location. The purpose of this was to allow inferences about the extent of the visual field to be made. The duration of the stimulus presentation was short enough to preclude the possibility of a participant being able to fixate on the location of the central vision task, acquire that information, and then fixate on the peripheral target. If the participant was able to acquire the information from the central vision task and correctly report the location of the peripheral target then the known dimensions of his BFOV had a lower bound in time (110 ms) and space (the eccentricity of the peripheral target detected). If the participant was able to report the peripheral target location but not the central vision task information the trial was discarded because no inference about the spacial dimension of BFOV could be made.

The scores of the Central Task and Peripheral Tasks were analyzed separately. The nature of these two tasks are different. One, the Central Task, required directed vision at the center of the field and was given priority. The other, the Peripheral Task, was secondary and involved efficiency at the edge of the field. A summary of the performance on the Center Task of the laboratory BFOV will be found in Table 8. Due to unequal variance in the two samples, Cochran's t was used (SAS Institute Inc., Cary, NC, 1988).

There was no significant difference in the scores of the two groups. This suggests that when the duration of the presentation of visual information is on the order of a single eye fixation and the participants attention was directed to the correct location, there is no significant difference in young or old drivers. No participant is this study failed the measure of acquisition of briefly presented information at the 110 ms level.

In order to analyze the Peripheral Task, a proportion was calculated for each of three levels of eccentricity, based on the location of the targets on the imaginary

TABLE 9
ANOVA Summary Table for Laboratory Brief Field of View

Source	*Sum of squares*	*Degrees of freedom*	*Mean square*	*F*
Between subjects				
Cohort	27.68	1	27.68	136.55*
Subjects(Cohort)	7.70	38	0.20	
Within subjects				
Eccentricity	0.929	2	0.465	19.08*
Cohort X Eccentricity	0.168	2	0.084	3.45
Eccentricity X Subjects(Cohort)	1.85	76		0.024
Task	0.007	1	0.007	0.16
Cohort X Task	0.066	1	0.066	1.60
Task X Subjects(Cohort)	1.59	38	0.042	
Eccentricity X Task	0.053	2	0.027	3.13
Source	*Sum of squares*	*Degrees of freedom*	*Mean square*	*F*
Cohort X Eccentricity X Task	0.029	2	0.015	1.71
Eccentricity X Task X Subjects(Cohort)	0.647	76	0.009	
Total	91.98	239		

*$p < 0.0001$

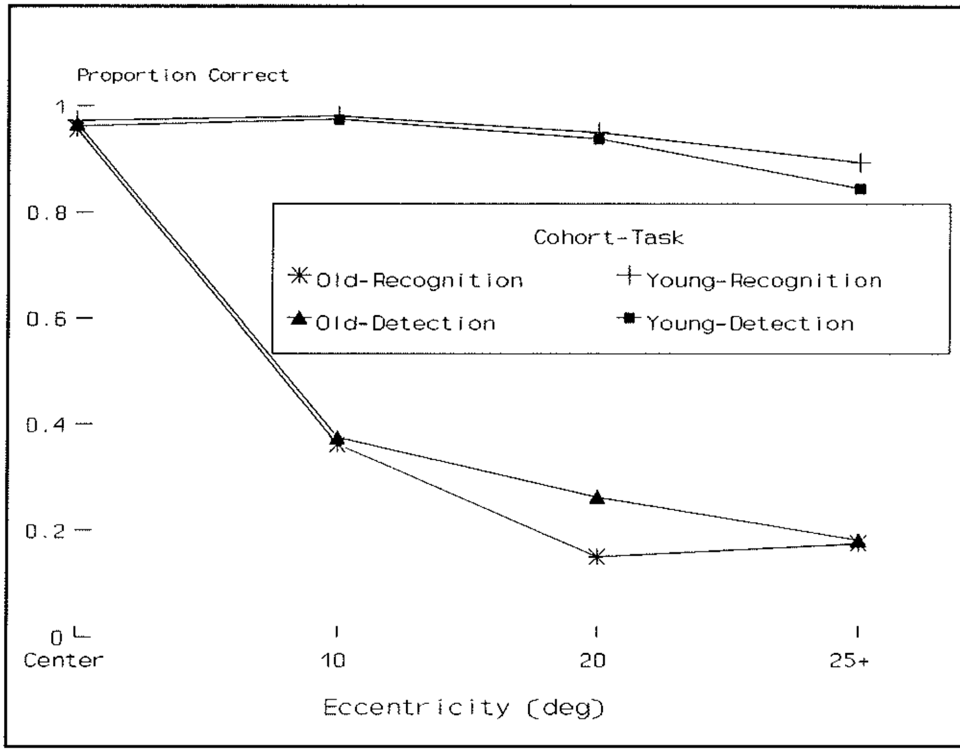

Figure 23. *Laboratory brief field of view performance for both central vision tasks by cohort and across all levels of eccentricity.*

polar coordinate grid, for each participant. These levels were 10°, 20° and 25+°. The score for the 25+° level was the sum of both the two 25° eccentricities and the six 30° eccentricities. A summary of ANOVA on the Peripheral Task is presented in Table 9. Both the factors of age group and level of eccentricity of the target had a significant effect on the scores of the participants. There was no significant difference in performance caused by the level of task imposed on the drivers. No factor interacted with any other to cause an effect in the ability of the participants to report the target.

The young group scored better than did the old group. The young drivers had a mean score of 0.9302 compared with the old driver score of 0.2510. Using Tukey's HSD to compare the mean scores at the levels of eccentricity, 10°, 20°, and 25+°, no significant difference was found between the 20° and 25+° levels. These means were 0.5750 and 0.5234 respectively. However, the mean score of 0.6734 at the 10° level was significantly better than the others ($T(76) = 4.581, p < 0.005$). The mean proportion correct across the levels of eccentricity and task is illustrated in Figure 23.

A figure of merit (FOM) was developed for both the identification task condition and for the matching task. The identification BFOV figure of merit was called LALL. LALL was the sum of Center Task correct responses plus the sum of all Peripheral Task correct responses divided by total opportunities.

$$LALL = \frac{CENTER + EDGE}{48}$$

The figure of merit for the matching task was called SALL. A formula similar to LALL was used to calculate SALL.

$$SALL = \frac{CENTER + EDGE}{48}$$

A value for both LALL and SALL was assigned to each participant as a general measure of laboratory BFOV. The FOM as a collapsed measure of overall ability of BFOV in the laboratory setting is summarized in Table 10. Cochran's t was used to compare the mean scores due to the high level of variance in the results.

TABLE 10
Laboratory BFOV Figure of Merit Analysis by Cohort

Figure of merit	*Cohort*	*Mean*	*Standard deviation*	*t(19)*
LALL	Old	0.5927	0.1440	10.559*
	Young	0.9573	0.0555	
SALL	Old	0.6198	0.1353	8.7904*
	Young	0.9406	0.0913	

*$p < 0.0001$

TABLE 11
Standardized Overall Laboratory BFOV Performance by Task and Cohort

Figure of merit	*Cohort*	*Mean*	*Range*
LALL	Old	62%	28% - 100%
	Young	Standard	82% - 104%
SALL	Old	65%	47% - 97%
	Young	Standard	62% - 106%

To the extent that this single value, LALL or SALL, can be considered a measure of overall performance in this complex task, individuals and groups can be ranked by their scores or means of their scores. If the mean value of LALL or SALL for the young group were taken as the standard performance for laboratory BFOV, then the relative rankings are summarized in Table 11.

Although the young drivers were clearly better than the old drivers in the tests of laboratory BFOV, the best members of both groups had nearly the same scores as measured by the FOM's. The range of the scores of the old drivers was much greater than that of the young cohort. Individual drivers in the old cohort performed at a higher level than some of the drivers in the young cohort.

Driving BFOV Performance

The data collected during the driving BFOV is in the form of the proportion of correct identification of the signal light conditions at each trip wire location. This data has a floor of 0.00 and a ceiling of 1.00. As was stated in Experiment 3, data in this form violates the assumptions of the Analysis of Variance. The data can be transformed (Lentener, and Bishop, 1986; Collyer and Enns, 1988) and analyzed. The recommended transformation (Lentener and Bishop, 1986) is as follows:

$$XFORM = \arcsin\sqrt{(PROPORTION)}$$

Both the transformed data set and the untransformed data were analyzed using PROC ANOVA from the SAS statistical package (see Appendix). At $\alpha = 0.005$ the analysis of either data set supports the same conclusions. As stated above, the concept of the ratio of correct responses to the total number of opportunities is more readily understood than the obtuse transformation of that ratio. The results of the analysis of the proportion data set will be presented in the body of this paper. A summary of this analysis is presented in Table 12.

The levels of Distance correspond to target eccentricities of 2.5°, 5.0°, 7.5°, 10°, and 12.5°. Neither the factor Distance nor the interaction Cohort and Distance were found to have a significant effect on the proportion correct. However, age was found to have a significant influence on performance. The performance of the two cohorts is illustrated in Figure 24.

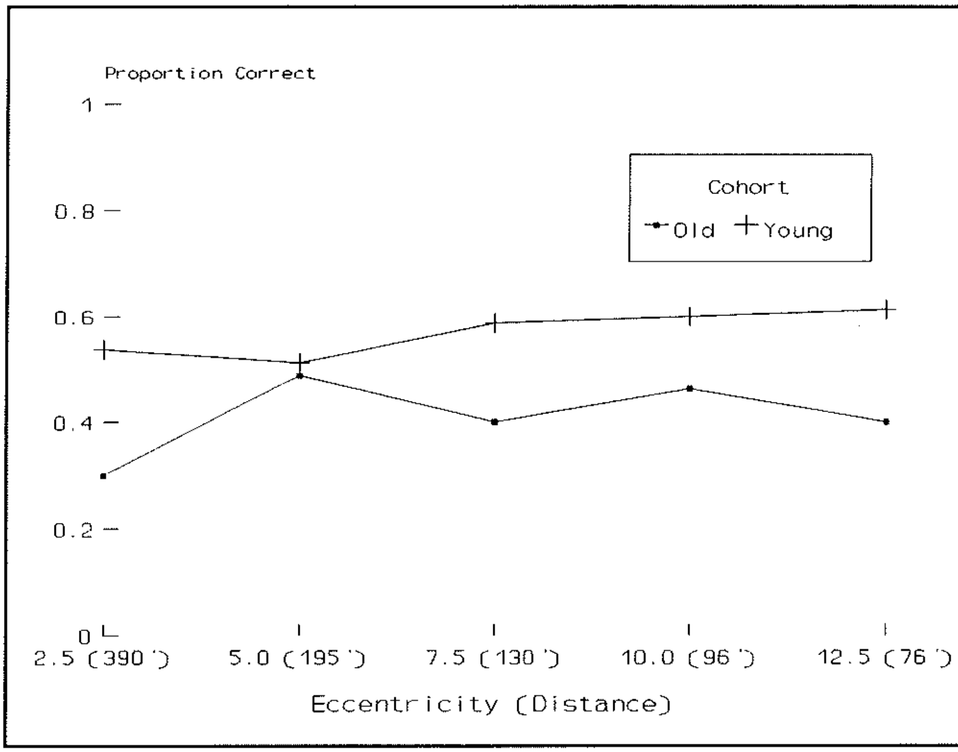

Figure 24. *Driving brief field of view performance for both cohorts and all levels of eccentricity.*

TABLE 12
ANOVA Summary of Driving BFOV Performance

Source	*Sum of squares*	*Degrees of freedom*	*Mean square*	*F*
Between subjects				
Cohort	1.2800	1	1.2800	14.41*
Subjects(Cohort)	3.3750	38		0.0888
Within subjects				
Distance	0.2863	4	0.0718	1.55
Cohort x Distance	0.2825	4	0.0706	1.53
Distance x Subjects(Cohort)	7.0063	152	0.0461	
Total	12.2300	199		

* $p < 0.0005$

TABLE 13
Driving BFOV Figure of Merit Analysis by Cohort

Figure of merit	*Cohort*	*Mean*	*Standard deviation*	*t(38)*
RUNXCN	Old	0.4125	0.1087	3.528*
	Young	0.5650	0.1599	

*$p < 0.002$

A figure of merit (FOM) was generated from a collapsed measure of overall performance in the driving BFOV test. This FOM was called RUNXCN and was calculated as follows:

$$RUNXCN=\frac{\sum COUNT}{20}$$

To the extent that RUNXCN is a measure of overall ability in the driving BFOV test this FOM could be used compare participants and the age groups. A comparison of the mean RUNXCN for the two age groups is summarized in Table 13.

The young cohort had a significantly higher score when compared with the old drivers. For the first time the range of scores for a test is greatest for the young cohort.

If this single value, RUNXCN, can be considered a measure of overall performance in this complex task, individuals and groups can be ranked by their scores and means of their scores. If the mean value of RUNXCN for the young group were taken as the standard performance for driving BFOV, then the relative rankings are summarized in Table 14.

In this measure, performance in the simulated intersection, the worst member of the old cohort did no worse than the worst member of the young drivers. On the other hand the best of the young appeared to be considerably better than the best of the old cohort. BFOV has been measured in two different venues, the laboratory and at the Hazard Avoidance Facility. The efficiency of the young cohort is significantly better in both locations. However, there was a relative improvement in the level of achievement of the older drivers by moving to the field and the level of the young drivers deteriorates. This phenomenon is presented in Figure 25.

Correlation Analysis

The question of a correlation between laboratory and field was at the heart of this study. However, the nature of the data presented a difficulty in the analysis of correlation. A large degree of variation was found in the scores on all tests. The

TABLE 14
Standardized Driving BFOV Performance by Cohort

Figure of merit	*Cohort*	*Mean*	*Range*
RUNXCN	Old	73%	44% - 106%
	Young	Standard	44% - 168%

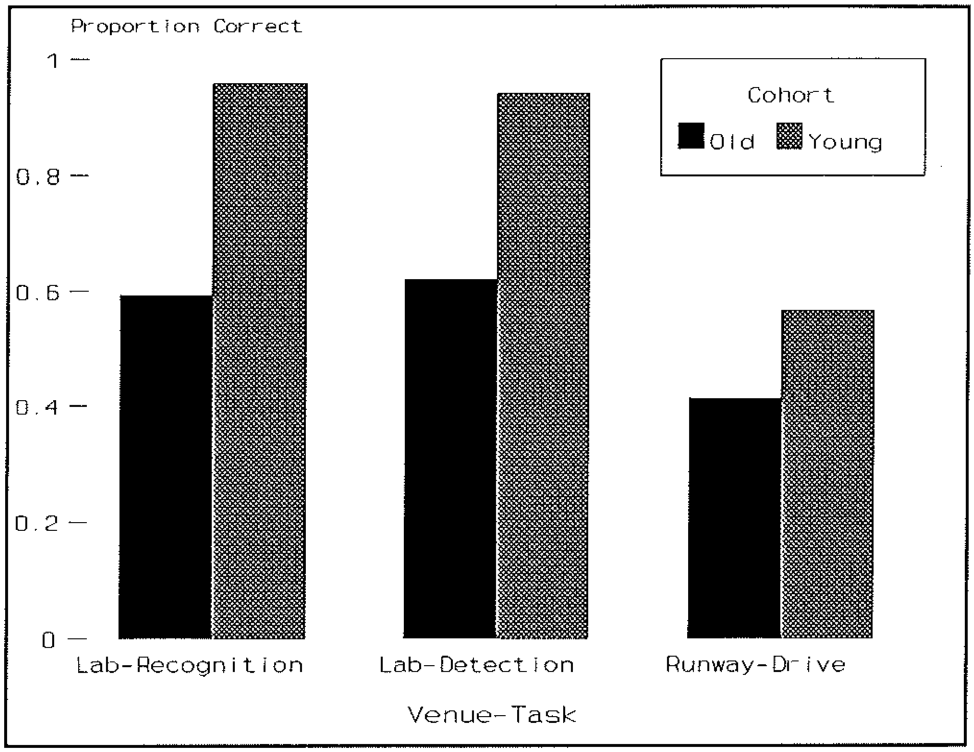

Figure 25. *Comparison of scores on both central vision tasks of laboratory BFOV and driving BFOV by cohort.*

TABLE 15
Correlation Coefficients between all Figures of Merit using All Participant Scores

	SVA	*DYNAM*	*LALL*	*SALL*	*RUNXCN*
SVA	1.000	0.418*	0.475*	0.351	0.421*
DYNAM		1.000	0.460*	0.405*	0.353
LALL			1.000	0.666*	0.347
SALL				1.000	0.280
RUNXCN					1.000

*$p < 0.001$

TABLE 16
Correlation Coefficients between all Figures of Merit using Young Cohort Scores

	SVA	*DYNAM*	*LALL*	*SALL*	*RUNXCN*
SVA	1.000	0.171	0.243	0.095	0.066
DYNAM		1.000	0.053	0.005	0.111
LALL			1.000	0.241	-0.218
SALL				1.000	-0.123
RUNXCN					1.000

TABLE 17
Correlation Coefficients between all Figures of Merit using Old Cohort Scores

	SVA	*DYNAM*	*LALL*	*SALL*	*RUNXCN*
SVA	1.000	0.331	0.332	-0.013	0.580
DYNAM		1.000	0.199	0.108	0.280
LALL			1.000	0.631	0.502
SALL				1.000	0.131
RUNXCN					1.000

members of the old cohort obtained scores with large variation in particular as can be seen by the standard deviation values presented in the tables. The difference in the variance in the scores of the old and young groups were such that Cochran's *t* was required to compare means for the Center Task scores of laboratory BFOV, LALL, and SALL. The ranges of scores for the two groups were very different for SVA, DYNAM, and RUNXCN. This raised a question regarding the homoscedasticity of the data. The correlation matrixes are presented below for the overall data set, the young cohort, and the old cohort. Kendall's Taü b was used to compute the correlation values in Tables 15, 16, and 17. The correlation coefficients are modest and are statistically significant only when all participant scores are used.

The measures of BFOV in the laboratory setting do not have a significant correlation to the measures of BFOV obtained in the controlled field study. The laboratory BFOV measures taken under the two different central vision task levels are significantly correlated when all participant's scores are used. However, when either cohort is considered alone no significant correlation exists between any pair of tests.

The only laboratory test to have a significant correlation with the controlled field study measure was SVA, the one vision test used in all fifty of the United States. Only the overall measure of dynamic visual acuity, DYNAM, was significantly correlated to all other laboratory tests. Static visual acuity, SVA, was significantly correlated with laboratory BFOV when the central vision task was identification but not when the central vision task was matching.

CONCLUSIONS AND RECOMMENDATIONS

Based on the sample of young and old drivers examined in this study, some of the old drivers have static visual acuity scores as good or better than the average young driver. On the other hand, some of the old drivers have static visual acuity scores below the required standard in the state of Texas even though they hold valid licenses. The young drivers, as a group, are significantly better at seeing small details in stationary targets.

The greater range of static visual acuity in the older driver group makes it harder to make a general statement about that group concerning static visual acuity. Past studies do not show a strong correlation between static visual acuity and traffic accidents.

The young drivers in this study were better at seeing details in moving targets compared to the old drivers. The critical speed at which dynamic visual acuity begins to break down appears to be between 60 deg/sec and 90 deg/sec for these participants. In this study a modest correlation was found between overall static visual acuity and overall dynamic visual acuity when all participants scores were considered.

The methodology developed for assessing Brief Field of View, in a laboratory setting, appears to be effective. Young drivers have a larger window of attention, as measured by Brief Field of View, compared to older drivers. There is a greater range in Brief Field of View among older drivers than among younger drivers. Some older drivers have a window of attention as large as the average young driver.

The older drivers in this study did not exhibit deficits in the ability to focus attention, compared to young drivers, as measured by the central vision task of the Laboratory Brief Field of View tests. When prepared and directed at a 5 degree area, the old drivers were not significantly different than the young drivers at detection or recognition. The older driver had difficulty acquiring data from the portions of the visual field distal to the center of focus. Under these test conditions, the central processes of the young and old participants appeared equally intact.

The lack of significant correlation between the measures of Laboratory Brief Field of View and Runway Brief Field of View is disturbing. It is possible that the controlled field setting lacked sufficient verisimilitude with the laboratory and the same variables were not being assessed. The controlled field situation required the participants to engage in a skilled motor task while the task in the laboratory was completely perceptual in nature. Relative differences in skill could have required more attention to be paid to the driving task at the expense of the perceptual task. The laboratory task required the detection of a shape difference of target and distractors. In the field, the clue was not shape but color. Does color test a different segment of the visual system?

The marked drop in the performance of the young drivers in the Runway Brief Field of View test, compared to their laboratory performance, was completely unexpected. It appears that the window of attention of the older driver is smaller but more robust. The young group appeared to have a significantly larger window of attention even if it was reduced. The older drivers had vastly greater driving experience than the young drivers. Were the overlearned motor skills of the old drivers allowing them to allocate their moderate perceptual skills to the search task? In any case, the poor correspondence between Laboratory Brief Field of View and performance on a task very widely used to assess and train accident avoidance suggests that Brief Field of View or Useful Field of View must be more thoroughly investigated before it is considered for adoption as a driver license screening tool.

The modest, but significant, correlation found between static visual acuity and overall runway Brief Field of View supports the utility of this measure of visual functioning. static visual acuity is mostly a measure of the integrity of the front end of the visual system, from the cornea to the retina. If this portion is not functioning at a nominal level, the entire visual system is impaired regardless of the efficiency of the central processing.

Recommendations

Participants from different age groups should be evaluated for performance in Brief Field of View to determine the distribution of this characteristic throughout the driving public. The effect of alcohol on Brief Field of View should be assessed.

The effect of simultaneous tasks on the measure of Brief Field of View could lead to some conclusions regarding task allocation for given system missions. The placement of annunciators in relation to the size of the window of attention for different user populations is an area that could affect safety.

What is the effect of venue and the associated environmental factors on Brief Field of View? Do shape, color, or size have individual windows of attention? What factors can be manipulated to obtain a window of attention equal to that of the young driver for the old driver? The Brief Field of View methodology can be used to assess conspicuity of targets for different user populations.

The Brief Field of View methodology is relatively simple to apply and allows a quantification of attention. The Brief Field of View methodology can be applied to research in the arena of situational awareness.

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APPENDICES

APPENDIX A

Instructions for DVA

"This is a test of dynamic visual acuity. That is your ability to see details when either you, the target, or both are moving. In this test you will remain seated in that chair and the targets will move around this 180 degree screen in front of you. (Indicate the instruction slide.)

This is the kind of targets we will use in this test. They are called Landolt rings. As you can see they are rings that have a gap in them. They will be of various sizes and the gaps will be proportional to their size. Your task will be to tell me where the gap is located. We will use the directional convention you see on the slide - - Up, Down, Left, Right, Upper Right, Lower Right, Lower Left, and Upper Left. As you can see the gap in this ring is in the Upper Right. (Answer any questions and clarify the test situation for the participant.)

I want to see how well you do with this kind of target when they are standing still. (Project the Combined slide with eight Landolt rings.) This slide has eight rings. Starting with the largest ring in the upper left hand corner of the slide, tell me where the gaps are in these rings. (Record this information for DVA at angular velocity = 0.)

(Go to a dark screen.) I can put these rings into motion. From now on, the slides will only have one ring on them.(Turn on the rotary pursuit table holding the front surface mirror. Adjust the angular velocity to 60 degrees/sec. in a CCW direction.) We are going to test at three speeds. The first speed is 60 degrees/second. We will test at 90 degrees/second and 120 degrees/second.

The rings will go from your right to your left all the way around this 180 degree screen. You can turn your head, your shoulders, your entire body to look at them. All I ask is that you do not get out of the chair. We will start with very large rings and go to very small rings. Then we will go back up from small rings to large rings. Some of the rings will be easy and some will be very difficult, maybe impossible. It is alright to guess. In fact, I urge you to guess. We will let the rings come by as many times as you wish. We are not in a hurry. I am looking for your best performance. (Answer any questions.)

If you are ready, we will start now. (Project slides one at a time and record the answers on the answer sheet.)

Now we will go to 90 degrees/second. (Adjust the rotary pursuit table and project next set of slides and record the answers.)

Now we will try it at 120 degrees/second. (Adjust the rotary pursuit table and project the last set of slides and record the answers.) "We are done with this test."

APPENDIX B

Instructions for laboratory BFOV

Turn on both the Fixation and Stimulus projectors and insure that they are in register. Cycle the slide changer to place the fixation point slide in projection in one projector and the first training slide in projection in the other projector. Turn on the Projection Tachistoscope Control unit on. Check the random load assignment table to determine which workload, Letter Condition or Shape Condition, is to be presented first for this person. The BFOV test covered the following steps.

Seat research participant directly in front of the back projection screen and direct their gaze at the fixation point on the illuminated screen. Adjust the chin rest to insure the participant is in the correct position and comfortable.

"That bright spot is a fixation point." (Indicate the point on the screen.) Some important information will appear at or near that spot. I will explain more about that later. Let me adjust the chin rest so that you are comfortable." (Inquire about their comfort as the chin rest is set.) "If that becomes uncomfortable let me know and we will stop and change it."

Take your position at the Tachistoscope Control Unit and open the shutter to project the first slide (familiarization slide) in the training sequence.

"I am going to show you a number of slides that will look very much like this one. It may look somewhat confusing now but it really just has three parts and I will explain those parts." (change to the labeled training slide.)

"The slide has three main parts. The large box in the center is called the letter box and contains a letter pair. In all the slides this box will appear at or near the fixation point. The letter pair is the most important thing on the slide. Under one condition I will ask you to tell me what these letters are and under another condition I will ask you to tell me if the letters in the box are the same or different from each other. That is the Center Task in this experiment. Under the letter condition you would tell me that these letters are TA. Under the same or different condition would tell me that they were different. We are going to use the (letter,same-different) condition first."(Answer any questions and explain the work load conditions further if necessary.)

"Surrounding the letter box are a number of smaller boxes. They are the dummy boxes. Their main function is to clutter the scene and to confuse you because I am also interested in your ability to locate the target embedded in this confusion. That is the Edge Task.

The target is that stop sign shape with the word stop written in it that you see labeled target and located above the letter box in this slide. The target will always be that stop sign shape. It can appear at its present location or at any place you now see a dummy box." (Answer any questions at this time. Change to the direction training slide.)

"We are going to use the directional conventions you see here: Up, Down, Left, Right, Upper Right, Lower Right, Lower Left, and Upper Left. The target in this slide it located in the Lower Right." (Answer any questions. Close the shutter and change to the first feedback training slide.)

"I will present these slides to you very briefly. (Adjust T-scope duration to .8 sec.) It will go something like this ... READY (pause no more than one sec. and actuate the T-scope.).... (Open shutter to reveal the slide.) As you can see the Center Task was (give correct answer) and the target was located (give correct answer). I am most interested in the letters in the center then the location of the target if you can get it. Lets try some others...." (present the three remaining feedback training slides at .5 sec., .4 sec., and .3 sec.)

"If you are ready, we will do the experiment now. Remember we are in the (Center Task work load) condition. The letters in the center are most important. If you can see the target then be sure to tell me its location. It is ok to guess if you are not sure where it is located. .....READY....." (Present the five speed training slides at .7 sec., .5 sec., .5 sec., .4 sec., and .3 sec. When finished with the speed training, go to test condition without further discussion with the research participant. Test condition is at .110 sec. presentation time for all 24 stimulus slides.)

At the end of the test sequence, tell the participant to relax. When the participant indicates a willingness to continue, proceed with the next load condition.

" If you are ready, we will continue the experiment now. Remember we are in the (Center Task work load) condition.(give a few examples of the correct answers in this condition and contrast them with the former Center Task work load answers.)

The letters in the center are most important. If you can see the target then be sure to tell me its location. It is alright to guess if you are not sure where it is located. .....READY....." (Present the five speed training slides at .7 sec., .5 sec., .5 sec., .4 sec., and .3 sec. When finishes with the speed training, go to test condition without further discussion with the research participant. Test condition is at .110 sec. presentation time for all 24 stimulus slides.)

APPENDIX C

Instructions for driving BFOV

When the participant was comfortable with the car, the Lights Training was given. The driver parked the car at the 390 feet tape switch facing the Signal Light Array. The participant was instructed to watch the lights and the following instructions were given.

"The three traffic lights you see in front of you are called the Hazard Avoidance Facility. Your task will be to drive the car through the center lane, under the center light, and to tell me what you see when the lights change. The lights are in their neutral condition. That is they are all yellow. This is the condition they will be in most of the time.

There are five trip switches on the pavement in this lane between here and the signal lights. When you drive over the active switch the lights will change out of the neutral condition into one of four test conditions. Only one of the switches will be active per trip but we will talk more about that later.

Let me tell you about the four possible test conditions. In one condition all three lights will go to red. In the other three conditions, one light will be green. The green light could be over the left lane and the center lane light and right lane light would be red. In the third condition, the green light could be over the center lane and the left and right lane lights would be red. In the last condition, the green light could be over the right lane and the left and center lane lights would be red." (Have the participant repeat the four possible light test conditions and answer any questions they might have.)

Under the test conditions, the lights will be presented very briefly. They will just flash on and then off. It may be so fast that you will only have an impression of what you saw. Your best strategy is to look at or near the center light and try to catch the others out of the corners of your eyes. You may not feel comfortable saying if there was a green light or where it might have been. That is alright. I am interested in even an impression. I feel you have more information than you know. If this were a driving emergency you would act on an impression if that was all you had. I want you to guess. In fact, I will insist you guess."(Answer any questions and reassure the participant of the acceptability of guessing under these research conditions.)

"Now let me have my assistant demonstrate the light test conditions and show you all the possible durations for the flash of the lights. He/She will give us all four possible test conditions for 2 sec. first. Then he/she will give them for 1.5 sec. Next we will see them at 0.5 sec. He/She will run through them twice at 0.2 sec. Finally, he/she will present all four conditions three times at 0.1 sec." (Signal for Light Training Session One (see Appendix D). "Go ahead and tell me the lights as you see them." (Insure that the participant is seeing the lights correctly for the 2 sec. duration. Insure the participant is able to correctly report at least the center lane light at the 0.1 sec. duration. Repeat training until criteria are met or disqualify the participant.)

"Now we are ready for the trip switch training. As I said earlier, the lights will change when you drive over the active trip switch. There are five trip switches taped to the pavement in the tire path of this center lane. One of the switches is located right here where we are parked now. The other four are located at various distances from here up to almost under the signal lights.

I want you to drive down the center lane of the HAF five times. Each time you drive through a different switch will be active. You won't know which switch is the active one. This training will give you a feel for the location of the switches and practice for the test." (Answer any questions and signal the assistant to start Training Session 2 (see Appendix E).

"That completes the training, do you feel ready for testing?" (If the participant indicates that they are ready for testing, signal your assistant to begin test session (see Appendix F) " Your task is to drive through the center lane 24 times and tell me what the lights look like when they change, that is: No green, Green Left, Green Center, or Green Right." (Record the participants responses and encourage them in order to maintain high motivation in the participant. Upon completion of the 24 test trips drive the participant back to the Proving Grounds office and answer any questions they have.)

APPENDIX D

Lights training schedule

TRAINING SESSION 1

Purpose: to teach the participants the light configurations and to demonstrate the brevity of the presentation.

Timer 2.010 sec.

Lights	Show 1	Show 2	Show 3	Show 4
Left	Green	Red	Red	Red
Center	Red	Red	Red	Green
Right	Red	Green	Red	Red

Timer 1.510 sec.

Lights	Show 1	Show 2	Show 3	Show 4
Left	Red	Red	Red	Green
Center	Green	Red	Red	Red
Right	Red	Red	Green	Red

Timer 0.510 sec.

Lights	Show 1	Show 2	Show 3	Show 4
Left	Green	Red	Red	Red
Center	Red	Red	Green	Red
Right	Red	Red	Red	Green

Timer 0.210 sec.

Light	Show 1	Show 2	Show 3	Show 4	Show 5	Show 6	Show 7	Show 8
Left	Red	Red	Red	Green	Red	Red	Green	Red
CTR	Red	Green	Red	Red	Green	Red	Red	Red
Right	Green	Red	Red	Red	Red	Green	Red	Red

Timer 0.110 sec.

Lt	1	2	3	4	5	6	7	8	9	10	11	12
L	R	R	G	R	R	R	R	G	G	R	R	R
C	R	G	R	R	G	R	R	R	R	R	G	R
R	G	R	R	R	R	G	R	R	R	R	R	G

APPENDIX E

Trip switch training

TRAINING SESSION 2

Purpose: to teach the switch locations.

Timer 0.810 sec.

Run	Lights (L-C-R)	Switch
1	G R R	1
2	R G R	3
3	R R G	4
4	R R R	2
5	R R G	5

APPENDIX F

DRIVING BFOV TEST LIGHT ORDER
Test Sequence for Hazard Avoidance Facility

Run	Green Location	Switch	Timer
1	LEFT	5	0.110
2	RIGHT	2	"
3	RIGHT	1	"
4	LEFT	2	"
5	LEFT	1	"
6 ***********	ALL RED ****	3 *********	0.510*********
7	CENTER	5	0.110
8	RIGHT	5	"
9	ALL RED	2	"
10 **********	RIGHT *******	4 **********	0.510 *******
11	LEFT	3	0.110
12	ALL RED	1	"
13	CENTER	1	"
14	RIGHT	3	"
15	LEFT	4	"
16 *********	ALL RED *****	4 ***********	0.510 *******
17	ALL RED	5	0.110
18	CENTER	2	"
19	RIGHT	4	"
20	CENTER	3	"
21 *********	LEFT *******	3 **********	0.510 ********

22	ALL RED	4	0.110
23	ALL RED	3	"
24	CENTER	4	"

APPENDIX G

SVA Analysis

OBS	SUBJECT	COHORT	AGE	GEND	Y_DRV	D60	D90	D120	DO	ORTHO
1	Y03	K	35	M	19	6	8.0	14.0	4	0.83
2	Y04	K	23	M	7	11	11.0	22.0	8	1.25
3	Y07	K	21	F	4	5	18.0	25.0	2	0.91
4	Y17	K	29	M	15	3	15.5	15.0	2	0.83
5	Y19	K	30	M	17	3	4.0	9.0	2	0.83
6	Y20	K	24	F	8	3	29.0	25.5	2	0.83
7	Y21	K	24	M	8	4	11.0	29.0	2	0.91
8	Y22	K	22	F	6	3	4.0	14.0	2	1.11
9	Y23	K	22	F	6	5	8.0	14.0	4	1.43

OBS	L_CT	L_10	L_20	L_30	S_CT	S_10	S_20	S_30	TRP5	TRP4	TRP3
1	24	8	8	8	14	6	4	4	3	2	2
2	22	7	8	7	24	8	8	8	1	1	2
3	24	8	8	8	23	8	8	7	1	2	1
4	24	8	8	8	24	8	8	8	2	1	2
5	23	8	8	4	22	8	6	7	2	3	1
6	23	8	7	8	23	8	8	6	1	4	1
7	24	8	8	8	24	8	8	8	3	1	2
8	24	8	8	8	24	8	8	8	0	0	3
9	24	8	8	8	23	8	8	6	1	0	1

OBS	TRP2	TRP1	SVA	DOA	D60A	D90A	D120A	DYNAM
1	3	2	1.20482	0.250	0.16667	0.12500	0.07143	0.61310
2	1	3	0.80000	0.125	0.09091	0.09091	0.04545	0.35227
3	2	4	1.09890	0.500	0.20000	0.05556	0.04000	0.79556
4	2	3	1.20482	0.500	0.33333	0.06452	0.06667	0.96452
5	3	2	1.20482	0.500	0.33333	0.25000	0.11111	1.19444
6	2	1	1.20482	0.500	0.33333	0.03448	0.03922	0.90703
7	1	1	1.09890	0.500	0.25000	0.09091	0.03448	0.87539
8	3	1	0.90090	0.500	0.33333	0.25000	0.07143	1.15476
9	1	2	0.69930	0.250	0.20000	0.12500	0.07143	0.64643

OBS	LWLP	SWLP	RPLP	LWLX	SWLX	RPLX
1	1.00000	0.58333	0.60	1.57080	0.86912	0.88608
2	0.91667	1.00000	0.40	1.27795	1.57080	0.68472
3	1.00000	0.95833	0.50	1.57080	1.36523	0.78540
4	1.00000	1.00000	0.50	1.57080	1.57080	0.78540
5	0.89583	0.89583	0.55	1.24216	1.24216	0.83548
6	0.95833	0.93750	0.45	1.36523	1.31812	0.73531
7	1.00000	1.00000	0.40	1.57080	1.57080	0.68472
8	1.00000	1.00000	0.35	1.57080	1.57080	0.63305
9	1.00000	0.93750	0.25	1.57080	1.31812	0.52360

SAS

OBS	SUBJECT	COHORT	AGE	GEND	Y_DRV	D60	D90	D120	DO	ORTHO
10	Y24	K	24	F	7	6	4.0	18.0	2	1.43
11	Y25	K	29	F	14	4	4.0	8.0	2	1.11
12	Y27	K	34	F	21	8	11.0	18.0	4	1.00
13	Y28	K	33	M	17	4	4.0	22.0	2	0.83
14	Y29	K	28	M	12	3	11.0	14.0	2	1.00
15	Y30	K	23	M	7	6	9.0	14.0	2	1.00

16	Y31	K	22	M	5	4	8.0	18.0	2	1.00
17	Y32	K	24	M	8	8	11.0	14.0	2	1.25
18	Y33	K	27	F	12	4	18.0	25.5	2	0.91

OBS	L_CT	L_10	L_20	L_30	S_CT	S_10	S_20	S_30	TRP5	TRP4	TRP3
10	24	8	8	7	24	8	8	5	1	3	2
11	23	8	8	6	24	8	7	7	3	3	2
12	23	7	8	8	24	8	8	8	3	3	1
13	24	8	8	8	24	8	8	8	4	4	4
14	24	8	7	7	23	8	7	6	1	2	4
15	24	8	8	8	24	8	7	6	2	3	3
16	24	8	8	8	23	7	8	8	4	3	3
17	23	8	6	5	24	8	7	4	3	2	4
18	23	8	7	8	24	8	8	8	2	2	4

OBS	TRP2	TRP1	SVA	D0A	D60A	D90A	D120A	DYNAM
10	2	3	0.69930	0.500	0.16667	0.25000	0.05556	0.97222
11	3	4	0.90090	0.500	0.25000	0.25000	0.12500	1.12500
12	3	2	1.00000	0.250	0.12500	0.09091	0.05556	0.52146
13	4	3	1.20482	0.500	0.25000	0.25000	0.04545	1.04545
14	2	3	1.00000	0.500	0.33333	0.09091	0.07143	0.99567
15	2	1	1.00000	0.500	0.16667	0.11111	0.07143	0.84921
16	3	3	1.00000	0.500	0.25000	0.12500	0.05556	0.93056
17	4	1	0.80000	0.500	0.12500	0.09091	0.07143	0.78734
18	2	2	1.09890	0.500	0.25000	0.05556	0.03922	0.84477

OBS	LWLP	SWLP	RPLP	LWLX	SWLX	RPLX
10	0.97917	0.93750	0.55	1.42595	1.31812	0.83548
11	0.93750	0.95833	0.75	1.31812	1.36523	1.04720
12	0.95833	1.00000	0.60	1.36523	1.57080	0.88608
13	1.00000	1.00000	0.95	1.57080	1.57080	1.34528
14	0.95833	0.91667	0.60	1.36523	1.27795	0.88608
15	1.00000	0.93750	0.55	1.57080	1.31812	0.83548
16	1.00000	0.95833	0.80	1.57080	1.36523	1.10715
17	0.87500	0.89583	0.70	1.20943	1.24216	0.99116
18	0.95833	1.00000	0.60	1.36523	1.57080	0.88608

SAS

OBS	SUBJECT	COHORT	AGE	GEND	Y_DRV	D60	D90	D120	D0	ORTHO
19	Y34	K	24	M	7	4	11.0	22.0	2	1.00
20	Y35	K	21	F	5	6	6.0	14.0	4	1.11
21	M04	O	78	F	56	18	50.0	57.0	4	1.00
22	M05	O	80	M	65	11	14.0	25.0	4	2.00
23	M06	O	68	F	54	13	11.0	18.0	4	1.43
24	M07	O	86	M	70	22	32.5	18.0	4	3.33
25	M08	O	65	F	53	11	25.5	25.5	4	1.11
26	M09	O	78	M	65	15	11.0	15.0	4	1.11
27	M10	O	68	M	57	9	18.5	18.0	4	1.67

OBS	L_CT	L_10	L_20	L_30	S_CT	S_10	S_20	S_30	TRP5	TRP4	TRP3
19	23	7	7	7	23	7	8	8	4	2	2
20	20	8	6	4	24	8	8	5	2	0	3
21	24	5	3	3	24	3	2	2	2	3	4
22	24	0	0	1	24	0	0	0	0	2	1
23	24	2	0	1	24	4	1	2	2	2	0
24	22	0	0	1	22	6	4	1	0	1	2
25	23	6	0	0	24	6	2	2	2	3	2
26	24	0	0	0	21	0	0	0	1	2	2
27	23	6	1	0	23	8	3	2	0	3	0

OBS	TRP2	TRP1	SVA	D0A	D60A	D90A	D120A	DYNAM
19	2	2	1.00000	0.500	0.25000	0.09091	0.04545	0.88636
20	3	4	0.90090	0.250	0.16667	0.16667	0.07143	0.65476
21	2	1	1.00000	0.250	0.05556	0.02000	0.01754	0.34310
22	1	1	0.50000	0.250	0.09091	0.07143	0.04000	0.45234
23	2	1	0.69930	0.250	0.07692	0.09091	0.05556	0.47339
24	2	1	0.30030	0.250	0.04545	0.03077	0.05556	0.38178
25	1	3	0.90090	0.250	0.09091	0.03922	0.03922	0.41934
26	2	2	0.90090	0.250	0.06667	0.09091	0.06667	0.47424
27	1	1	0.59880	0.250	0.11111	0.05405	0.05556	0.47072

OBS	LWLP	SWLP	RPLP	LWLX	SWLX	RPLX
19	0.91667	0.95833	0.60	1.27795	1.36523	0.88608
20	0.79167	0.93750	0.60	1.09681	1.31812	0.88608
21	0.72917	0.64583	0.60	1.02346	0.93338	0.88608
22	0.52083	0.50000	0.25	0.80624	0.78540	0.52360
23	0.56250	0.64583	0.35	0.84806	0.93338	0.63305
24	0.47917	0.68750	0.30	0.76456	0.97760	0.57964
25	0.60417	0.70833	0.55	0.89033	1.00029	0.83548
26	0.50000	0.43750	0.45	0.78540	0.72273	0.73531
27	0.62500	0.75000	0.25	0.91174	1.04720	0.52360

SAS

OBS	SUBJECT	COHORT	AGE	GEND	Y_DRV	D60	D90	D120	D0	ORTHO
28	M11	0	70	F	58	6	9.0	14.0	2	0.83
29	M12	0	66	M	54	6	8.0	18.0	2	1.43
30	M13	0	72	F	50	11	18.0	57.0	4	1.67
31	M14	0	67	M	51	8	11.1	15.0	4	1.25
32	M15	0	80	F	65	18	29.0	29.0	4	1.25
33	M16	0	67	M	51	6	9.0	8.0	2	1.11
34	M17	0	77	F	65	18	39.5	43.0	4	1.43
35	M18	0	78	M	66	22	29.0	29.0	4	1.43
36	M19	0	68	M	56	6	11.1	14.0	4	1.25

OBS	L_CT	L_10	L_20	L_30	S_CT	S_10	S_20	S_30	TRP5	TRP4	TRP3
28	24	0	0	0	24	0	0	0	1	3	2
29	21	5	2	2	23	2	3	2	1	2	3
30	24	0	0	0	24	0	0	0	1	1	1
31	24	6	2	1	24	8	7	5	2	2	2
32	24	7	5	4	18	7	7	5	1	3	2
33	24	8	7	7	23	7	6	4	1	2	2
34	24	0	0	0	24	0	0	0	1	1	1
35	13	0	0	0	24	0	0	0	1	1	1
36	24	4	1	1	23	4	4	0	2	2	3

OBS	TRP2	TRP1	SVA	D0A	D60A	D90A	D120A	DYNAM
28	2	1	1.20482	0.500	0.16667	0.11111	0.07143	0.84921
29	3	2	0.69930	0.500	0.16667	0.12500	0.05556	0.84722
30	3	2	0.59880	0.250	0.09091	0.05556	0.01754	0.41401
31	1	2	0.80000	0.250	0.12500	0.09009	0.06667	0.53176
32	2	1	0.80000	0.250	0.05556	0.03448	0.03448	0.37452
33	2	2	0.90090	0.500	0.16667	0.11111	0.12500	0.90278
34	2	1	0.69930	0.250	0.05556	0.02532	0.02326	0.35413
35	1	2	0.69930	0.250	0.04545	0.03448	0.03448	0.36442
36	3	2	0.80000	0.250	0.16667	0.09009	0.07143	0.57819

OBS	LWLP	SWLP	RPLP	LWLX	SWLX	RPLX
28	0.50000	0.50000	0.45	0.78540	0.78540	0.73531

29	0.62500	0.62500	0.55	0.91174	0.91174	0.83548
30	0.50000	0.50000	0.40	0.78540	0.78540	0.68472
31	0.68750	0.91667	0.45	0.97760	1.27795	0.73531
32	0.83333	0.77083	0.45	1.15026	1.07161	0.73531
33	0.95833	0.83333	0.45	1.36523	1.15026	0.73531
34	0.50000	0.50000	0.30	0.78540	0.78540	0.57964
35	0.27083	0.50000	0.30	0.54734	0.78540	0.57964
36	0.62500	0.64583	0.60	0.91174	0.93338	0.88608

SAS

OBS	SUBJECT	COHORT	AGE	GEND	Y_DRV	D60	D90	D120	D0	ORTHO
37	M20	O	73	M	57	6	25.5	42.5	4	1.11
38	M21	O	71	F	50	22	29.0	14.0	4	1.43
39	M22	O	74	M	60	14	29.0	53.0	4	2.00
40	M24	O	76	F	64	8	25.5	25.5	4	1.00

OBS	L_CT	L_10	L_20	L_30	S_CT	S_10	S_20	S_30	TRP5	TRP4	TRP3
37	24	0	0	0	24	0	0	0	2	3	1
38	22	4	0	1	23	5	3	4	1	1	2
39	23	2	1	3	24	0	0	0	1	1	2
40	24	3	2	3	24	0	0	0	1	2	1

OBS	TRP2	TRP1	SVA	D0A	D60A	D90A	D120A	DYNAM
37	1	1	0.90090	0.250	0.16667	0.03922	0.02353	0.47941
38	2	0	0.69930	0.250	0.04545	0.03448	0.07143	0.40137
39	2	3	0.50000	0.250	0.07143	0.03448	0.01887	0.37478
40	1	3	1.00000	0.250	0.12500	0.03922	0.03922	0.45343

OBS	LWLP	SWLP	RPLP	LWLX	SWLX	RPLX
37	0.50000	0.50000	0.40	0.78540	0.78540	0.68472
38	0.56250	0.72917	0.30	0.84806	1.02346	0.57964
39	0.60417	0.50000	0.45	0.89033	0.78540	0.73531
40	0.66667	0.50000	0.40	0.95532	0.78540	0.68472

TTEST PROCEDURE

Variable: SVA STATIC ACUITY

COHORT	N	Mean	Std Dev	Std Error
K	20	1.00110519	0.16691892	0.03732420
O	20	0.76014157	0.20700766	0.04628832

Variances	T	Method	DF	Prob>|T|
Unequal	4.0524	Satterthwaite	36.4	0.0003
		Cochran	19.0	0.0007
Equal	4.0524		38.0	0.0002

For H0: Variances are equal, F' = 1.54 DF = (19,19)
Prob>F' = 0.3563

****

Variable: ORTHO VISUAL ANGLE

COHORT	N	Mean	Std Dev	Std Error
K	20	1.02850000	0.18968880	0.04241571
O	20	1.44200000	0.54331923	0.12148987

Variances	T	Method	DF	Prob>|T|

Unequal	-3.2134	Satterthwaite	23.6	0.0038
		Cochran	19.0	0.0046
Equal	-3.2134		38.0	0.0027

For H0: Variances are equal, F' = 8.20 DF = (19,19)
Prob>F' = 0.0000

APPENDIX H

DVA Analysis

Analysis of Variance Procedure
Class Level Information

Class	Levels	Values
SUBJECT	40	M04 M05 M06 M07 M08 M09 M10 M11 M12 M13 M14 M15 M16 M17 M18 M19 M20 M21 M22 M24 Y03 Y04 Y07 Y17 Y19 Y20 Y21 Y22 Y23 Y24 Y25 Y27 Y28 Y29 Y30 Y31 Y32 Y33 Y34 Y35
COHORT	2	K O
SPEED	4	0 120 60 90

Number of observations in data set = 160

Tests of Hypotheses using the Anova MS for SUBJECT(COHORT) as an error term

Source	DF	Anova SS	F Value	Pr > F
COHORT	1	0.32212352	34.08	0.0001

Tests of Hypotheses using the Anova MS for SUBJEC*SPEED(COHORT) as an error term

Source	DF	Anova SS	F Value	Pr > F
SPEED	3	2.16791941	204.16	0.0001

Tests of Hypotheses using the Anova MS for SUBJEC*SPEED(COHORT) as an error term

Source	DF	Anova SS	F Value	Pr > F
COHORT*SPEED	3	0.10574179	9.96	0.0001

Analysis of Variance Procedure
Tukey's Studentized Range (HSD) Test for variable: DVA
NOTE: This test controls the type I experimentwise error rate, but generally has a higher type II error rate than REGWQ.
Alpha= 0.005 df= 114 MSE= 0.00354
Critical Value of Studentized Range= 4.815
Minimum Significant Difference= 0.0453
Means with the same letter are not significantly different.

Tukey Grouping	Mean	N	SPEED
A	0.3594	40	0
B	0.1640	40	60
C	0.0971	40	90
C			
C	0.0561	40	120

Level of COHORT	Level of SPEED	N	DVA Mean	DVA SD
K	0	20	0.43125000	0.12483542
K	120	20	0.06297533	0.02316544
K	60	20	0.22871212	0.07779746
K	90	20	0.13302464	0.07503700
O	0	20	0.28750000	0.09158689
O	120	20	0.04914895	0.02613044
O	60	20	0.09926102	0.04653477
O	90	20	0.06109613	0.03315896

COHORT	N	Mean	Std Dev	Std Error
K	20	0.21395384	0.05392257	0.01205745
O	20	0.12425152	0.04261527	0.00952906

APPENDIX I

LABORATORY BFOV

Central Vision Task Identification

TTEST PROCEDURE

************************ OFF CENTER=0 ************************

Variable: PORTION RATIO

COHORT	N	Mean	Std Dev	Std Error
K	20	0.97291550	0.04117108	0.00920613
O	20	0.95625000	0.10425351	0.02331179

Variances	T	Method	DF	Prob>|T|
Unequal	0.6649	Satterthwaite	24.8	0.5122
		Cochran	19.0	0.5141
Equal	0.6649		38.0	0.5101

For H0: Variances are equal, F' = 6.41 DF = (19,19)
Prob>F' = 0.0001

****

Variable: XFORM TRANSFORMED

COHORT	N	Mean	Std Dev	Std Error
K	20	1.46318100	0.13114701	0.02932536
O	20	1.45542650	0.19408917	0.04339966

Variances	T	Method	DF	Prob>|T|
Unequal	0.1480	Satterthwaite	33.4	0.8832
		Cochran	19.0	0.8839
Equal	0.1480		38.0	0.8831

For H0: Variances are equal, F' = 2.19 DF = (19,19)

Prob>F' = 0.0958

Central Vision Task Matching

TTEST PROCEDURE

************************* OFF CENTER=0 *************************

Variable: PORTION RATIO

COHORT	N	Mean	Std Dev	Std Error
K	20	0.96249900	0.09257987	0.02070149
O	20	0.96666600	0.06135647	0.01371972

Variances	T	Method	DF	Prob>|T|
Unequal	-0.1678	Satterthwaite	33.0	0.8678
		Cochran	19.0	0.8685
Equal	-0.1678		38.0	0.8676

For H0: Variances are equal, F' = 2.28 DF = (19,19)
Prob>F' = 0.0808

****

Variable: XFORM TRANSFORMED

COHORT	N	Mean	Std Dev	Std Error
K	20	1.45940250	0.17524149	0.03918519
O	20	1.46051650	0.15535231	0.03473783

Variances	T	Method	DF	Prob>|T|
Unequal	-0.0213	Satterthwaite	37.5	0.9831
		Cochran	19.0	0.9832
Equal	-0.0213		38.0	0.9831

For H0: Variances are equal, F' = 1.27 DF = (19,19)
Prob>F' = 0.6047

Laboratory BFOV

TABLE 18
Number of Correct Target Reports Given by the Young Cohort by Axis and Eccentricity when Matching was the Central Vision Task

Young Cohort

	AXIS								
	D			L			LL		
	OFFCTR			OFFCTR			OFFCTR		
	10	20	25	10	20	25	10	20	25
	COUNT	COUNT	COUNT	COUNT	COUNT	COUNT	COUNT	COUNT	COUNT
	SUM	SUM	SUM	SUM	SUM	SUM	SUM	SUM	SUM
CENTRAL VISION M	17	18	14	20	16	17	19	20	17

	AXIS								
	LR			R			U		
	OFFCTR			OFFCTR			OFFCTR		
	10	20	25	10	20	25	10	20	25
	COUNT	COUNT	COUNT	COUNT	COUNT	COUNT	COUNT	COUNT	COUNT
	SUM	SUM	SUM	SUM	SUM	SUM	SUM	SUM	SUM
CENTRAL VISION M	19	18	17	20	16	19	19	15	21

	AXIS					
	UL			UR		
	OFFCTR			OFFCTR		
	10	20	25	10	20	25
	COUNT	COUNT	COUNT	COUNT	COUNT	COUNT
	SUM	SUM	SUM	SUM	SUM	SUM
CENTRAL VISION M	20	19	17	20	19	17

TABLE 19
Number of Correct Target Reports Given by the Old Cohort by Axis and Eccentricity when Matching was the Central Vision Task

GROUP O

	AXIS								
	D			L			LL		
	OFFCTR			OFFCTR			OFFCTR		
	10	20	25	10	20	25	10	20	25
	COUNT	COUNT	COUNT	COUNT	COUNT	COUNT	COUNT	COUNT	COUNT
	SUM	SUM	SUM	SUM	SUM	SUM	SUM	SUM	SUM
CENTRAL VISION M	7	2	4	10	9	9	10	6	3

	AXIS								
	LR			R			U		
	OFFCTR			OFFCTR			OFFCTR		
	10	20	25	10	20	25	10	20	25
	COUNT	COUNT	COUNT	COUNT	COUNT	COUNT	COUNT	COUNT	COUNT
	SUM	SUM	SUM	SUM	SUM	SUM	SUM	SUM	SUM
CENTRAL VISION M	6	4	3	10	6	6	3	1	1

	AXIS					
	UL			UR		
	OFFCTR			OFFCTR		
	10	20	25	10	20	25
	COUNT	COUNT	COUNT	COUNT	COUNT	COUNT
	SUM	SUM	SUM	SUM	SUM	SUM
CENTRAL VISION M	6	6	0	6	4	1

TABLE 20
Number of Correct Target Reports Given by the Young Cohort by Axis and Eccentricity when Identification was the Central Vision Task

	AXIS								
	D			L			LL		
	OFFCTR			OFFCTR			OFFCTR		
	10	20	25	10	20	25	10	20	25
	COU-NT	COU-NT	COU-NT	COU-NT	COU-NT	COU-NT	COU-NT	COU-NT	COU-NT
	SUM	SUM	SUM	SUM	SUM	SUM	SUM	SUM	SUM
CENTRAL VISION I	20	20	20	20	19	19	19	20	18

	AXIS								
	LR			R			U		
	OFFCTR			OFFCTR			OFFCTR		
	10	20	25	10	20	25	10	20	25
	COU-NT	COU-NT	COU-NT	COU-NT	COU-NT	COU-NT	COU-NT	COU-NT	COU-NT
	SUM	SUM	SUM	SUM	SUM	SUM	SUM	SUM	SUM
CENTRAL VISION I	20	19	18	20	19	20	19	18	16

	AXIS					
	UL			UR		
	OFFCTR			OFFCTR		
	10	20	25	10	20	25
	COU-NT	COU-NT	COU-NT	COU-NT	COU-NT	COU-NT
	SUM	SUM	SUM	SUM	SUM	SUM
CENTRAL VISION I	20	20	17	20	18	17

TABLE 21
Number of Correct Target Reports Given by the Old Cohort by Axis and Eccentricity when Identification was the Central Vision Task

	AXIS								
	D			L			LL		
	OFFCTR			OFFCTR			OFFCTR		
	10	20	25	10	20	25	10	20	25
	COUNT	COUNT	COUNT	COUNT	COUNT	COUNT	COUNT	COUNT	COUNT
	SUM	SUM	SUM	SUM	SUM	SUM	SUM	SUM	SUM
CENTRAL VISION I	8	2	1	8	5	6	9	6	4

	AXIS								
	LR			R			U		
	OFFCTR			OFFCTR			OFFCTR		
	10	20	25	10	20	25	10	20	25
	COUNT	COUNT	COUNT	COUNT	COUNT	COUNT	COUNT	COUNT	COUNT
	SUM	SUM	SUM	SUM	SUM	SUM	SUM	SUM	SUM
CENTRAL VISION I	7	3	4	8	4	8	4	0	0

	AXIS					
	UL			UR		
	OFFCTR			OFFCTR		
	10	20	25	10	20	25
	COUNT	COUNT	COUNT	COUNT	COUNT	COUNT
	SUM	SUM	SUM	SUM	SUM	SUM
CENTRAL VISION I	8	2	1	3	2	1

Analysis of Variance Procedure
Class Level Information

Class	Levels	Values
SUBJECT	40	M04 M05 M06 M07 M08 M09 M10 M11 M12 M13 M14 M15 M16 M17 M18 M19 M20 M21 M22 M24 Y03 Y04 Y07 Y17 Y19 Y20 Y21 Y22 Y23 Y24 Y25 Y27 Y28 Y29 Y30 Y31 Y32 Y33 Y34 Y35
COHORT	2	K O
OFFCTR	3	10 20 30
TASK	2	I M

Number of observations in data set = 240

Tests of Hypotheses using the Anova MS for
SUBJECT(COHORT) as an error term

Source	DF	Anova SS	F Value	Pr > F
COHORT	1	61.42269506	131.74	0.0001

Tests of Hypotheses using the Anova MS for
SUBJE*OFFCTR(COHORT) as an error term

Source	DF	Anova SS	F Value	Pr > F
OFFCTR	2	1.92224508	16.64	0.0001

Tests of Hypotheses using the Anova MS for
SUBJE*OFFCTR(COHORT) as an error term

Source	DF	Anova SS	F Value	Pr > F
COHORT*OFFCTR	2	0.21044846	1.82	0.1687

Laboratory BFOV

Analysis of Variance Procedure

Dependent Variable: XFORM TRANSFORMED

Tests of Hypotheses using the Anova MS for
SUBJECT*TASK(COHORT) as an error term

Source	DF	Anova SS	F Value	Pr > F
TASK	1	0.00205604	0.02	0.8932

Tests of Hypotheses using the Anova MS for
SUBJECT*TASK(COHORT) as an error term

Source	DF	Anova SS	F Value	Pr > F
COHORT*TASK	1	0.11649023	1.03	0.3156

Tests of Hypotheses using the Anova MS for

SUBJ*OFFC*TASK(COHO) as an error term

Source	DF	Anova SS	F Value	Pr > F
OFFCTR*TASK	2	0.14928749	3.30	0.0421

Tests of Hypotheses using the Anova MS for
SUBJ*OFFC*TASK(COHO) as an error term

Source	DF	Anova SS	F Value	Pr > F
COHORT*OFFCTR*TASK	2	0.04926407	1.09	0.3415

Tukey's Studentized Range (HSD) Test for variable: XFORM

NOTE: This test controls the type I experimentwise error rate, but generally has a higher type II error rate than REGWQ.

Alpha= 0.005 df= 76 MSE= 0.057752
Critical Value of Studentized Range= 4.581
Minimum Significant Difference= 0.1231

Means with the same letter are not significantly different.

Tukey Grouping	Mean	N	OFFCTR
A	1.0355	80	10
B	0.8930	80	20
B			
B	0.8200	80	30

Level of COHORT	Level of OFFCTR	N	------------XFORM------------ Mean	SD
K	10	40	1.51253875	0.14244418
K	20	40	1.43962100	0.21457848
K	30	40	1.31414075	0.29614778
O	10	40	0.55856075	0.54175282
O	20	40	0.34644375	0.40444372
O	30	40	0.32593700	0.34300941

Laboratory BFOV

Analysis of Variance Procedure

Level of COHORT	Level of TASK	N	------------XFORM------------ Mean	SD
K	I	60	1.44120450	0.22244057
K	M	60	1.40299583	0.25544981
O	I	60	0.38535567	0.42330270
O	M	60	0.43527200	0.47110923

Analysis of Variance Procedure

Level of OFFCTR	Level of TASK	N	------------XFORM------------ Mean	SD
10	I	40	1.03385650	0.61349658
10	M	40	1.03724300	0.63569423
20	I	40	0.85896150	0.66057296

20	M	40	0.92710325	0.61945143
30	I	40	0.84702225	0.60688175
30	M	40	0.79305550	0.57995959

Analysis of Variance Procedure

Level of COHORT	Level of OFFCTR	Level of TASK	N	-----------XFORM----------- Mean	SD
K	10	I	20	1.51659450	0.13238701
K	10	M	20	1.50848300	0.15520196
K	20	I	20	1.44616600	0.19999926
K	20	M	20	1.43307600	0.23328379
K	30	I	20	1.36085300	0.28864672
K	30	M	20	1.26742850	0.30350009
O	10	I	20	0.55111850	0.51423449
O	10	M	20	0.56600300	0.58127935
O	20	I	20	0.27175700	0.36023013
O	20	M	20	0.42113050	0.44073745
O	30	I	20	0.33319150	0.34182247
O	30	M	20	0.31868250	0.35291630

Laboratory BFOV

Analysis of Variance Procedure
Class Level Information

Class	Levels	Values
SUBJECT	40	M04 M05 M06 M07 M08 M09 M10 M11 M12 M13 M14 M15 M16 M17 M18 M19 M20 M21 M22 M24 Y03 Y04 Y07 Y17 Y19 Y20 Y21 Y22 Y23 Y24 Y25 Y27 Y28 Y29 Y30 Y31 Y32 Y33 Y34 Y35
COHORT	2	K O
OFFCTR	3	10 20 30
TASK	2	L S

Number of observations in data set = 240

Dependent Variable: PORTION RATIO

Tests of Hypotheses using the Anova MS for
SUBJECT(COHORT) as an error term

Source	DF	Anova SS	F Value	Pr > F
COHORT	1	27.67604167	136.55	0.0001

Tests of Hypotheses using the Anova MS for
SUBJE*OFFCTR(COHORT) as an error term

Source	DF	Anova SS	F Value	Pr > F
OFFCTR	2	0.92929688	19.08	0.0001

Tests of Hypotheses using the Anova MS for
SUBJE*OFFCTR(COHORT) as an error term

Source	DF	Anova SS	F Value	Pr > F

COHORT*OFFCTR	2	0.16809896	3.45	0.0367

Dependent Variable: PORTION RATIO

Tests of Hypotheses using the Anova MS for
SUBJECT*TASK(COHORT) as an error term

Source	DF	Anova SS	F Value	Pr > F
TASK	1	0.00651042	0.16	0.6953

Tests of Hypotheses using the Anova MS for
SUBJECT*TASK(COHORT) as an error term

Source	DF	Anova SS	F Value	Pr > F
COHORT*TASK	1	0.06666667	1.60	0.2143

Tests of Hypotheses using the Anova MS for
SUBJ*OFFC*TASK(COHO) as an error term

Source	DF	Anova SS	F Value	Pr > F
OFFCTR*TASK	2	0.05325521	3.13	0.0495

Tests of Hypotheses using the Anova MS for
SUBJ*OFFC*TASK(COHO) as an error term

Source	DF	Anova SS	F Value	Pr > F
COHORT*OFFCTR*TASK	2	0.02903646	1.71	0.1885

Tukey's Studentized Range (HSD) Test for variable: PORTION

NOTE: This test controls the type I experimentwise error
rate, but generally has a higher type II error rate
than REGWQ.

Alpha= 0.005 df= 76 MSE= 0.024349
Critical Value of Studentized Range= 4.581
Minimum Significant Difference= 0.0799

Means with the same letter are not significantly different.

Tukey Grouping	Mean	N	OFFCTR
A	0.6734	80	10
B	0.5750	80	20
B			
B	0.5234	80	30

Level of COHORT	Level of OFFCTR	N	-----------PORTION----------- Mean	SD
K	10	40	0.97812500	0.05581204
K	20	40	0.94375000	0.10572552
K	30	40	0.86875000	0.17206793
O	10	40	0.36875000	0.36902288
O	20	40	0.20625000	0.27669930
O	30	40	0.17812500	0.22268665

Tukey Grouping	Mean	N	TASK
A	0.5958	120	M

```
A
A            0.5854    120  I
```

Laboratory BFOV

Analysis of Variance Procedure

Level of COHORT	Level of TASK	N	PORTION Mean	PORTION SD
K	I	60	0.94166667	0.11614087
K	M	60	0.91875000	0.13965947
O	I	60	0.22916667	0.29035216
O	M	60	0.27291667	0.32013277

Level of OFFCTR	Level of TASK	N	PORTION Mean	PORTION SD
10	I	40	0.67187500	0.40000751
10	M	40	0.67500000	0.41196060
20	I	40	0.55000000	0.44198706
20	M	40	0.60000000	0.41234943
30	I	40	0.53437500	0.41408253
30	M	40	0.51250000	0.38997863

Level of COHORT	Level of OFFCTR	Level of TASK	N	PORTION Mean	PORTION SD
K	10	I	20	0.98125000	0.04579344
K	10	M	20	0.97500000	0.06539355
K	20	I	20	0.95000000	0.08506963
K	20	M	20	0.93750000	0.12500000
K	30	I	20	0.89375000	0.16856105
K	30	M	20	0.84375000	0.17619423
O	10	I	20	0.36250000	0.35332071
O	10	M	20	0.37500000	0.39319876
O	20	I	20	0.15000000	0.23855376
O	20	M	20	0.26250000	0.30591752
O	30	I	20	0.17500000	0.22725478
O	30	M	20	0.18125000	0.22388246

Laboratory BFOV
Figure of Merit

TTEST PROCEDURE

Variable: IALL ID-PORTION

COHORT	N	Mean	Std Dev	Std Error
K	20	0.95729167	0.05552242	0.01241519
O	20	0.59270833	0.14409601	0.03222085

Variances	T	Method	DF	Prob>|T|
Unequal	10.5585	Satterthwaite	24.5	0.0001
		Cochran	19.0	0.0000
Equal	10.5585		38.0	0.0000

For H0: Variances are equal, F' = 6.74 DF = (19,19)
Prob>F' = 0.0001

```
*****************************************************************

Variable: MALL        MAT-PORTION

COHORT        N          Mean          Std Dev        Std Error
-----------------------------------------------------------------
K            20     0.94062500      0.09125581      0.02040542
O            20     0.61979167      0.13533229      0.03026122

Variances        T    Method             DF     Prob>|T|
---------------------------------------------------------
Unequal    8.7904    Satterthwaite      33.3      0.0001
                     Cochran            19.0      0.0000
Equal      8.7904                       38.0      0.0000

For H0: Variances are equal, F' = 2.20    DF = (19,19)
                             Prob>F' = 0.0941
```

APPENDIX J

Runway BFOV

```
                 Analysis of Variance Procedure
                    Class Level Information

Class     Levels    Values

SUBJECT       40    M04 M05 M06 M07 M08 M09 M10 M11 M12 M13
                    M14 M15 M16 M17 M18 M19 M20 M21 M22 M24
                    Y03 Y04 Y07 Y17 Y19 Y20 Y21 Y22 Y23 Y24
                    Y25 Y27 Y28 Y29 Y30 Y31 Y32 Y33 Y34 Y35

DISTANCE       5    1 2 3 4 5

COHORT         2    K O

            Number of observations in data set = 200


                          Runway BFOV

                 Analysis of Variance Procedure

Dependent Variable: XFORM   TRANSFORMED

Tests of Hypotheses using the Anova MS for
SUBJECT(COHORT) as an error term

Source                   DF        Anova SS  F Value   Pr > F

COHORT                    1      2.19325568    13.52   0.0007

Tests of Hypotheses using the Anova MS for
SUBJE*DISTAN(COHORT) as an error term

Source                   DF        Anova SS  F Value   Pr > F

DISTANCE                  4      0.43316800     1.34   0.2570

Tests of Hypotheses using the Anova MS for
```

SUBJE*DISTAN(COHORT) as an error term

Source	DF	Anova SS	F Value	Pr > F
DISTANCE*COHORT	4	0.59629139	1.85	0.1227

TABLE 22
Signal Light Configurations and Sums of Responses by Distance and Cohort

Young Cohort

	DISTANCE																			
	1				2				3				4				5			
	RESPONSE				RESPONSE				RESPONSE				RESPONSE				RESPONSE			
	C	L	N	R	C	L	N	R	C	L	N	R	C	L	N	R	C	L	N	R
	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
CONFIG																				
C	18	1	1	.	18	.	1	1	18	1	1	.	17	.	2	1	12	1	6	1
L	1	11	1	7	.	11	4	5	3	8	3	6	.	4	8	8	.	7	9	4
N	1	3	11	5	.	3	10	7	1	2	12	5	.	1	12	7	.	4	15	1
R	1	3	7	9	1	5	5	9	2	4	5	9	3	2	7	8	1	2	8	9
ALL	21	18	20	21	19	19	20	22	24	15	21	20	20	7	29	24	13	14	38	15

Old Cohort

	DISTANCE																			
	1				2				3				4				5			
	RESPONSE				RESPONSE				RESPONSE				RESPONSE				RESPONSE			
	C	L	N	R	C	L	N	R	C	L	N	R	C	L	N	R	C	L	N	R
	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
CONFIG																				
C	15	1	3	1	18	.	2	.	15	1	2	2	17	.	3	.	9	2	8	1
L	3	5	9	3	1	5	11	3	1	6	11	2	2	6	9	3	.	.	13	7
N	2	4	8	6	1	2	11	6	2	3	8	7	3	1	9	7	3	3	10	4
R	4	2	10	4	2	4	11	3	2	5	10	3	3	2	8	7	2	2	11	5
ALL	24	12	30	14	22	11	35	12	20	15	31	14	25	9	29	17	14	7	42	17

Runway BFOV

Analysis of Variance Procedure
Tukey's Studentized Range (HSD) Test for variable: XFORM
NOTE: This test controls the type I experimentwise error rate, but generally has a higher type II error rate than REGWQ.

Alpha= 0.005 df= 38 MSE= 0.162185
Critical Value of Studentized Range= 4.215
Minimum Significant Difference= 0.1697

Means with the same letter are not significantly different.

Tukey Grouping	Mean	N	COHORT
A	0.8849	100	K
B	0.6754	100	O

Tukey's Studentized Range (HSD) Test for variable: XFORM

NOTE: This test controls the type I experimentwise error rate, but generally has a higher type II error rate than REGWQ.

Alpha= 0.005 df= 152 MSE= 0.080705
Critical Value of Studentized Range= 4.986
Minimum Significant Difference= 0.224

Means with the same letter are not significantly different.

Tukey Grouping	Mean	N	DISTANCE
A	0.8312	40	2
A			
A	0.8050	40	1
A			
A	0.7919	40	3
A			
A	0.7789	40	4
A			
A	0.6938	40	5

Level of DISTANCE	Level of COHORT	N	------------XFORM------------ Mean	SD
1	K	20	0.94248000	0.33332524
1	O	20	0.66759000	0.24727357
2	K	20	0.91630000	0.28804262
2	O	20	0.74613000	0.17562078
3	K	20	0.92939000	0.37484056
3	O	20	0.65450000	0.28804262
4	K	20	0.78540000	0.44135670
4	O	20	0.77231000	0.17968191
5	K	20	0.85085000	0.40624534
5	O	20	0.53669000	0.26145530

Runway BFOV

Analysis of Variance Procedure
Class Level Information

Class	Levels	Values
SUBJECT	40	M04 M05 M06 M07 M08 M09 M10 M11 M12 M13

```
                M14 M15 M16 M17 M18 M19 M20 M21 M22 M24
                Y03 Y04 Y07 Y17 Y19 Y20 Y21 Y22 Y23 Y24
                Y25 Y27 Y28 Y29 Y30 Y31 Y32 Y33 Y34 Y35

DISTANCE    5   1 2 3 4 5

COHORT      2   K O

          Number of observations in data set = 200


                      Runway BFOV

               Analysis of Variance Procedure

Dependent Variable: PORTION

Tests of Hypotheses using the Anova MS for
SUBJECT(COHORT) as an error term

Source                DF        Anova SS  F Value    Pr > F

COHORT                 1      1.28000000    14.41    0.0005

Tests of Hypotheses using the Anova MS for
SUBJE*DISTAN(COHORT) as an error term

Source                DF        Anova SS  F Value    Pr > F

DISTANCE               4      0.28625000     1.55    0.1899

Tests of Hypotheses using the Anova MS for
SUBJE*DISTAN(COHORT) as an error term

Source                DF        Anova SS  F Value    Pr > F

DISTANCE*COHORT        4      0.28250000     1.53    0.1956


                      Runway BFOV

              Analysis of Variance Procedure
  Tukey's Studentized Range (HSD) Test for variable: PORTION
 NOTE: This test controls the type I experimentwise error
       rate, but generally has a higher type II error rate
       than REGWQ.

           Alpha= 0.005  df= 38  MSE= 0.088816
         Critical Value of Studentized Range= 4.215
          Minimum Significant Difference= 0.1256

 Means with the same letter are not significantly different.
       Tukey Grouping              Mean      N  COHORT
                    A            0.5700    100  K

                    B            0.4100    100  O
  Tukey's Studentized Range (HSD) Test for variable: PORTION

 NOTE: This test controls the type I experimentwise error
       rate, but generally has a higher type II error rate
       than REGWQ.

           Alpha= 0.005  df= 152  MSE= 0.046094
         Critical Value of Studentized Range= 4.986
          Minimum Significant Difference= 0.1693
```

Means with the same letter are not significantly different.

Tukey Grouping	Mean	N	DISTANCE
A	0.5312	40	2
A			
A	0.5062	40	1
A			
A	0.5000	40	4
A			
A	0.4938	40	3
A			
A	0.4188	40	5

Level of DISTANCE	Level of COHORT	N	-----------PORTION----------- Mean	SD
1	K	20	0.61250000	0.24967084
1	O	20	0.40000000	0.20519567
2	K	20	0.60000000	0.22064499
2	O	20	0.46250000	0.16770510
3	K	20	0.58750000	0.27235571
3	O	20	0.40000000	0.22064499
4	K	20	0.51250000	0.30859401
4	O	20	0.48750000	0.17158319
5	K	20	0.53750000	0.29552585
5	O	20	0.30000000	0.17396309

Runway BFOV

TTEST PROCEDURE

Variable: RUNXCN PORTION-RUNWAY

COHORT	N	Mean	Std Dev	Std Error
K	20	0.56500000	0.15985191	0.03574397
O	20	0.41250000	0.10867019	0.02429939

Variances	T	Method	DF	Prob>|T|
Unequal	3.5283	Satterthwaite	33.5	0.0012
		Cochran	19.0	0.0022
Equal	3.5283		38.0	0.0011

For H0: Variances are equal, F' = 2.16 DF = (19,19)
Prob>F' = 0.1009