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EFFECT OF MARIHUANA AND ALCOHOL ON VISUAL SEARCH PERFORMANCE

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October 1976
Final Report

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16. Abstract

Two experiments were performed to determine the effects of alcohol and marihuana on visual scanning patterns in a simulated driving situation. In the first experiment 27 male heavy drinkers were divided into 3 groups of 9, defined by three blood alcohol levels produced by alcohol treatment: 0.0%, 0.075%, and 0.15% BAC's. Significant changes in visual search behavior including increased dwell duration, decreased dwell frequency and increased pursuit duration and frequency were found under alcohol. In the second experiment 10 male social users of marihuana were tested under both 0 mcg and 200 mcg tetrahydrocannabinol per kilogram bodyweight. Marihuana was found to have no effect on visual search behavior. The results are related to previous studies of alcohol and marihuana effects on information processing. Implications for highway safety are discussed.

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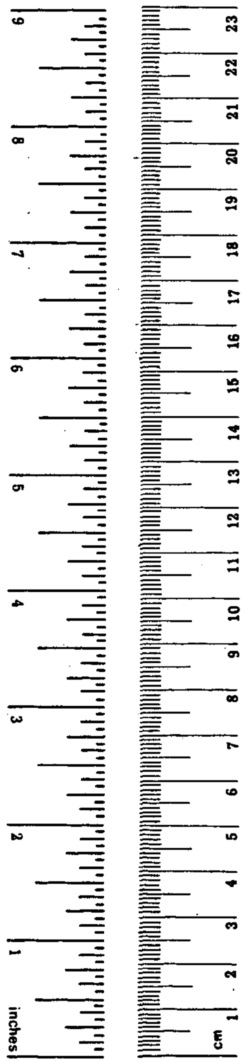
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

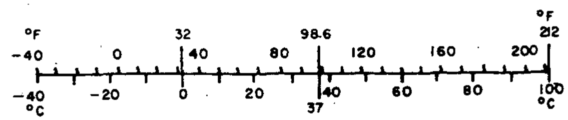
Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
	AREA			
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
	MASS (weight)			
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
	VOLUME			
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
	TEMPERATURE (exact)			
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
	AREA			
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
	MASS (weight)			
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
	VOLUME			
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
	TEMPERATURE (exact)			
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



DEPARTMENT OF TRANSPORTATION
NATIONAL HIGHWAY TRAFFIC SAFETY ADMINISTRATION

TECHNICAL SUMMARY

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REPORT TITLE Effect of Marihuana and Alcohol on Visual Search Performance	REPORT DATE January 1976
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Perceptual errors have been found to be the immediate cause of a substantial percentage of alcohol-related automobile accidents. Although laboratory experiments have identified many aspects of perceptual performance that are affected by alcohol, it is not obvious as to how the deficits demonstrated in the laboratory interact with demands of driving. Several investigators have approached this problem through the use of eye movement recording as an insight into the cognitive processes (as reflected in visual search strategies) and perceptual performance of drivers under the influence of alcohol.

The present study examined visual search processes at three blood alcohol levels (0%, 0.075%, and 0.15%) for subjects viewing a traffic movie in a driving simulator. Subjects searched the movie for events of importance to a driver and, in addition, performed two subsidiary tasks: (1) Responding with a switch mounted on the steering wheel each time an event was detected, and (2) Responding with the turn signal lever to right- and left-pointing arrows superimposed on the driving scene at various locations at random times. An independent group design was used with nine subjects in each group. All subjects were heavy drinkers.

A second experiment was performed to examine the effects of marijuana on visual search processes as this drug has also been reported to produce perceptual deficits, although of a different nature than those pro-

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duced by alcohol. A pilot study (N=7) and a final study (N=10) were performed with social users as subjects. A repeated measures design was used with two treatments, 0 mcg and 200 mcg THC per kg body weight. Identical procedures to the alcohol study were used, except that for the final study the nature of the subsidiary task stimulus was changed to a Landolt C-ring pointing left or right and presented at a single, central screen location.

A computerized data collection and analysis system was developed for this study which enabled large amounts of eye movement data to be analyzed by computer.

The results of the alcohol study showed a substantial increase in mean dwell or fixation time and a corresponding decrease in dwell frequency under alcohol. Fewer points in the visual field were examined and fewer shifts of attention occurred under alcohol. Pursuit or eye following activity increased under alcohol. A detailed analysis of various categories of events looked at indicated differential effects of alcohol on different categories of events (duration of looks for flashing lights and traffic lights increased under alcohol whereas they decreased or remained the same for pedestrians).

It is hypothesized that the longer dwell times found in this study are a consequence of decreased information processing rate previously demonstrated under alcohol. Thus, visual search efficiency can decrease as the need to examine each area for a longer time results in a decrease in the amount of the visual field that can be examined. The increased pursuit behavior found under alcohol appears to be more a "fixation of gaze" phenomenon than it is related to the need for additional information.

The marihuana results, on the other hand, indicate no change in visual search patterns or performance for any of the measured quantities. The results are discussed in terms of prior studies in which differences in the effects of alcohol and marihuana were examined.

Implications of the results for understanding the perceptual involvement in alcohol-related accidents are discussed.

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Mr. R. W. Burger, Jr. and Mr. R. A. Kemmerer developed the on-line data collection programs.

The assistance of Dr. L. G. Summers, Contract Technical Monitor, National Highway Traffic Safety Administration, U.S. Department of Transportation, is greatly appreciated.

The development of computer programs for eye movement analysis and the use of a PDP-8 computer for data collection was made possible through a contract to Amex Civil Systems from the U.S. Department of Transportation, Office of Management Systems. The assistance of Mr. L. Oliver, Contract Technical Monitor, is gratefully acknowledged.

Data Processing was made possible through the facilities of the UCLA Campus Computing Network.

PREFACE

This report is divided into the main body, which presents the most important aspects of the study, and a series of appendices which present additional supporting data and discussion. In particular, the following should be noted: Appendix A contains a brief discussion of perception and driving accidents. Appendix B presents a theoretical discussion and literature review of eye movement studies as related to visual search and driving. Appendix C contains a description of the eye movement analysis techniques that were developed for this investigation and a discussion of measurement errors. This appendix would be of interest to others performing eye movement analyses and for quantitative comparison with other studies. An important result concerning the effect of the subsidiary task on visual search is elaborated in Appendix H. Additional data tabulations are contained in Appendix K.

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1.0 Introduction

On-site investigations of alcohol-related automobile accidents have frequently found the immediate cause to be a perceptual error (Clayton, 1972, Perchonok, 1972)[1]. This is scarcely surprising given the extensive experimental evidence demonstrating that alcohol severely impairs many aspects of perceptual performance, often at blood alcohol concentration (BAC) below 0.05% (Moskowitz, 1973 a; Moskowitz and Sharma, 1974). What is less clear is how the deficits identified in laboratory investigations interact with demands of the driving situation. Several investigators have recently attempted to clarify this issue through the use of eye movement recording as an insight into the cognitive processes of the subjects (Belt, 1969; Buikhuisen and Jongman, 1972; Mortimer and Jorgeson, 1972; Schroeder, Ewing and Allen, 1974)[2]. Both the Belt (1969) and the Mortimer and Jorgeson (1972) studies were performed in actual cars on the road with two subjects each at three BAC levels. Belt reported a constricted horizontal field of view but Mortimer et al did not. While Mortimer reported increased fixation duration Belt found this only in open road situations and not when car following. The Buikhuisen and Jongman (1972) and Schroeder et al (1974) studies examined eye movements while the subjects in a laboratory situation viewed films of road drives. Both these studies reported changes in spatial distribution of fixations with Schroeder et al also reporting decreased frequency of eye movements.

All four studies relied upon either frame by frame analysis of films or hand analysis of oscillographic records to obtain eye position data. This limit in data handling capability leads to either small subject samples, use of short periods for analysis and/or low data sam-

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[1]See Appendix A

[2]See Appendix B

pling rates. The current study was undertaken to examine eye movements while viewing driving scenes using an experimental apparatus with a relatively high data sampling rate (100 per second), a relatively long trial length (17+ minutes) and a computer data recording and analysis system permitting the rapid extraction of a wide variety of performance variables.

A second experiment was performed to examine the effects of marijuana as this drug has also been reported to produce perceptual deficits in performance, albeit of a rather different character than those produced by alcohol (Moskowitz and Sharma, 1972; Moskowitz and McGlothlin, 1974).

2.0 Alcohol Experiment

2.1 Method

2.1.1 Apparatus

Subjects sat in a driving simulator consisting of the front half of an actual car body facing a twelve foot wide rear projection screen. 35mm driving films were projected on the screen which subtended a 70 degree horizontal visual angle. Scene luminance ranged from 0.3 to 6.0 Ft-Lamberts. A 35mm slide projector superimposed stimuli on the screen for a subsidiary task as well as slides used to calibrate the Eye Point of Regard (EPR) system.

Eye movements were measured with a Biometrics system using sensors mounted in a spectacle frame. Horizontal eye position was measured using the difference in reflectivity between sclera and iris; vertical position was measured using the reflectivity difference between the eyelid and the eyeball*. A helmet worn by the subject was attached to a moveable rod via a two-axis goniometer which enabled head

*As discussed in Appendix C, vertical accuracy is substantially poorer than horizontal accuracy.

rotation and translation. The information from both the eye and head movement sensors fed into a Systems Technology, Inc. Eye Point of Regard analogue computer which produced six channels of output: the horizontal and vertical coordinates of the eye position relative to the head, the head position relative to the screen and the resulting EPR relative to the screen.

The outputs of the EPR computer were simultaneously routed into a PDP-8 computer for on-line digitization, and into 2 oscilloscopes for display of an eye mark spot. One oscilloscope was used for monitoring and adjustment of the EPR computer while subjects viewed calibration slides. A video camera recorded the eye mark of the second oscilloscope enabling the experimenters to mix the EPR position with the image from a second video camera focused on the film screen. The mixed video signal was observed on-line on a video monitor and recorded on a video recorder, thus permitting experimenters to see what the subjects were observing in the driving films during the film and subsequently for analysis. The PDP-8 produced an IBM compatible data tape with nine tracks of data sampled at a rate of 100 per second for subsequent analysis on an IBM-360. Besides the eye and head position data, a frame count of the driving film was recorded to relate the EPR to the film contents. Data analysis was performed on the UCLA CCN IBM-360 using a series of computer programs especially developed for this project[3].

Two driving films were utilized in the study. An eight minute film was used during training sessions. A 17 minute 3 second film was utilized in all experimental test sessions. This latter film was broken

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[3]Complete descriptions of the data collection system and data analysis program are given in Burger et al (1975) and Niemann and Ziedman (1975). A short overview of the simulation and data analysis system is given in Ziedman, Sharma, and Niemann (1975).

into five segments separated by seven second interludes during which a single center dot was projected as a calibration check. Prior to and after the traffic portions of the film, a series of dots was displayed on the screen. The subject fixated each dot in turn to calibrate the EPR system.

The film segments were continuous drive sequences filmed in Venice, California, an urban area with moderate to heavy traffic density. In addition to chance events, the films contained a number of predetermined staged events such as the presence of pedestrians of a wide age range, bicycles, motorcycles, various configurations of stationary and moving vehicles and even a ball thrown into the street. After completion of the film it was reviewed independently by three observers, experienced in traffic research. Upon agreement by the observers, events or objects in the film were identified as "critical events" which an alert driver should observe since they might potentially contain a demand for a safety reaction[4].

The frame counts for the appearance of the "critical events" and the spatial coordinates of these events in time were determined and entered into the computer program so that it could be determined whether the subject viewed the events during the drive.

2.1.2 Subjects

Subjects were recruited by placing advertisements at offices of the California State Human Resources Department. All subjects were males between the ages of 21 and 57 (average = 30.6) possessing current driving licenses, with no current medical problems or attendance at any alcohol treatment facility. They were required to be very heavy alcohol users as the study involved a large alcohol dose for some subjects. Moreover, the emphasis of the study was on the behavior under alcohol of heavy alcohol users, a group disproportionately rep-

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[4]The film time line is given in Appendix D.

resented in drinking driving offenses and accidents. Alcohol use was assessed by the Cahalan, Cisin and Crossley drinking practice scale (1969) and the Oates-McCay drinking questionnaire (1974). Subjects read and signed consent forms describing the procedures and treatments in conformity with the standards for human subjects of HEW[5].

21 subjects were studied, divided randomly into 3 alcohol treatment groups with the constraint that the age distribution in the three groups be roughly similar. Each subject attended two sessions, a training session and an experimental test session one week later.

2.1.3 Treatments

The basic experimental design involved a comparison of the performance of three alcohol treatment groups. The groups were defined in terms of the blood alcohol level (BAC) produced by the three alcohol treatment doses at the time of performance testing, i.e., 0.0%, 0.075% and 0.15% BAC.

For the experimental session subjects were required to have drunk no alcohol during the preceding evening and subsequently. Prior to treatment administration subjects were checked to ensure that they were initially at zero BAC. All testing for BAC was done using a breath analysis by gas chromatography.

The beverage for the 0.0% BAC group consisted solely of orange juice. The beverage for the active alcohol treatments contained equal volumes of 80 proof vodka and orange juice. Subjects in the high dose treatment group were administered 1.37 grams alcohol per kilogram bodyweight (g al/kg b.w.) in 7 equal measures at 15 minute intervals. 30 minutes after the last drink they were tested for BAC level and if below 0.16% BAC given a final supplementary drink computed to bring their BAC level to 0.16%. This level was chosen since there

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[5]See Appendix E for the alcohol use and health screening questionnaire and Appendix G for the consent forms.

would be approximately 45 minutes after the last BAC test before the start of the experimental test. Since it was desired to begin performance testing with subjects at 0.15% it was necessary that they be at a slightly higher BAC level at this earlier time.

Subjects in the low dose treatment group received .735 g al/kg b. w. in 4 equal measures at 15 minute intervals. This was intended to produce 0.085% BAC when measured a half hour after consuming the last drink. If the subject's BAC was below 0.085% he was given an additional drink whose alcohol content depended on the actual BAC level. The intent was that all subjects in the low dose treatment group be at 0.075% at the beginning of performance testing[6].

The placebo group received 3.1 milliliters of orange juice per kg b. w. administered in 4 equal measures at 15 minute intervals. A teaspoon of vodka was floated on top of each drink.

During the training session all subjects received an active alcohol treatment to familiarize them with experiencing alcohol in the laboratory situation. On that occasion all subjects received .414 g al/kg b. w. in a mixture containing equal volumes of 80 proof vodka and orange juice. The drink was consumed in 30 minutes and produced roughly a peak mean of 0.05% BAC.

2.2 Procedure

2.2.1 Training Session

The single training session provided practice on the eye movement calibration procedures, as well as on the performance tasks. This was done with the subject sober and at a BAC of about 0.05%. In addition, the training period allowed a final screening of subjects

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[6]BAC results are presented in Appendix F. The mean pre-simulation and post-simulation BAC levels were 0.082% and 0.067% for the 0.075% group; 0.16% and 0.13% for the 0.15% group.

with regard to compatability with the eye movement recording procedures.

A BAC reading was taken at the beginning of the training session after which instructions were read to the subject[7]. The eye movement device was mounted on the subject, he was seated in the simulation car, calibration instructions were presented, and the eye and head movement devices were calibrated. The above procedures took about 30 minutes. The 10-minute training film was then shown to the subject. He was instructed to perform all tasks; however, the data were not collected.

After the film, the subject rested for an hour. He then was given an alcohol dose of .414 g al/kg b. w. and allowed 30 minutes in which to consume the drink. An additional 30 minutes was allowed for absorption to approximately peak BAC. For the training sessions no attempt was made to adjust BAC. After a BAC test the subject was re-run in the driving simulator where he viewed the same training movie. Again, he was asked to perform all tasks.

The subject was released after his BAC level was 0.03% or lower.

2.2.2 Test Session

After a preliminary BAC check, the subject was administered the appropriate treatment for his group. After a BAC reading and dose adjustments, if necessary, the subject was taken to the simulator, fitted with the eye movement apparatus and run through the 17+ minute test film. The subject was fed and rested after testing and was released when his BAC registered 0.03% or lower.

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[7] See Appendix G.

2.2.3 Subject Tasks

The prime task of the subject was to watch the traffic movie as if he were actually driving. In addition subjects were required to perform two other tasks:

a. A response switch attached to the steering wheel had to be kept depressed at all times during the movie scene. He was requested to release the switch momentarily each time he saw an event that he felt was important for a driver to notice. The button was to be released once per event, with no limitation on the number of total responses. This task was used primarily to maintain subject motivation and attention to events in the film and to ensure an active role on his part.

b. A subsidiary task required identifying the direction of projected arrows subtending a visual angle of 1.6^{o} vertically and horizontally. They were superimposed on the traffic scene at quasi-random intervals during the film. The arrows were located at 18 points defined by the intersections of a 3 x 6 grid with two arrow presentations (one left, one right) at each intersection. The horizontal grid coordinates were at 5, 15 and 25 degrees both left and right of center of the driver's visual axis. The vertical coordinates were at zero (straight ahead), 6 degrees up and 6 degrees down from straight ahead.

The time of occurrence, sequence of right-left, and spatial locations of the arrows were randomized within constraints of a fixed number of conditions and limitations on inter-trial intervals. Each arrow remained on ten seconds unless a correct response was executed by the subject, whereupon the arrow was terminated. An incorrect response did not turn off the arrow. Subjects were requested to respond to the appearance of an arrow as soon as they saw it by activating a turn signal switch lever mounted on the left side of the steering column. A depression of the switch was required when a left-pointing arrow appeared, and it was to be moved up when a right-pointing arrow appeared. Time of response and direction of response were scored. Inappropriate responses, such as activating the switch when no arrow was present, or incorrect responses to an arrow presentation were also scored.

2.3 Results - Alcohol Experiment

This section will present the data summarizing the effects of the alcohol treatments upon the duration and frequency of eye movement variables, the spatial distribution of dwells, and responses to the subsidiary task and critical events.

2.3.1 Allocation of Viewing Time

Table 1 shows the allocation of viewing time to dwells, pursuits, saccades and blinks during the 17+ minute (1022 sec) of actual traffic scenes. Note that the times for dwells, pursuits and saccades for each treatment group sum to 96% - 97% of the total viewing time, the remainder being attributable to blink time (Note 3 in Table 1). This indicates the eye state classification software is not missing or excluding any appreciable amount of data.

For the placebo group,dwells accounted for 64% of total viewing time, pursuits for 19% and saccades for 14%. In comparison, the alcohol treatment groups showed a trend towards decreased time in dwells and saccades but increased time in pursuits. In contrast to the small changes in total time allocated to dwells, pursuits and saccades, there were many large changes in the frequencies and mean durations of dwells and pursuits, as can be seen in Table 2.

The most important finding was a large and statistically significant (p=.004)[8] increase in the average dwell time from .37 sec to

[8]Due to the wide range of individual differences in many eye movement variables, all statistical tests of significance were performed using the Kruskal-Wallis one way analysis of variance in the alcohol experiment.

.47 and .48 sec respectively for the low and high alcohol dose treatment. This finding is consistent with laboratory studies suggesting that alcohol reduced the rate at which information is processed (Moskowitz and Burns, 1971; Moskowitz and Murray, 1976). Thus, the presence of alcohol requires subjects to extend the duration of their dwells or fixation in order to extract the required information.

While a small trend toward a lower total time in dwell under alcohol appeared, it was not significant statistically or in magnitude. Of necessity, given the relatively constant total time in dwell and the greatly increased duration of dwells, the number or frequency of dwells decreased sharply (p=.004). This decrease in the number of fixations or dwells under alcohol would reduce the driver's ability to search the environment for potential dangers or attend to the cues necessary for proper lane maintenance and heading.

Pursuit activity, except length of the pursuit, increased under alcohol. Frequency of pursuits increased about 20% (p=.04), total time in pursuit increased 30% - 50% (p=.01), and mean pursuit duration increased 11% - 20% (p=.05). The apparent inconsistency between a slight decrease in pursuit length and an increased pursuit duration under alcohol is apparently accounted for by a change in the relative distribution of type of events viewed, as will be discussed in the section on critical events.

Behavior changes under the influence of alcohol can be summarized as (1) an increase in mean time per dwell with a (2) concomitant decrease in dwell frequency combined with (3) an increase in both the frequency of pursuits and mean duration of pursuits. Thus, a person under alcohol can examine fewer events or examine the same event fewer times. He tends to pursue moving objects more often and for a longer time, further limiting the opportunity for sharing attention between different events.

A typical effect of alcohol on psychomotor performance is to increase variability. Table 2 compares the means of the individual subjects' standard deviations for dwell times, pursuit times, and pursuit lengths. Both time per dwell and time per pursuit showed statistically significant increases of within subject variability under alcohol.

Table 2 also presents the standard deviations for each variable previously discussed which provides an index of between subject variability.

Mean time per dwell shows an increase in between subject variability, as it did for within subject variability. Mean time per pursuit and mean pursuit length are ambiguous, showing increased variability under 0.075% BAC, and a decreased variability under 0.15% BAC, compared to the placebo. All other measures show a decrease in between subject variability under alcohol.

Thus, dwell time variability, both within or between subjects shows an increase under alcohol. Increased variability is characteristic of performance under alcohol and reflects the decreased control of factors necessary for performance. The decreased variability in dwell and pursuit frequencies, on the other hand, is likely artificial, resulting from the decreased frequencies of dwells and pursuit placing upper limits on the range of these frequencies.

Due to the necessity for a 60 Hz low pass filter in the recording circuit to remove 60 Hz power line noise, the initiation and ends of saccades are not defined sufficiently well for a comparative analysis of saccade durations which are, of course, considerably shorter in duration than either dwells or pursuits.

2.3.2 Spatial Distribution of Dwells

The spatial distribution of dwells was analyzed by dividing the movie display area into 21 cells (3 vertical x 7 horizontal) and counting the number of dwells falling in each cell. In addition, the total time in dwell and mean time per dwell in each of the cells were tabulated. The horizontal cell boundaries were $\pm 5^{0}$ around center (0^{0}), and 5^{0} to 15^{0}, 15^{0} to 25^{0} and $>25^{0}$ left and right. The vertical cell boundaries were -6^{0} (down) to 0^{0}, 0^{0} to 6^{0}, and 6^{0} to 12^{0} (up). For a convenient summary measure of spatial distribution, the centroid (or center of gravity) of all dwells was calculated, as was the standard deviation of dwell locations relative to the centroid. These data were examined to determine the spatial distribution of attention in the movie.

The results for horizontal distribution of dwells show 51.6% fell in the central 10 degrees and 86.9% in the central 30 degrees with the remiander beyond the central 30 degrees[9]. This horizontal dispersion is considerably greater than typically found by Mourant and Rockwell (1970) in their studies and may partially be due to the urban, highly populated areas shown in the driving film and the lack of a central tracking task in this study. As will be clear from later discussion, the spatial distribution of dwells is highly dependent upon the immediate stimulus presentation and will be shown to be influenced by the distribution of the subsidiary task.

Comparison across the alcohol treatments reveals no evidence for any change in the horizontal spatial distribution of dwells. However, the vertical spatial distribution showed a dose related increase in the relative number of dwells in the lower portions of the screen. Thus the vertical centroid values were 0.9^{0}, 0.4^{0}, and 0.08^{0} above the straight-ahead line for the placebo, 0.075% and 0.15% BAC conditions, respectively. This agrees with Mortimer and Jorgeson (1972) who also reported a similarly non-significant trend toward lowered preview distances.

The lack of an alcohol effect on horizontal distribution of dwells was unexpected in view of the reports of such a phenomenon by

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[9]Complete tabulations of spatial distribution data are in Appendix K.

some investigators. Post hoc it was realized that the arrow subsidiary task might have had a controlling influence on the horizontal distributions of dwells. The subjects might have given greater priority to the search for the arrows than to the search for critical film events. In turn,this attentional priority to the arrows would obscure both the effects of alcohol and the influence of the critical events in determining the spatial dwell distribution. It has been shown that while ability to attend to a variety of demands decreases under alcohol, performance can be maintained on the item of highest priority with most losses confined to the lower priority items (Moskowitz and DePry, 1968; Moskowitz and Sharma, 1974).

To test this post hoc explanation,the subsidiary task for the second experiment with marijuana was changed. All stimuli were presented at a single location in the center of the subject's visual axis with neither vertical nor horizontal dispersion. Again the subsidiary task stimuli required a response indicating whether it faced left or right so it was similar in character to the task in the alcohol study. The dispersion of dwells was compared between the placebo treatments in the two experiments. In the marijuana study where there was only one spatial location for subsidiary task presentations, the percentage of dwells in the central 10 degrees rose to 62.9% from the 51.6% in the alcohol study. For the central 30 degrees, the marijuana study reported 93.7% compared to the alcohol study report of 86.9%[10]. Clearly, the subsidiary task strongly affected the spatial distribution of dwells. While subsidiary tasks have proven a sensitive measure of attention required in driving performance (cf: Moskowitz, 1973 a, they were generally presented in such a manner as not to directly affect the character of the main task. Instead they clearly required sharing attention between the main and subsidiary tasks.

[10]See Appendix H.

Superimposing the subsidiary task upon the screen containing the main task was clearly an error.

2.3.3 Subsidiary Tasks

The subjects were required to correctly identify the direction of the arrows projected upon the screen. There was no effect of alcohol upon the number of correctly identified arrows (roughly 75% under all treatments) nor upon the speed of responding to the arrows.

Information extraction thus was unaffected by alcohol for this class of events (the arrows). It is of interest that the mean dwell time per arrow was considerably greater (placebo 0.947 sec and high dose 1.085 sec) than for most other categories of events[11].

Response time and number of correctly identified arrows was a function of distance from the center of the screen. 88% of the arrows at $\pm 5^{o}$ were correctly identified in contrast to 48% at $\pm 15^{o}$ [12].

The subsidiary task was included in this study because it has been shown that the detremental effects of alcohol on performance are related to the number of tasks which are required to be simultaneously performed (Moskowitz and Sharma, 1974; Moskowitz and DePry, 1968). Since driving is a skill requiring the simultaneous performance of a complex search and recognition task as well as a complex tracking task, the subsidiary task was included as a substitute for the lack of a tracking task. Rather than being subsidiary, it apparently became of primary importance since it was the task with the more obvious response demands (the turn signals). As noted earlier, it affected the spatial distribution of eye movements in the driving observation task.

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[11]See Appendix I.

[12]See Appendix K for additional subsidiary task data.

2.3.4 Critical Events

As discussed in the methods section, the movie contained a series of "critical events" defined as stimuli which traffic experts believed should be looked at. This section will examine the effect of alcohol upon a variety of measures which define different visual scanning behavior during these critical events. In addition,the critical events were divided into categories and the analysis attempted to determine if alcohol had differential effects upon specific categories. The presumption that such a differential effect would occur is based on the observation that when performance decreases under the influence of alcohol, the least important events from the subject's viewpoint suffer most. However, this expectation was limited by two factors. First, the influence of the highly attended subsidiary task would obscure the possible differential scanning behavior which might have occurred in response to the differential importance of the critical events. Second, the individual categories are not entirely homogeneous. For example, the category of vehicle includes moving and parked cars, turning cars, cars with opening doors, etc. Placing this mixed bag of stimuli into a single category to be compared with another category for relative attentional importance is necessarily a crude and first step of analysis.

The initial analysis was in terms of whether an event was looked at or not. 'Looking at' was defined in terms of an EPR occurring within an error box about the event on any given movie frame.

Overall, 77% of the events were seen by the placebo group, 73% by the 0.075% BAC group, and 72% by the 0.15% BAC group, indicating a trend towards decreased detection of critical events as a function of alcohol level.

Given the large decrease in frequency of dwells under alcohol, it was surprising that only a small drop occurred in the number of critical events seen, which may well testify to the importance assigned many of these critical events by our subjects. Surprisingly, a fourth were unobserved on each drive despite their high valence for our traffic experts. Pedestrians were seen least by all treatment groups. (Note that the pedestrian group contained the most peripherally located events.) Kruskal-Wallis significance tests did not show a statistically significant effect of alcohol on the number of events seen, either for the entire 189 events or for any category of critical events. The analysis of critical events by categories was further extended using nine measures of visual scanning behavior. Categories with less than 13 critical events were dropped as being too small for comparative statistical analysis. Table 4 summarizes the data and stastistical tests for the nine response variables which are described below:

1. Look ratio (ratio of time event looked at to the total time event is on the screen).
2. Frequency of separate looks to (or from) events (i.e., only those transitions which represent a change from not looking at the event to looking at the event or vice versa).
3. Total dwell time on events in secs.
4. Mean time per dwell on events in secs.
5. Frequency of repetitive dwells on events (i.e., a count of all dwells regardless of whether a given dwell was a result of a transition from outside the event).
6. Total pursuit time on events in secs.
7. Mean time per pursuit on events in secs.
8. Frequency of pursuits on events (i.e., the number of separate pursuits on each event).
9. Time of first look at events in secs (relative to a somewhat arbitrary time when the event was judged recognizable determined during the selection of critical events).

These data were obtained by (1) analyzing the scanning patterns of each subject on each event, then (2) averaging for each subject across all events in an event category to obtain results by event category for individual subjects, and (3) averaging across subjects for each event category to obtain overall results for each category[13].

Since several of the derived scores might be strongly affected by averaging across events not looked at, the averaging analysis was performed twice, first for all events regardless of whether they were looked at and then for only those events actually looked at. The first average includes all possible effects of alcohol whereas the second average examines whether there is a difference in performance other than frequency of observation.

The analysis by both methods produced similar results so the data in Table 4 are only for critical events actually looked at, the more meaningful category. Only significance levels below or approaching a 0.05 level were tabulated.

Examining the data of Table 4 it can be seen that the response measure of repetitive dwells on the same events has decreased significantly for pedestrians, vehicles and traffic lights and has also decreased, although not significantly, for turn signals. This effect may be related to a compensatory attempt by subjects to overcome some of the lost time in increased dwell durations by making less frequent repeated dwells upon the same events.

This result is perhaps not surprising since when subjects under the influence of alcohol were required to reduce their overall frequency of dwells or fixations, they could partially compensate by reducing the number of repetitive or confirmation dwells for events already looked at once before. The significance of this for driving safety is of course a function of the subject's capability of extracting the necessary information from a single dwell in place of the several he might usually take.

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[13] See Appendix J.

There also appears a tendency towards increased frequency and duration of pursuits on all categories of critical events under alcohol, although the increase was statistically significant only for pursuit durations on vehicles, turn signals and traffic lights.

The high valence attached to turn signals is emphasized in the look ratio, where turn signals under alcohol are examined for longer periods than are other categories of critical events. While no obvious interpretations are available for this observation, it appears analogous to the experience of the California Highway Patrol, which has reported that intoxicated drivers have often "homed in" on the flashing signals of parked patrol cars and hit them.

The total dwell time (total time spent in the dwell state when looking at an event) and the mean time of first look at events did not show statistically significant alcohol effects for any event category except bicycles. Inspection of Table 4 does indicate, however, that all first looks at critical events under 0.075% and 0.15% BAC occurred later compared to the placebo for all event categories except turn signals, which show a trend towards being seen sooner. This finding is consistent with the look ratio results indicating that turn signals were looked at longer under alcohol. As turn signals are the only flashing lights in the movie, unique results related to their perception by subjects might be expected. Mean time per dwell increased significantly for all events, emphasizing the importance of this effect of alcohol.

A significant decrease in the frequency of separate looks to and from events was found for the pedestrain and vehicle categories. Although these events were looked at (as measured by dwells) for the same total amount of time by all groups, fewer shifts of attention occurred under alcohol.

To attempt to relate the differential critical event scanning patterns to the perceptual differences and significances of the event categories is necessary but perhaps premature based on our current knowledge. As previously mentioned, turn signals as flashing lights are unique and show unique results with regard to look ratio and pursuit results. Traffic signals are also highly conspicuous, and, along with turn signals, are particularly important stimuli to the driver. Thus, the large increase in pursuit activity related to these two classes of stimuli may indicate a "fixing of gaze" beyond the point where additional useful information can be obtained. With regard to vehicles, their general prominence, the variety of situations under which they occur, and their importance to the driver may explain the finding of both increased pursuit time and decreased look frequency.

Pedestrians, on the other hand, were generally less conspicuous, were in the scene for shorter periods compared, say, to traffic signals, and may be considered less important to drivers, as in the case of pedestrians on the sidewalk. In fact, the results indicate that pedestrians generally received fewer separate looks and fewer repeated dwells than the other categories.

The results for bicycles only showed a statistically significant difference for total dwell time.

In general, the results for critical events indicate that, compared to the placebo, if an event is looked at under alcohol, then, (a) the internal details of the event are examined less (fewer distinct, separate dwells on the event itself as indicated by the decreased frequency of repeated dwells), and (b) less attention is paid to other events during this time (smaller number of looks between events and other screen locations, as well as increased pursuit activity). Finally, the nature of the change of visual search activity as a function of alcohol seems to be related to the type of event under consideration and to its significance to the driver.

3.0 Marijuana Experiment

3.1 Method

3.1.1 Apparatus

Experiment 2 with marijuana used the same experimental apparatus as did Experiment 1 with alcohol.

3.1.2 Subjects

Subjects were recruited by advertisements at the University Placement Office and the State Human Resource Department. The advertisement solicited subjects for a psychological experiment and subjects were informed that the experiment involved drugs after they applied. Subjects were selected from males between the ages of 21 and 45, and who possessed a current driver's license. They were required to have had 10 prior experiences with marijuana but not to be currently using it more frequently than three times weekly. Thus the subject population can be described as social or moderate marijuana users. Only subjects falling within broadly normal emotional/psychological functioning as defined by the MMPI and a personal interview were accepted into the study.

Ten subjects ranging in age from 21 to 26 (mean age = 23.8 years) participated in the study. All signed consent forms indicating knowledge of the nature of the study and treatments in accordance with the standards of HEW.

3.1.3 Treatments

Subjects were required not to eat for four hours prior to the experimental sessions. They were also required not to take any drugs or marijuana for the duration of the study.

Three marijuana dose levels were used: 0, 50, and 200 mcg delta-9 tetrahydrocannabinol per kilogram bodyweight (mcg THC). These dose levels were made up from mixtures of detoxified marijuana and marijuana containing 2.45% delta-9 THC. The marijuana for this study was obtained from the National Institute on Drug Abuse.

The subjects smoked the marijuana in a cigarette, weighing approximately 0.5 g, within 10 minutes. The smoking procedure required subjects to inhale within 10 seconds, retain the smoke in their lungs for 15 seconds and to exhale and resume smoking within 10 seconds. Glass tubes 7.5 cm in length were used in smoking the cigarette butts so that all the marijuana could be consumed.

Pulse rates were taken before and after smoking marijuana and at half hour intervals after testing until the subject was released. Subjects were released only when all subjective effects of marijuana had disappeared, and pulse rates had reached base line levels.

3.1.4 Experimental Design

A repeated measures design was used to compare the effects of a placebo with a drug treatment of 200 mcg THC/kg b. w. This is a large dose by the standards of the users participating in this study. Subjects attended three sessions, a training session similar to the training session used in the alcohol study, and two experimental test sessions. As in the alcohol study, 2 runs occurred during the training sessions, the second under the influence of a small dose level. For the marijuana study, subjects received a 50 mcg THC/kg b. w. dose.

Half the subjects received the active drug treatment on the first session and half the placebo to counterbalance the order of treatment. The first experimental test session occurred one week after the training session and the second two weeks later.

3.1.5 Subsidiary Task

The subsidiary task differed from the alcohol study which used arrows pointing either left or right at 18 different locations. In the marijuana study the subsidiary task used Landolt C-rings subtending 1.2° (gap opening = 0.25°) which were presented at only one position, at eye level in the center of the screen. The breaks in the C-rings faced either right or left and subjects were required to respond with the turn signals to indicate the direction of the breaks. The C-rings were presented at the same random time intervals as were the arrows in the alcohol study.

It was anticipated that changing the subsidiary task would produce changes in various response categories, especially the spatial distribution of dwells. Since the marijuana experiment also produced a change in the type of subjects (i.e., younger, and more moderate drinkers of alcohol) it was necessary to examine the effect of using marijuana smokers as subjects with the subsidiary task used in the alcohol experiment. Nine subjects chosen from the same subject pool as the final marijuana subjects were examined in a pilot experiment under both placebo and active treatments. Under the placebo treatment none of the response measures differed to any significant degree from those found for the placebo treatment in the alcohol study. Therefore, differences in response measures between the placebo treatments in the alcohol and marijuana experiments can be ascribed to the influence of the subsidiary task, as suggested in our prior discussion of the results of the alcohol experiment[14].

3.2 Procedure

The subjects attended a training session and two test sessions. The interval between the training session and the first test session was a week, and two weeks elapsed between the test sessions.

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[14] A detailed analysis of the differences between placebo groups for the alcohol, pilot marijuana, and final marijuana studies is given in Appendix H.

3.2.1 Training Session

The subjects were run twice in the simulator, once sober and once after smoking marijuana containing 50 mcg THC/kg b. w. A BAC reading and a small urine sample were collected at the beginning of the first run, after which instructions were read to the subject. The eye and head movement recording devices were mounted on the subject who was then seated in the car. Calibration instructions were presented via an intercom and the devices were then calibrated. The training movie was then presented to the subject. He was required to watch the movie as if he were driving, to detect the orientations of the C-ring, and to release the steering-wheel-mounted switch whenever he saw something he felt was important for a driver to notice. The entire procedure took about an hour. No data were collected during the training run.

After the movie the subject rested for an hour. He was then remounted with the eye/head movement device and seated in the car. The devices were calibrated, and the subject smoked a 50 mcg THC/kg b. w. dose cigarette. After smoking, the devices were rechecked for calibration and the subject was re-run, viewing the same training movie.

3.2.2 Test Session

After a preliminary BAC check and collection of a small urine sample, the subject was mounted with the eye/head movement device. The devices were calibrated and either the 0 or the 200 mcg THC dose was administered. The 17+ minute movie was run after a recheck on eye movement calibration. The procedure took about an hour.

Pulse rates were taken before smoking, after smoking, after completion of the runs and at half hour intervals until the subject was released. The subject was released after his pulse rate returned to baseline levels and after all subjective effects of marijuana had disappeared.

The second test session was conducted two weeks after the first. The procedure for the second test was the same as for the first except that the marijuana dose was different.

3.3 Results - Marijuana Experiment

All the response measures examined for treatment effects in the alcohol experiment were similarly examined for possible marijuana effect. It was noteworthy that not a single variable was affected to any degree by the rather large marijuana treatment.

Table 5 indicates that neither dwell nor pursuit frequency, duration or variability were influenced by marijuana. Nor, for that matter, was the horizontal or vertical spatial frequency distribution of dwells. Similarly, an analysis of the various categories of critical events for the response variables discussed in the results section on alcohol failed to exhibit a single marijuana treatment effect. Finally, the subsidiary task exhibited no evidence for a marijuana effect[15].

For all the variables included in the above discussion on marijuana, there was not a single test of statistical significance that approached the significance level.

This result was initially rather surprising in view of the frequent subjective report of disturbed perceptions and a series of experimental investigations which have demonstrated large perceptual deficits in auditory and visual signal detection (Moskowitz and McGlothlin, 1974; Moskowitz and Sharma, 1974; Sharma and Moskowitz, 1973; Moskowitz, Hulbert and McGlothlin, 1976). However, a recent series of studies has at least reassured us that the results are likely reliable, if as yet not fully explained. Sharma and Moskowitz (1973) demonstrated a very large, dose related deficit in visual sig-

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[15]More complete tabulations of marijuana results are given in Appendix K.

nal detection under marijuana using an adaptation of the Mackworth clock technique. In an as yet unpublished study by Moskowitz and Sharma using eye movement recording while performing this vigilance task, it was found that the increased failure to detect signals under marijuana was unrelated to the ability of the subjects to follow the "clock's" movement. That is, the subjects continued to visually track the clock but were unable to report what they were looking at and following with their eyes. Clearly, looking at the stimulus is a necessary but insufficient condition for "seeing". Whatever marijuana does that produces the reported impairment of visual performance, it does not do so at the central nervous levels that control the ability of the eyes to track environmental stimuli[16].

In the discussion above we have been comparing the performance of subjects under active and placebo marijuana treatments. The marijuana study was undertaken with the revised subsidiary task, and, as noted in the alcohol results section, comparison of the placebo treatments for the marijuana and alcohol study showed large differences in the spatial distribution and duration of dwells resulting from the difference in subsidiary tasks. Other measures of visual search behavior were then examined to determine if they would be affected by the change in the subsidiary task. The placebo group from the pilot marijuana study, which used the same subsidiary task as did the alcohol study, was included in this comparison[17].

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[16]Results for the pilot marijuana study, using 7 subjects, in a repeated measures design, are identical to those of the final study: no difference between treatment conditions. If the pilot and final studies are considered together we have a large body of data (17 subjects, about 1300 separate dwells and 150 separate pursuits per subject, and two subsidiary tasks) indicating no effect of marijuana on visual search patterns.

[17]See Appendix H.

Surprisingly large and statistically significant differences related to the differences in subsidiary task were found for the following response variables: mean time per dwell and pursuit, dwell frequency, mean pursuit length, and the standard deviations of dwell and pursuit durations. Of the response variables examined, only pursuit frequency and total time in dwell and pursuit were not significantly changed. Thus, the subsidiary task affected nearly all variables to a significant degree, indicating how labile visual search behavior is, and how dependent it is upon the nature of the stimuli being attended to. Its sensitivity to such factors of set also suggest that such search behavior might be trained in a simulator situation for transfer to actual driving.

4.0 Discussion and Conclusions

4.1 Discussion

The results demonstrate that alcohol and marijuana have quite disparate effects on objective measures of visual search behavior. While alcohol produced large decrements in these behaviors, the same measures were unaffected by marijuana. Differences between these drugs have also appeared in behaviors where the reverse has occurred, i.e., marijuana has produced large decrements but alcohol has not. Thus, marijuana has strongly affected visual autokinesis, vigilance and measures of concentrated attention, in situations where alcohol has produced no impairment (Sharma and Moskowitz, 1972; Moskowitz and Sharma, 1972; Moskowitz and McGlothlin, 1974; Moskowitz, 1973b). Thus, both drugs have produced impairment in response measures important for skills performance, albeit different measures.

The most important finding regarding the effect of alcohol upon eye movement in the driving situation is the large change in dwell duration and frequency. For understanding the change in behavior under alcohol, the change in dwell duration is most significant. We have suggested that its cause is decreased information processing rate under alcohol. This hypothesis has been tested by Moskowitz and Murray (1976) using backward masking of tachistoscopically presented material to measure the amount of information transmitted from a sensory image into short term memory with processing time limited by the masking procedure. Using alcohol doses producing .05% and .10% BAC's, there was an increase of 7 and 17 milliseconds respectively in the time necessary to process 4 randomly presented letters. In the current study, where the subject must observe events with far greater informational content, it is perhaps not surprising that the increase in dwell time, which we ascribe to the need for greater processing time, is in excess of 100 milliseconds. The increased time necessary for information extraction is sufficiently great to possibly affect emergency situations in driving. However, the concomitant reduction in the number of dwells appears potentially even more dangerous for driving. The 29% decrease in number of dwells at .075% BAC for heavy experienced drinkers is indeed a surprising result. It has already been demonstrated that alcohol produces an impairment in the ability to maintain observations over a wide range of input sources which are frequently found in driving (Moskowitz, 1973 a, 1974). This current data supports the view that the decreased ability to process data is the reason that individuals attend to a smaller number of inputs.

A matter of equal interest perhaps is the change in pursuit duration and frequencies under alcohol. While the increase in pursuit duration can be ascribed to the same need for greater time to extract information, as accounts for the greater dwell time, it is not clear what underlies the greater frequency of pursuits. What can be noted is that this finding parallels subjective reports of fixation on some categories of objects for as yet unknown reasons. An example is the increased time attending to flashing signals in this study. Fixation of attention or inability to shift attention is perhaps the best description of these effects of alcohol.

As discussed within the results section, no evidence for an effect on the spatial distribution of attention was found for alcohol. However, given the influence of the unwisely chosen subsidiary task, no conclusions can be drawn from this data. The distribution of attention to events, however, was not contaminated by the subsidiary task and it is clear that when under the stress of alcohol a shift in attentional distribution does take place. What remains for further experimental study is to offer an explanation for the increasing attraction of turn signals. Is it the intermittancy of the signals which raise its valency under alcohol? Or is it merely that with a reduced capacity to absorb information, that other inputs are sacrificed to maintain attention to signals which potentially are the most informative for avoiding traffic dangers?

A matter of considerable importance is to note that these results were derived from examining very heavy drinkers. Perhaps only 7% of males would be capable of drinking without illness the quantity of alcohol used for the high dose treatment within the time specified. These are individuals who through heavy alcohol use have developed both a chronic tolerance and a rapidly attained acute tolerance for alcohol (cf: Moskowitz, Daily, and Henderson, 1974). Yet even for these chronic heavy drinkers there were massive changes in their ability to absorb information and survey their environment under relatively low doses, i.e., 0.075% BAC. It suggests that social or moderate drinkers would be affected to a far greater extent at equal BAC levels.

In conclusion, this study suggests that a major factor underlying the increased accident potential of alcohol use while driving is the impairment of visual search behavior due to a decreased ability to process information, as reflected primarily in increased time necessary for information extraction in dwells and pursuits. On the other hand, this explanatory mechanism does not account for whatever deficits are associated with marijuana use in driving.

4.2 Conclusions and Recommendations

4.2.1 Application to Driving Safety

This experiment provides additional evidence that alcohol produces a deficit in perceptual performance which interferes with driving performance. The nature of the deficit appears centered in a decreased rate of information processing. This conclusion is of significance in planning countermeasures for reducing the accident potential of alcohol abuse. While hopefully, the number of drinking drivers will be reduced by educational and legal counter-measure programs, we must consider the usefulness of changes in the driving situation to reduce the accident liability of those individuals still driving under the influence of alcohol.

The import of our results suggests that to communicate potential dangers in the roadway environment to the driver, his decreased capacity to detect and recognize messages, must be considered. Thus, roadway signs and other such information displays should not be designed on the basis of the normal range of visual capacity of the driving population, but should take into account periods such as weekend evenings when perhaps more than 30% of the drivers will have limited capacity to interpret roadway communications.

There is already one study whose results suggest that such a program will produce positive results. California instituted a program of improved signing on exits from freeways to decrease the frequency of wrong-way driving. Both the number of signs used and sign conspicuity were increased. A major concern in that study was whether the improved signing would affect the drinking driver, who constitutes a large fraction of the wrong-way driving population. In their words ..."Since the at-fault drivers in wrong-way accidents, especially the more severe accidents, have been drinking; and since it is generally assumed that the drinking driver is more difficult to influence; there was some concern that the preventative measures might not be too effective in reducing wrong-way driving by drinking motorists. As can be seen ..., the rate of wrong-way driving was decreased almost the same degree at night for the sober and the drinking driver. During daylight hours, however, the drinking driver incident rate was decreased to a substantially greater degree (70% versus 57% for the sober)."[18]

Thus, in a situation where more conspicuous and more frequent stimuli were presented, the driver under the influence of alcohol was often capable of recognizing potential danger and of responding appropriately.

More generally, this point is relevant to the overall characteristics of highways. Highways must be designed so that the performance requirements are within the capacity of all large populations, such as fatigued, aged, inexperienced, as well as drinking drivers. In particular, it is at least clear that the prime performance deficit for drinking drivers is in their rate of information acquisition. This deficit can be partially compensated by more frequent and more perceptually striking forms of communication.

4.2.2 Selectivity of Drug and Alcohol Effects on Driving

The present results emphasize the importance of selecting response measures which are appropriately sensitive to the particular effects of a given drug. In this study, alcohol was found to have a substantial effect on visual search patterns whereas marihuana had no effect. However, both have been previously shown to have degrading effects on information processing. Visual search data, by themselves, are a measure of "looking" behavior, but not detection or recognition performance. In the context of previous results it can be tentatively concluded that although both drugs affect detection and recognition performance, only alcohol affects "looking" behavior. Whatever effects alcohol has on information processing, they are reflected in the output of the oculomotor system whereas marihuana effects are apparently not so reflected.

Thus, in the study of drugs, alcohol or other stresses on driving performance, the choice of appropriate response measures is

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[18] Tamburi, T.N. Interim Report No. 2 on Wrong-Way Driving (Phase III), Sacramento, Ca: Division of Highways, Ca. Transportation Agency, 1968, p. 42.

seen as critical. Correspondingly, the types of driving accidents involved with different drugs or stresses are likely to differ.

4.2.3 Visual Search and Driver Training

Although it was not the primary intent of this study, the dependence of visual search behavior on situational and instructional variables was clearly demonstrated. This was shown in the strong dependence of visual search patterns on the nature of the subsidiary task. These results have application to training of novice drivers as well as experienced drivers. Strategies of visual search are not usually included in driver education, nor are objective measures of student driver visual search performance. However our data suggests the importance of such training.

In addition, knowledge of how visual search performance degrades under stress may be useful to experienced drivers in that it may be possible to learn compensatory behavior. One pilot study has indicated that novice drivers can be trained to improve search strategies.[19]

It is suggested that additional study of visual search training is a potentially fruitful area in driver education.

4.2.4 Future Directions

The findings of the present study suggest methodological improvements as well as other issues to be studied. These are:

Methodological

Increased time-sharing demands and improvement of subsidiary tasks. As noted, the subsidiary task in the present study interacted unduly with visual search of the driving scene. Thus, in future studies of this type a more appropriate subsidiary task should be used. A related issue is the need for additional tasks in the simulation to more realistically

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[19] Mourant, R. R. and Rockwell, T. H. Augmented Feedback and the Development of Driver Search and Scan Patterns. Proc. of the 16th Annual Meeting of the Human Factors Society, Oct. 17-19, 1972.

simulate the attention-sharing demands of driving.
The use of a steering control task in combination with a route sign detection and recognition task is suggested as the solution to both issues.

Related Research Issues

Reduce information content of traffic films. The traffic films used in this study represented urban, high density areas. This type of scene would tend to maintain alertness and produce a relatively large amount of eye movement activity, thereby partially counteracting the potentially degrading effects of alcohol. Therefore, the effects of alcohol on visual search should also be obtained in the context of rural, low density roadways. This point is emphasized by the fact that many alcohol related accidents are of the single-car "drive off the road" type, wherein lack of alerting environmental stimuli presumably is an important causal factor.

Replicate visual search study with moderate drinkers. The heavy drinkers used in this study, although overrepresented in traffic accidents, represent only a small fraction of the driving population. It can be reasonably expected that moderate drinkers would be equally affected as were the heavy drinkers, but at lower BAC levels. Thus, understanding of the effects of alcohol on information acquisition for the total drinking population requires study of the moderate drinking groups.

Further study of the "gaze fixation" phenomenon. The result that under alcohol certain stimuli such as turn signals and traffic lights received a disproportionate amount of attention is an important finding which may explain the specific causal basis for many alcohol related accidents. As noted in the discussion, this effect seems to be more a "fixation of gaze" phenomenon than a lengthened dwell to obtain more information. This hypothesis should be examined to determine if long dwell periods of very low information input do, in fact, occur under alcohol.

The effects of fatigue on visual search. Fatigue is another important accident causation factor that may be related to inattention to roadway stimuli. As in the case of alcohol, the study of visual search patterns should be a useful tool for studying fatigue.

On-the-road studies. Field studies of the effects of alcohol (with suitable safety precautions) would permit testing and validation of specific conclusions drawn from the simulation findings. For example, the effect of various signing techniques could be realistically studied only in the field.

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Table 1. Allocation of Viewing Time (Alcohol)[1,4]

Treatment	Mean Total Times in Secs for: Dwells	Pursuits	Saccades[2]	Total Dwell, Pursuit and Saccade times	Blinks[3]
Placebo	653 (64%)	196 (19%)	140 (14%)	989	33 (3%)
0.075% BAC	601 (59%)	281 (27%)	103 (10%)	985	37 (4%)
0.15% BAC	628 (61%)	259 (25%)	104 (10%)	991	31 (3%)

Notes:

1. Total time for traffic portions of movie = 1022 sec.
2. Total saccadic time estimated by taking the product of total number fixations and mean interdwell times for each group.
3. Blinks were counted but their durations were not measured. The time remaining after dwell, pursuit and saccadic times are summed is attributed to blinks.

   As a rough indication of the reasonableness of this procedure, note that the mean number of blinks varied from 231 to 316 across groups - if one accepts 0.1 - 0.2 sec as the range of blink durations, then an estimate of the range of blink times is 23 sec to 62 sec. This range brackets the values of 31 to 37 sec given in the Table.
4. N = 9 per group.

Table 2. Dwell and Pursuit Times and Frequencies (Alcohol)

Measure	Placebo	.075% BAC	.15% BAC	Kruskal-Wall Signif. Level
Mean time per dwell (sec)	0.37	0.47 (+27%)	0.48 (+30%)	.0037
SD	0.046	0.073	0.082	
Mean time per pursuit (sec)	1.23	1.48 (+20%)	1.36 (+11%)	.0492
SD	0.17	0.26	0.11	
Dwell frequency	1753	1290 (-26%)	1297 (-26%)	.0042
SD	332	288	122	
Pursuit frequency	157	189 (20%)	192 (+22%)	.0389
SD	75	44	44	
Total time in dwells (sec)	653	601 (-8%)	628 (-4%)	NS
SD	104	83	76	
Total time in pursuits (sec)	196	281 (+43%)	259 (+32%)	.010
SD	103	98	54	
Mean pursuit length (deg)	5.9	5.5 (-7%)	5.3 (-10%)	NS
SD	0.95	0.49	0.82	
Mean of SD of dwell times (sec)	0.32	0.46 (+44%)	0.45 (+41%)	.0110
Mean of SD of pursuit times (sec)	0.79	1.06 (+34%)	0.85 (+8%)	.01
Mean of SD of pursuit lengths (sec)	3.9	3.9 (0%)	3.2 (-18%)	NS

Table 3. Critical Event Categories and Number Looked at (Alcohol) (N=9 each group)

Category	Total No.	Number Looked At (percentage of total number looked at in parentheses) Placebo	0.075%	0.15%
Pedestrians	95	67.3 (71)	62.6 (66)	63.1 (66)
Vehicles	23	20.0 (87)	20.0 (87)	19.1 (83)
Turn Signals	34	26.7 (79)	26.8 (79)	25.4 (75)
Traffic Lights	13	13.2 (100)	12.0 (92)	11.3 (87)
Bicycles	15	9.9 (66)	9.2 (61)	9.6 (64)
Motorcycles	2	2.0 (100)	1.8 (90)	2.0 (100)
Billboards	4	3.4 (85)	3.4 (85)	3.3 (83)
Other	3	2.8 (93)	2.3 (77)	2.3 (77)
TOTAL	189	145.3 (77)	138.1 (73)	136.1 (72)

Table 4. Visual Scanning Behavior on Critical Events (Alcohol)[1]

	Placebo	0.075% BAC	0.15% BAC	Sig.Level[2]
	FREQUENCY OF REPETITIVE DWELLS			
Pedestrian	2.35	2.03 (-14)	2.04 (-13)	0.01
Vehicles	4.10	2.84 (-31)	3.11 (-24)	0.005
Turn Sig.	2.98	2.50 (-16)	2.61 (-12)	N.S.
Traf. Lts.	4.57	3.11 (-32)	3.59 (-22)	0.025
Bicycles	2.09	2.28 (+9)	1.93 (-8)	N.S.
	TOTAL PURSUIT TIME (secs)			
Pedestrian	2.08	2.13 (+2.4)	1.99 (-4.3)	N.S.
Vehicles	1.90	2.84 (+49.5)	2.02 (+6.3)	N.S.
Turn Sig.	1.63	3.22 (+97.6)	2.39 (+46.6)	0.0092
Traf. Lts.	1.79	2.96 (+65.4)	2.39 (+33.5)	0.0425
Bicycles	1.12	1.15 (+2.7)	1.52 (+35.7)	N.S.
	FREQUENCY OF PURSUITS			
Pedestrian	1.23	1.19 (-3)	1.17 (-5)	N.S.
Vehicles	1.27	1.16 (-9)	1.25 (-2)	N.S.
Turn Sig.	1.13	1.28 (+13)	1.33 (+18)	N.S.
Traf. Lts.	1.25	1.52 (+22)	1.45 (+16)	N.S.
Bicycles	0.97	1.07 (+10)	1.11 (+14)	N.S.
	MEAN TIME/PURSUIT (secs)			
Pedestrian	1.70	1.77 (+4.12)	1.68 (-1.2)	N.S.
Vehicles	1.52	2.43 (+59.9)	1.62 (+6.6)	0.0344
Turn Sig.	1.47	2.47 (+68.0)	1.83 (+24.5)	0.0280
Traf. Lts.	1.33	1.92 (+68.0)	1.64 (+23.3)	0.0724
Bicycles	1.03	1.06 (+2.91)	1.35 (+31.1)	N.S.
	LOOK RATIO			
Pedestrian	0.30	0.27 (-10)	0.30 (0)	N.S.
Vehicles	0.43	0.44 (+2)	0.44 (+2)	N.S.
Turn Sig.	0.31	0.39 (+26)	0.34 (+10)	0.0073
Traf. Lts.	0.34	0.38 (+12)	0.35 (+3)	N.S.
Bicycles	0.23	0.36 (+13)	0.25 (+9)	N.S.

	Placebo	0.075% BAC	0.15% BAC	Sig.Level[2]
	TOTAL DWELL TIME (secs)			
Pedestrian	1.01	1.05 (+4)	1.08 (+6.9)	N.S.
Vehicles	1.91	1.73 (-9.4)	2.14 (+12)	N.S.
Turn Sig.	1.31	1.58 (+20.6)	1.61 (+22.9)	N.S.
Traf. Lts.	2.26	2.02 (-10.6)	2.48 (+9.7)	N.S.
Bicycles	0.80	1.18 (+47.5)	0.96 (+20)	0.0128
	TIME OF FIRST LOOK			
Pedestrian	1.26	1.38 (+10)	1.35 (+7)	N.S.
Vehicles	0.72	0.87 (+21)	0.93 (+29)	N.S.
Turn Sig.	0.93	0.77 (-17)	0.84 (-10)	N.S.
Traf. Lts.	0.95	1.09 (+15)	1.06 (+12)	N.S.
Bicycles	1.16	1.20 (+3)	1.18 (+2)	N.S.
	MEAN TIME/DWELL (secs)			
Pedestrian	0.43	0.53 (+23.3)	0.53 (+23.3)	0.0467
Vehicles	0.47	0.61 (+29.8)	0.70 (+48.9)	0.0045
Turn Sig.	0.43	0.63 (+46.5)	0.63 (+46.5)	0.0033
Traf. Lts.	0.49	0.65 (+32.7)	0.71 (+44.9)	0.0319
Bicycles	0.39	0.53 (+35.9)	0.50 (+28.2)	0.0055
	FREQUENCY OF SEPARATE LOOKS			
Pedestrian	2.19	1.92 (-12)	1.90 (-13)	0.0035
Vehicles	3.19	2.36 (-26)	2.49 (-22)	0.0008
Turn Sig.	2.64	2.41 (-9)	2.44 (-8)	N.S.
Traf. Lts.	4.87	4.15 (-15)	4.24 (-13)	N.S.
Bicycles	1.94	1.86 (-4)	1.71 (-12)	N.S.

Notes:

1) Values in parentheses opposite 0.075% BAC and 0.15% BAC refer to percent change relative to placebo condition.

2) Kruskal-Wallis significance level.

Table 5. Dwell and Pursuit Times and Frequencies (Marijuana)

Measure Dwell Frequency	Placebo (N=10)	200 THC (N=10)	t-test Significance
Mean time per dwell (sec)	0.57	0.57 (0%)	NS
SD	0.086	0.157	
Mean time per pursuit (sec)	1.59	1.60 (1%)	NS
SD	0.207	0.399	
Dwell frequency	1207	1234 (+2%)	NS
SD	211	261	
Pursuit frequency	149	146 (-2%)	NS
SD	37	46	
Total time in dwells (sec)	668	667 (0%)	NS
SD	55	46	
Total time in pursuits (sec)	235	220 (-7%)	NS
SD	57	44	
Mean pursuit length (deg)	4.80	5.50 (15%)	NS
SD	0.71	2.08	
Mean of SD of dwell time (sec)	0.61	0.64 (+6%)	NS

APPENDIX A

PERCEPTION AND DRIVING ACCIDENTS

The annual toll in the United States of some 55,000 deaths, 2,000,000 disabling injuries and more than 15,000,000 accidents warrants continued major research efforts to determine causal factors. In more than half of the accidents, there is evidence implicating the driver as a causal factor; i.e. the driver's capabilities fail to meet the requirements of the driving situtation.

The following is a table from an extensive analysis of causes of traffic accidents produced by the Department of Transportation and Environmental Planning, Birmingham University, England.

Deficiencies Seen as Causal Factors
in Traffic Accidents
(Mackay, 1967)

Suggested Causal Factor	Percent of Sample
Driver/environment interaction	48.9
Driver/vehicle, environment interaction	16.4
Driver	12.4
Driver/vehicle interaction	7.2
Vehicle	4.8
Vehicle, environment interaction	4.8
Environment	4.6

As can be seen, in 84% of the accidents the driver was found to be partially or fully responsible. Especially notable is the fact that nearly half of the accidents are due to apparent mismatches between the demands of the traffic situation and the performance level of the driver.

Further insight into the nature of the driver/environment match deficit is contained in another study performed at Birmingham University (Clayton, 1972). In this recent study a team of scientists was dispatched to the scene of accidents with the police and made an extensive analysis of the causes of the accidents. The following table represents the analysis of the causes of those accidents in which the investigators felt human error clearly was involved.

Distribution of Driver Error Groups
(Clayton, 1972)

Error Group	N	Percent
Failure to look	45	29
Misperception	29	18
Excessive speed	40	25
Panic reaction	14	9
Other errors of decision	30	19
Total Error Group	158	100%

It is clear that at least 47% of the accidents caused by human error fall into the category of obvious perceptual failure, either in failure to look or in misinterpretation of what was seen. Another 28% of driver-caused accidents result from failure of information processing, of which perception is one aspect.

The following excerpts from Clayton's paper indicate why his data point to perceptual failures as a prime cause of accidents:

> For errors of failure to look, the prime causal factor was distraction of the road user at the critical

> moment. The causes of this distraction varied widely and included signposts, side roads, and other landmarks. Sometimes the hazard was a sudden restriction of the road width caused, for example, by a parked car which the road user failed to see. Other causes of this error occurred at junctions with major roads. Here, it is possible that some road users were incapable of monitoring two sources of stimuli (that is, two traffic flows) virtually simultaneously. They may have sought to simplify the task by waiting for one lane to become free, assumed that it would remain clear, and then moved out when a gap appeared in the other traffic flow.
>
> For errors of misperception, the adoption of an incorrect set of perceptual expectancy appeared to be more prevalent than a visual defect. Many of the misperception errors were found to occur under either unfavorable or inadequate lighting or where the signs, markings, or design of the road had created an ambiguous situation ....
>
> Errors of panic reaction were primarily caused by one road user suddenly infringing or threatening to infringe the intended path of travel of another road user. A possible explanation of this phenomenon is that the reacting road users, because of their lack of driving experience, may have found it impossible to process all the available perceptual information accurately and quickly. Thus, instead of responding rationally to the situation, they merely tried to stop as quickly as possible. In doing so, they tended to lose control of their vehicles.

The results of these two British studies clearly suggest that perceptual failures account for the majority of accidents involving driver error.

It should be noted that Clayton reported that of those drivers for whom significant blood alcohol levels were reported, 80% demonstrated failures in either visual perception or central decision making, which were the prime cause of their accidents.

APPENDIX B

DIVIDED ATTENTION, VISUAL SEARCH, AND DRIVING

The discussion in Appendix A points to two areas or foci of investigation that must be considered for the study of the effects of alcohol and marijuana on driving. The first concerns the priorities governing the driver's selection of time-sharing strategies. That is, what are the social as well as the situational factors that determine allocation of how information processing capability in the normal as well as degraded perceptual states?

The second area concerns development of theoretical models or conceptualizations of the sites and information processing mechanisms that are involved in selective attention and which can provide a framework for the study of performance under alcohol and marijuana. It is clear that analysis of both of these questions requires measurements of the visual search process actually employed by drivers as a means of understanding the search priorities brought to the driving situation, how these priorities are changed by alcohol and marijuana as well as the differential effects of the two substances.

In the following material, visual search studies using EPR techniques are reviewed and applied to the questions posed above. The general literature is discussed first, followed by the relatively few studies available that are directly concerned with driving performance. An introductory section discusses some of the theoretical issues involved in the interpretation of eye movement data.

B.1 Interpretation of Eye Movement Data

In the present experiment measurement of the states of motion and positions of subject's eyes is used to infer relationships between the independent variable (alcohol treatment) and changes in information acquisition and processing. These relationships are potentially very complex.

Firstly, several eye states must be considered: dwells, pursuits, saccades and, to a lesser extent, blinks. Each of these states is under the control of neuro-muscular systems which are interrelated in a complex fashion.

Secondly, control of each state is due to a combination of built-in programming, learned priorities regarding information requirements for driving tasks, and deliberate control. For instance, without deliberate control, a dwell tends to be automatically terminated by a saccade after a duration of 0.2-0.4 sec; however, one can deliberately maintain a dwell for many seconds*.

Thirdly, the effects of drugs or other stresses must be considered on several levels. For instance, restriction of attention to a portion of the visual scene under alcohol could be attributed to a degraded information processing capacity which forces a reduction in the total amount of visual input that can be processed. The particular aspects of the scene selected under these circumstances might be related to the priorities established regarding values of different classes of information. However, one must also consider a more direct effect of alcohol on oculor-motor processes, as found, for instance, with barbiturates which selectively degrade the pursuit control system. In this case the effect of the drug is not through a decision process based on learned priorities combined with a condition of degraded information processing rate, but through a specific drug/neuro-muscular interaction.

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*The spatial distribution of dwells while driving is partially dependent on learned expectations as to locations of critical events. However, specific stimuli such as flashing lights can override such control of attention as can deliberate acts of attending.

A fourth issue, following from the above, is that ambiguity will generally exist regarding which of the above processes is most appropriate for an explanation of a given set of visual search results. In the present experiment, only a single independent variable, alcohol treatment, was used and the results by themselves would not be expected to allow specification of a unique explanation. It is therefore necessary to refer to other studies regarding effects of alcohol as well as to other visual search studies in order to elucidate the present findings.

A fifth issue deals with differences between "seeing" and "looking." "Looking" refers to the state of the EPR at a given time; "seeing" refers to information acquisition from a given region of the visual scene. Looking is measured by determining that portion of the scene imaged at the fovea, whereas seeing can take place foveally or extra-foveally. Therefore, an adequate analysis of visual search must include tests of "seeing" as well as measurement of "looking." Unfortunately, such tests were not fully implemented in the present study, as is discussed in the body of this report.

The above discussion is presented to provide a framework from which to evaluate the present experimental results. A large mass of data were obtained in this study which are difficult to organize unless related to a theoretical view of visual search on the one hand, and alcohol effects on the other. To this end, information acquisition and processing aspects of visual search and alcohol effects were emphasized in the organization of results. This approach is relevant to previous work on alcohol as well as to the general topic of visual search and driving. With the choice of this framework, it is relatively straightforward to relate the present results to other studies and to critique and modify the interpretations presented herein.

A final point in the interpretation of visual search data concerns the significance of the various eye states. As is well known, information is acquired by the visual system during periods of dwell and of pursuit movement. Time spent in saccades and blinks is lost time. Pursuit movements occur only with respect to moving objects and are an attempt to maintain a stable foveal image by following the object. (As indicated above, the fact that the eye is in a state of dwell or pursuit does not necessarily mean that information is being acquired during that time.) Efficient visual search would emphasize the saccadic movement/dwell process over the pursuit process because if much time is used in pursuits, then opportunity is decreased for sampling and time-sharing over the extensive visual area required for driving.

Note that the term "dwell" is used in this report rather than "fixation." Used strictly, the term fixation refers to a reasonably steady state of the eye over a period of at least 80-100 ms in which angular deviations from the mean position are less than 10-30 min arc. The eye state classification logic used to analyze the data reported herein considered the eye to be in a steady state if the EPR remained within a "cell" of larger dimensions (3^0 horiz and 6^0 vert) than usually used to define fixations. Therefore, the term "dwell" refers to the time during which the EPR remains within a small region on the screen, within which region short saccades and pursuits could occur. "Dwell" and "fixation" tend to be confused in the literature, however, it is believed that the distinction presented above is useful and should be maintained. A description of the logic used in classifying eye states is given in Appendix C. In particular, the reader should refer to Table C.1 which summarizes the classification logic.

B.2 Visual Search Studies

There is a large literature on EPR measurements made during performance of visual search tasks; however, nearly all of these studies are concerned with aircraft piloting or examinations of fixed imagery such as photographs and advertising material. A comparison of such tasks with the visual search aspects of driving is necessary to evaluate the extent to which their results are applicable to the driving situation.

The primary scanning task of the pilot is that of obtaining quantitative information needed to perform various maneuvers from his instrument displays. Although he has a significant monitoring function for which he must cover a wide visual field, all of his critical maneuvers require close attention to a relatively small control group of flight instruments. These instruments in many cases do not display independent information; the same maneuver often can be performed by using different combinations of instruments, and the instrument that needs to be sampled at any particular time may be a function of the state of other displays. The results of the pilot's control actions are also obtained from his instruments, and he rarely uses the exterior view to obtain guidance or control information (except for special cases such as landing, stunt flying, racing, etc.).

In contrast, the driver's primary area of visual concern lies outside his vehicle; only occasional glances at the instrument panel are required for most situations. Furthermore, the bulk of the information that must be obtained is not quantitative in the sense of reading an altimeter (or speedometer). The driver must monitor the position of his own vehicle with respect to the roadway. He must monitor the positions of other vehicles, including estimation of their velocities and courses relative to his own. He must use these data to execute maneuvers of his vehicle with respect to others and the roadway, and he must detect the road signs and markers. His scanning patterns are often performed using two rear-view mirrors and head and shoulder movements as wl:l as eye movements. Thus, the visual world of the driver is primarily an external, changing, pictorial scene compared to the fixed, interior instrument arrangement used by the pilot. Although this distinction should not be overemphasized (helicopter flight, landing, etc., place more weight on the external scene), it points out a critical difference in tasks between the two situations that must be kept in mind when applying pilot scan data to driving. In fact, most of the pilotage EPR studies that have been performed were exclusively concerned with instrument panel scanning. An aircraft is inherently stable under normal flight conditions, and the pilot can usually ignore his control function for a much longer time than can the driver. Furthermore, the extensive use of peripheral vision by the driver is not typically found in flying or in pictorial viewing.

In spite of these differences, the studies reviewed below are important to our purposes, because they indicate the roles of learned scanning patterns and of scan strategy selection in complex perceptual tasks and serve as clues to the parameters which are likely to be important in driving. Furthermore, they provide data useful for developing theoretical considerations of attention mechanisms.

Senders et al. (1969) review a series of extensive Air Force studies conducted during the early 1950's and of the extensions of that work carried out by Senders and his collaborators. The pilot EPR studies "were directed at finding out the patterns of eye movements actually used by the pilots and the interpretations of these as indicators of the relative importance of the various instruments" (Senders et al., 1969). "Such knowledge ... can form a scientific basis for improving the design of aircraft instruments, increasing the efficiency of pilots, and simplifying the task of instrument flying" (Jones et al., 1949). These studies allowed aircraft designers to group and position instruments in a rational manner and to design individual instruments for minimal "look" time.

Stern and Bynum (1970) studied eye movement patterns of experienced and novice helicopter pilots during a cross-country flight (but did not include head movements, a critical omission for comparison with other studies). They found that skilled pilots "engage in significantly more visual search activity in the horizontal plane than is true of novice pilots". Also, both groups of pilots changed their search patterns in such a direction as to suggest a "decrease in visual search activity as a function of time-on-task". In further analysis of the same data Troy, Chen and Stern (1972) found that the incidence of single saccades (taken as a measure of general alertness in the search process) decreased for both groups as a function of time-on-task but that "when we partialed out differences in absolute number of saccades and restricted our analysis to relative patterns, the differences between skilled and novice pilots previously reported disappeared". These results are interesting in that they indicate that relative decrements of search activity over time are similar for skilled and novice operators, although the absolute level of eye movements may be higher for the skilled groups. However, these data must be interpreted cautiously as only eye movements were recorded and thus the actual search activity which requires measurement of the EPR was unknown.

Many studies have been performed of eye movement patterns while searching a static field. Visual search of photographs or pictorial displays is strongly influenced by specific detail in the display as well as by the expectations and experience of the observer. Mackworth and Morandi (1967) found that when viewing pictures, outstanding areas (areas judged to be unique and easily recognizable) received high concentrations of fixations. Enoch (1959) found that display size and structure influenced the distribution and efficiency of fixations (for example, a too small display resulted in many fixations falling outside the display area) and that oblique aerial photographs received relatively few fixations in the area of the compressed scale. Schroeder and Holland (1968) were able to establish control over frequency of fixations in a given quadrant of the visual field by varying the schedule of reinforcement through frequency of signal presentations. Mackworth and Bruner (1970) compared fixation patterns of young adults and six year old children when searching sharp and blurred photographs of the same object (blurred photos were used to provide a high level of difficulty). The children showed much lower efficiency in visual search as evidenced by restricted scan patterns, shorter average fixation distances, more attention to irrelevant details, etc. In general, the adults used more highly developed strategies in evaluation of the pictures.

Noton and Stark (1971) have studied scan patterns when subjects are asked to view an outline drawing of a familiar scene under low illumination so that they must use foveal vision to identify the drawing. They found that a characteristic path of scan patterns was used about 75% of the time although each subject might have a different characteristic pattern. These results support the earlier work of Yarbus (1967), who also demonstrated consistency of scan patterns while viewing pictures and who studied variations in scans produced by instructional sets. Yarbus contended that visual scanning reflects aspects of thought processes. Noton (1969, 1970) has related such scan patterns to a sequential model of search, identification and recognition of patterns.

A study by Nodine and Lang (1971) lends additional weight to the argument that visual search patterns are under central/or cognitive control. They compared visual scan patterns of children of kindergarten age with third-graders on a visual discrimination task involving matched and unmatched pairs of words. The results supported the conclusion that "the development of perceptual strategies is a direct result of increasing cognitive control over eye movements."

The relationship between eye movements, perception and other muscular control systems has been studied by various authors. Such studies have demonstrated information transfer and mutual effects between the manual and oculomotor control systems. For instance, Angel and Garland (1972) showed that eye tracking of a moving spot was more accurate (lower saccade frequency) when the target was moved by the subject via a hand controller than when the identical motion was generated by a taped signal. The implication is that command information in the manual control system was available to the oculomotor control system. The interaction between signals in the eye movement control system and perception has been clearly elucidated by Festinger and others in the development of the concept of "efferent copy". The basic concept is that perception is correlated with the availability of a set of afferent programs which are triggered by a particular efferent set of signals (Festinger, 1971; Festinger and Caston, 1974). In turn, the efferent programs become established, in part, through experience in viewing scenes and response feedback. Any new transformation between efferent output and afferent signals (such as distorting prisms (or drugs?)) produces inappropriate perceptions and motor responses until new programs can be learned.

The results of the studies reviewed above and many others unequivocally relate visual scan patterns to search strategies learned by the observer in the course of many perceptual experiences. The search strategies seem to be programmed; that is, a particular situation will call up the particular search procedure applicable to that situation and, furthermore, they are modifiable through various techniques such as instructions, operant reinforcement techniques and one would assume, although there is little specific evidence, through drugs and alcohol.

Of particular interest to experimental design for driving studies is the finding that scan patterns are idiosyncratic although consistent. This implies a requirement for reasonably large groups of subjects to ensure representative sampling. Another finding of importance to driving is the fact that eye scan patterns can be trained -- driver training programs might well take advantage of this fact if tentative conclusions regarding different scan patterns in novice and experienced drivers are upheld (see below).

The particular stimuli present in the visual scene have a strong effect on visual scan patterns. Highlights, familiar objects, or any highly conspicuous feature will tend to attract central fixation even if the feature is irrelevant to the task and causes deviation from an optimal or previously learned scan behavior. This is of particular significance to driving since a driver is presented with many high contrast targets (headlights, rearlights, commercial and highway signs, etc.) which can very likely cause event the alert driver to remain fixated too long. Indeed, evidence presented below indicates that an important effect of stress on visual search behavior is prolongation of following movements and increases in average fixation duration.

B.3 Eye Movements and Drugs

The effect of drugs on eye movements has been of interest to persons studying CNS centers for eye movement control and those attempting to use various abnormalities of eye movements as indicators of neurological disease. A now classic study by Rashbass (1961, demonstrated that barbiturates eliminate pursuit movements without significantly affecting saccades; this study and others showing similar results have been used in support of eye movement system models in which the pursuit and saccadic movements are controlled by different CNS centers. With respect to alcohol, studies have demonstrated decreased saccadic velocities under alcohol (e.g., Franck and Kuhlo, 1970; Wilkinson, Kime and Purnell, 1974) and effects of alcohol on maximum following velocity (Mizoi, Aishida and Maeba, 1969).

Numerous other drug effects on eye movements have been demonstrated, e.g., Schroeder et al (1974); these results are mentioned here to indicate that alcohol has a "direct" effect on eye movements in addition to what may be viewed as an "indirect" effect, through attention mechanisms, etc. (It is not clear as to the loci of the direct versus indirect effects, and, indeed, this is an important research question which is related to the more general questions of drug effects on visual search and attention.) However, the changes induced by alcohol on eye movement functions, such as reduced saccadic velocity do not seem to be of sufficient magnitude to account for perceptual deficits in alcohol-related driving accidents.

B.4 Visual Search and Driving

Several studies of visual search behavior while driving have been reported from the group at Ohio State University (Rockwell, 1971; Bhise and Rockwell, 1973a, 1973b). The latest EPR system used by this group consists of a corneal reflectance eyespot sensed by a TV camera and superimposed on the driver's visual scene recorded by a second head-mounted TV camera. A third TV camera pointed at the eye is used to detect out-of-range eye movements (rear view mirrors) and blinks. The horizontal eye movement range is 40^{o}, the vertical is 35^{o}. The outputs of the three cameras are mixed through a special TV mixing unit and recorded on video tape. Eyespot location within the visual field viewed by the head-mounted camera is measured using frame-by-frame playback. The entire apparatus is mounted in an experimental car instrumented for several vehicle and subject responses.

Mourant and Rockwell (1970a) examined the effect of route familiarity and open road driving versus car following on eye scan patterns. Eight subjects were run three trials each on two courses. Each course was about three minutes long. The authors found that sampling was confined to a smaller area after subjects became more familiar with the route. They concluded that the "results lend support for the hypothesis that the peripheral area of the eye is used to monitor other vehicles and the road lane markers in order to direct the fovea for closer examinations ..." The car following task apparently induced a greater visual workload as evidenced by more samples and larger visual travel distances to road signs and other traffic.

Mourant and Rockwell (1972a) compared visual search strategies of novice and experienced drivers on freeway and neighborhood routes. Six novice and four experienced drivers were used. The novice drivers were run after about three hours experience, half-way through, and after completion of a driver training course. Results are given as a function of training level (novice group) and for various subtasks of each route (approach to stop sign, left turn, lane change, etc.). They found that the novice drivers concentrated their fixations in a smaller area as they gained experience, looked closer to the vehicle (less preview distance) than the experienced drivers, sampled their mirrors less frequently, and made pursuit movements on the freeway route whereas the experienced drivers made only saccadic movements. Experienced drivers showed a greater range of horizontal fixations.

Significant scan data were ignored in the neighborhood route study because data were analyzed only between the time of brake application and zero velocity for the various subtasks (for example, on approach to a stop sign). General conclusions regarding the effect of practice are difficult to draw from the study because substantial differences with respect to training are shown between the various subtasks, and it is unclear whether these are real differences, subject-task interactions, subject-training level interactions, etc. The authors' conclusion that "driver training had a detrimental effect on the visual performance of the novice drivers" (because the range of horizontal fixations decreased during training) does not seem justified unless one can show that such a decrease was actually maladaptive to the particular training stage of the novice drivers. The scan range results do agree with helicopter studies in which experienced pilots also were found to search over a wider field than inexperienced pilots

(Stern and Bynum, 1970).

Two earlier studies by the Ohio group also were concerned with comparison of novice and experienced drivers. Zell (1969) examined four novice and two experienced drivers under five driving conditions. The novice drivers were tested on four occasions (one day per month, one month intervals) and the experienced drivers on two occasions over the test routes. On the first occasion the novice drivers had only four hours experience. As practice increased new drivers shifted their mean fixation point from the left to the right side of the highway and the spread of their fixation patterns was reduced. The novice drivers tended to look a constant distance ahead of the car whereas the experienced drivers increased their lead distance as velocity increased (constant preview time). Fixation rates and durations did not change for the novice group with practice and did not differ from that of the experienced group.

Mourant and Rockwell (1970b) reported on a comparison of two novice drivers (fifty hours experience) and one experienced driver over a single highway course. The authors analyzed the results in terms of directional cues (looking ahead to determine road curvature) and lane position cues (looking to the side to determine lateral position in the lane). They found that the experienced driver spent more than 95% of the time looking for directional cues whereas the novice drivers spent about 65% of the time on directional cues and 35% on lane position cues. The novice drivers made many more transitions in their look direction than did the experienced driver (which would seem to follow from the finding that the experienced driver looked in one general direction nearly all the time). The authors interpreted the results as indicating a greater reliance on peripheral cues for lane position by the experienced driver.

In a recent report Mourant and Rockwell (1972b) describe a training program undertaken with a single novice driver in which TV feedback of the driver's scan patterns was used to train him in (presumably) more efficient search behavior. The results showed that the trainee's scan patterns were wider and exhibited more mirror use than did those of a control group of trainees.

Although development of rules for the explicit training of efficient visual search during driving is a desirable goal, it does not appear that sufficient knowledge exists of the actual changes in information acquisition strategies which occur during training to specify optimal training programs. Especially lacking is an understanding of the relationship of the trainee's scan patterns to his performance level on the other skills in driving. To attempt training of novices in scan patterns appropriate to experienced drivers could result in overload during a period when the beginner can attend to only one primary aspect of the scene at a time.

Recent reports (Bhise and Rockwell, 1973a, 1973b) documented an extensive series of experiments concerned with how drivers search for and read highway signs. Eight studies were conducted on Ohio highways in which subjects were given driving tasks ("Drive to Larksburg from Highway 307") and eye movements were recorded. Analyses were performed to determine attention sharing between road and signs and the time course of sign reading. A model of sign reading performance was developed which contains variables such as time of first look at sign, attention sharing between sign and road as a function of workload, and theoretically determined quantities such as the time at which a sign is first readable, time at which sign can no longer be read, etc. This model has been incorporated into a computer program which is intended for use as a sign evaluation system.

Several earlier studies have been reported from Ohio (Whalen, Rockwell and Mourant, 1968; Mourant, Rockwell, and Rockoff, 1968; Mourant and Rockwell, 1968). These studies are summarized as a group because they seem to overlap in experimental conditions and results. Unfortunately, the authors do not identify subjects or runs so the reader cannot tell whether the various data are independent or different aspects of the same experiment.

Tests were run on highways with repeated trials to determine the effects of route familiarity, and with different instructions to vary workload (for instance, read all highway signs versus read only those essential to following the route). Car following and open road driving were compared. Six to eight subjects were used in each experiment and about three minutes of eye scan data were collected on each run. Greater familiarity caused the center of location of the scan pattern to shift down and to the left (subjects looking at signs less often), and instructions to look at every sign increased and spread the scan pattern. Car following increased visual workload as measured by increased sampling rates on lane markers, long eye-movement distances to road signs, and more fixations at closer distances to the driver's vehicle. These results provide additional confirmation that visual sampling behavior is sensitive to both rask and instructional variables, or set.

Kaluger and Smith (1970) compared driving under sleep deprivation conditions. Under sleep deprivation eye fixation patterns shifted to the right and down (3 seconds less preview time), fixations were more widely distributed, and pursuit movement duration and quantity were greater. The authors suggested that pursuit movements are a sensitive measure of scan efficiency -- the fewer the pursuit movements the more time that can be spent in scanning other parts of the field.

Several other studies have been reported in which analysis of eye movements were made during driving:

Robinson et al. (1972) employed a novel technique by only measuring head movements to infer the direction of gaze in two driving maneuvers requiring large changes in the line of regard: (1) scanning a highway after a stop, and (2) changing lanes on a highway. Mean search time data are presented for both tasks which should be useful for analysis of time allocation during these maneuvers. Kelley et al. (1969) used eye scan measurements to compare several forms of rear view mirrors. They found that glance duration (the time the driver spends looking at the rear-view mirror and thus away from the primary field) is a sensitive measure of mirror effectiveness.

Brown and Huffman (1972) measured heart rate, galvanic skin response, steering wheel reversals and lateral eye movements on 16 drivers with good records and 16 with poor records. (Only eye movement amplitudes which corresponded to rear view and side view mirror looks were counted.) Tests were conducted day and night under four traffic conditions. Lateral eye movements were lower for night than during daytime; the highest eye movement rate occurred for residential driving and decreased progressively for business district, expressway and rural highway driving. Eye movement rates did not differentiate the good and bad driving groups.

Helander and Söderberg (1974) used a video eye mark system to study visual scanning behavior of 10 subjects driving over roads on which accident statistics were available. Eleven test points (road sign, intersection, etc.) were selected for analysis. Galvanic skin response data were also obtained. Quantitative summaries of search patterns were not given; the results for each test-point were described qualitatively. In general, subjects tended to look so as to maximize sight distances, i.e., looked to the left side of a right-turning-curve.

Gordon (1966) and Kondo and Ajimine (1968) both used aperture devices which restricted the driver's field-of-view and thus forced him to move his head to sample the visual field. These studies are mostly applicable to the question of what information is necessary for vehicle guidance and not directly relevant to the problems investigated in the present study.

B.5 Alcohol and Driving Visual Search

Five studies have been reported of visual scan patterns under alcohol in a driving or simulated driving situation. Three studies, to be reviewed first, used actual driving tasks and other two used TV or movie presentations of a driving scene.

Belt (1969) examined two subjects under three levels of alcohol for three different driving conditions. The nominal blood alcohol levels were 0, 0.037% and 0.075%. The three tasks were car following, short-interval open road driving, and long interval open road driving. The tasks were run in the above order on different stretches of road on the same day for each subject. One subject was tested twice on different days; the other was run only once. The long-period, open road driving task consisted of 12 minutes total driving time; several minutes of visual scan data were recorded but only a 60-second period of uniterrupted driving (no passing or cars cutting in front of the subject) was used for data analysis. Eye movements and visual field were recorded via a modified Polymentric Eye Mark Camera on 16 mm film. A battery of psychophysical tests was included in the experimental program.

The results showed no effect of alcohol level on mean eye travel distance. An increased amount of fixation time in the most populous 3^{o} x 3^{o} visual angle block was shown under alcohol indicating that subjects paid less attention to the peripheral field under alcohol. The author interprets this as "tunnel vision" although this is not the usual meaning of tunnel vision, i.e., a loss of peripheral acuity or sensitivity. Mean fixation duration increased under alcohol under the open road mode but not under the car-following mode. The replicated data for the one subject show large differences in mean fixation durations under the no alcohol case which could not be attributed to differences in actual blood alcohol level. The results of this study can only be taken as very tentative due to the small number of trials and subjects.

Mortimer and Jorgenson (1972) studied visual scan patterns of two experienced drivers for three nominal levels of blood alcohol concentration, 0, 0.05%, and 0.10%. Driving on a two-lane road at 35mph and driving on an expressway at 60 mph were compared, as were car following and open road driving. A modified NAC eye mark device was used with TV recording of the eye spot and visual scene. Scan data were recorded for about 66 miles of driving for each subject, but the authors do not state whether all the data were analyzed.

The results showed an increase in eye fixation time at the 0.10% alcohol level and an indication (not statistically significant) that preview distances were decreased under alcohol (viewing closer to the vehicle). Differences in driver fixation locations were found between straight road driving (looks straight ahead) and driving on curves (looks to the side of the road).

Kobayashi (1974), in an incompletely reported study, found indications of larger fixation times in two subjects while driving a test course under alcohol.

Buikhuisen and Jongman (1970, 1972) conducted a laboratory study using a video display of a 4 1/2 minute film made from a car moving through typical suburban traffic. Twenty staged situations were included in the film in order to control the type and locations of events in the visual field. The film was shown to independent judges who selected 86 critical events, including the twenty staged ones, which were believed important to be noticed by a driver.

The film was displayed to the subjects via a closed circuit video system; the display subtended an angle of 60° at the subject's eyes. A Mackworth camera was used to record the EPR, and a film record was made of the subject's responses from a second monitor which displayed a mixed image of the film and the eye mark.

105 subjects were chosen from the driving population of Groningen, Netherlands; 55 were control subjects and 50 were alcohol treated. They were matched pair-wise on the basis of age and driving experience. The alcohol group ingested an amount estimated to result in a blood level of 0.08%. The BAL was confirmed with a Breathalyzer reading immediately after the film. At this time the subject was checked for the presence of nystagmus and a blood sample was taken. Twenty minutes later another Breathalyzer sample was taken.

A large number of different analyses was undertaken. In brief, the data indicated that under alcohol subjects looked to the sides somewhat less (concentrated on straight ahead more) and that fewer critical events were seen in cases of simultaneous occurrences of such events. The sober driver made more attention shifts and could divide attention more efficiently. In the central region of fixation (the "tunnel") intoxicated subjects saw about as many critical events as did sober subjects. It appears that a major effect of alcohol was to change the subjects' scan priorities so that more attention was paid to the central field; within this region the extra attention paid off for the intoxicated subjects as they were able to maintain a normal detection rate. However, this effort was paid for by poorer performance in the periphery. A particularly significant result in this regard is the finding that subjects under alcohol tended to look more towards the right side of the road. The importance of this result is in the fact that in Holland the driver on the right has the right of way, without qualification. This rule is rigidly enforced and apparently has sufficient weight in driving experience to cause the subjects to pay extra attention to this area. Thus under alcohol, subjects look mostly at those areas which are most sensitive to the basic task of driving (straight ahead) and to learned reinforcement of critical events (a traffic citation due to not giving another driver the right of way).

Schroeder, Ewing and Allen (1974) examined the combined effects of alcohol with methapyrilene and chlordiazepoxide on performance of a simulated driving task. Thirty male subjects were used in a repeated measures design. Subjects viewed a 6 min 10 sec movie in an Aetna-Driver-Trainer and were required to operate the steering wheel, accelerator and brake in response to nine critical events. Alcohol alone was found to generally suppress eye movement activity, and also, to decrease the proportion of saccades greater than 5^{o} to those less than 5^{o}, i.e., more attention was paid to central visual regions under alcohol. The frequency of driving errors did not increase under alcohol. Chlordiazepoxide alone increased the mean frequency of saccades whereas methapyrilene alone had no effect on saccadic frequency compared to the placebo. However, both chlordiazepoxide and methapyrilene had an antagonistic effect on the suppression of eye movement activity due to alcohol when they were used in combination with alcohol. Finally, the two drugs did not produce the restriction of visual field found under alcohol. The synergistic effect of the two drugs with alcohol is not fully explained nor are the consequences for driving performance. However, it ".... raises the possibility that many drugs act synergistically with alcohol to affect driving performance and the eye movement parameters are a sensitive measure of these effects." (Schroeder, Ewing and Allen, 1974).

APPENDIX C
EYE MOVEMENT MEASUREMENT TECHNIQUES, DATA ANALYSIS, AND SYSTEM ERROR ANALYSIS

C.1 Introduction

This appendix provides a summary of the eye state classification logic and critical event logic used in the eye movement analysis software. In addition, the numerical values of various parameters used for logical tests in the program and error sources are discussed. Finally, a comparison of manual versus computer classification is given.

A complete description of the eye movement analysis software is given in Niemann and Ziedman, 1975.

C.2 Traffic Film Sequence and Calibration Routine

The time line of the traffic movie is divided into a series of calibration intervals and analysis intervals. The calibration interval data are used by the two calibration subroutines (CALSUB which sums data and CALAV which averages) to determine the correspondence between the EPR voltages generated in the lab and the visual angle data which are to be analyzed by the program. Six calibration intervals were used in the traffic movie. The first contains a sequence of nine dots on the screen at known angles as shown in Figure C.1 (the center dot is shown three times). As the subject looks at the sequence of dots, the computer records the nine corresponding EPR voltages. During the analysis intervals, these calibration points can be used with a two-dimensional linear interpolation routine to determine a corrected visual angle corresponding to any EPR voltage. The second through fifth calibration intervals (which occur at several minute periods during the movie) contain only a single center dot. The nine calibration points determined in the first calibration interval are corrected after each subsequent calibration interval by shifting the nine points by the difference between the original center dot and the center dot in subsequent intervals. The sixth calibration interval (at the end of the movie) contains a repeat of the nine dot sequence of the first interval. The data from this calibration interval are printed out by the program to give an indication of the stability of the calibration data.

There are five analysis intervals in the experiment, corresponding to the five traffic movie sections which were separated by the calibration sequence. When the film frame count is within these intervals, the various analysis subroutines are called: TRK (tracking task, which was not used in this experiment), DIS (discrete task), CLASS (eye state classification) and EVENT (critical event analysis). When the end of the last of the five analysis periods has been reached, a statistical analysis routine (STAT) and output routine (OUTPUT) are called.

C.3 Classification Routine

The classification subroutine (SUBROUTINE CLASS) contains the program logic which determines the subject's eye state, i.e., determines fixations, saccades, pursuits and blinks. The first logic test is a test on the slope of the EPR data to determine if the eye is in a saccadic movement or a blink. The current data point is compared with the second following point (to get an average slope over two sampling intervals) and if the difference vector given by $EPR_{i+2} - EPR_i$ falls outside of an error ellipse, the state is classified as a saccade*. The semi-minor and semi-major axes used on the error ellipse were 1^o horizontal and 2^o vertical, which over two sampling intervals re-

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*$EPR_i - EPR_{i+2}$ = the angular distance between sample point i and sample point i+2.

present slopes of 50^{o}/sec and 100^{o}/sec, respectively. (In section C.8 the selection of these program parameters is discussed in detail.) A variable S(J) records the state of the eye, with S(J)=1 corresponding to a fixation, S(J)=±2 corresponding to a saccade, and S(J)=3 corresponding to a pursuit, with J being an index which is incremented by one for each new eye state. The sign on the S(J) value for a saccade indicates if the saccade is upward or downward for the vertical movement (or rightward or leftward for the horizontal channel). If a saccade of +2 is followed by a saccade of -2, or vice versa, the state is determined to be a blink. Blinks are recorded by a separate process from the S(J)'s and are counted by an index NB. Thus, if a blink comes in the middle of a pursuit or a fixation, and the EPR values at the end of the blink are the same as at the beginning, the fixation or pursuit is treated as though it were uninterrupted and no new state is indicated at the end of the blink. If the EPR values at the end of the blink differ from those at the beginning by more than a specified amount (say, 3^{o}), then a saccade is determined to have occurred simultaneously with the blink.

If the saccade slope test determines that the difference vector is within the error ellipse, then the EPR data is checked for either a fixation or a pursuit. The state is first classified as fixation in the fixation-pursuit branch of the program. If a fixation lasts long enough (say 0.5 sec.), it is tested as a possible pursuit by comparing the current EPR values with those at the beginning of the fixations. If the difference exceeds a given amount (say 3^{o}), the classification is changed to a pursuit. When the program enters the saccade-blink branch after being in the fixation branch, the length of the previous fixation is checked to see that it is long enough (say, 0.08 sec.) to be regarded as a fixation. If it is not, the fixation determination is erased, and a blink is a possibility. Blinks can be determined in two ways: a saccade classification can be made, followed by an entry into the fixation branch for a time too short to be considered a fixation, followed by a saccade determination of opposite sign to the previous saccade, or the slope of the EPR data can change sign without exiting the saccade branch, in which case a special test will determine the blink.

C.4 Critical Event Subroutine

The critical event (CR) subroutine (SUBROUTINE EVENT) compares the EPR data with the locations of certain predetermined critical events on the screen to determine if the subject is looking at the CE. The initial and final frame numbers for each event are read into the computer. The position of the CE is specified by enclosing the event in a rectangle, e.g., -5^o and -7^o horizontal and 5^o and 8^o vertical. These rectangles were determined for the initial and final frames of the event and every 10th frame in between, except for long events which are recorded at 20 or 30 frame intervals. The critical event data are read into the computer as an array CE (L, M, N), where L is the number of the critical event, M is the index corresponding to the frames for which CE data are recorded, and N=4 are the four rectangle boundaries. The program performs a linear interpolation on the data to obtain CE positions in between the 10, 20 or 30-frame intervals.

As the frame count is advanced, the frame number is compared with the initial frame number of a critical event. The CE data are read in order of increasing initial frame number. As the frame count passes each CE initial frame, an index L1 (which is the number of the CE) is increased by one. Since critical events in general overlap in time with as many as three other CE's, the CE which was last to pass its initial frame (i.e., the L1th), and the three preceding CE's are tested to see if the current frame count is still less than the final frame number of the respective CE's. If it is, then the CE is on the screen for that frame number and the EPR values are tested to see if they fall within the rectangle indicated for that CE.

For each critical event, the program outputs the total time the subject spent looking at the event, the total time not looking at the CE; the film frame number of the first look at the CE; the film frame number, time, and angular position of the first look at the CE relative to the frame number, time and angle at which the CE first appeared on the screen; the number of separate looks, number of fixations, number of pursuits, total fixation time and total pursuit time for the CE.

C.5 Discrete Response Analysis Subroutine

The discrete respnse channel contains signals indicating when a subsidiary task begins (e.g., the appearance of an arrow on the screen) and the subject's response (e.g., manipulation of the turn signal). The discrete response analysis routine (SUBROUTINE DIS) determines the time required for the subject to respond correctly (by activating the turn signal in the right direction), the number of incorrect responses (activating the turn signal in the wrong direction), and the time of incorrect responses. The routine also records the number of times a switch is activated on the steering wheel (indicating that the subject sees an event on the screen which he feels would be important for a good driver to see).

C.6 Statistical Analysis Routine

The statistical analysis routine (STAT) outputs statistical summaries of the EPR and classification data, including:

Total number of fixations
Total number of pursuits
Total fixation time
Total pursuit time
Ratio of pursuit time to fixation time
Average fixation duration
Standard deviation of fixation durations
Frequency of fixations
Average fixation transition length:
- Vertical
- Horizontal
- Total

Standard deviation of fixation transition lengths
- Vertical
- Horizontal
- Total

Average pursuit duration
Average pursuit transition length
Standard deviation of pursuit durations
Standard deviation of pursuit transition lengths
Average duration of saccades
Standard deviation of duration of saccades
Centroid of fixations -- horizontal and vertical coordinates
Standard deviation of fixations from centroid -- horizontal and vertical coordinates
Centroid of fixations weighted according to fixation duration -- horizontal and vertical coordinates
For field divided into NxM cells
- Matrix of total fixation time per cell
- Matrix of total number of fixations per cell
- Matrix of average fixation duration per cell

Standard deviations of fixations durations for each cell

For field divided into left and right central regions, left and right peripheral regions, left and right extra-peripheral regions, matrix of number of transitions from one region to another

Histogram of fixation transition lengths

Histogram of fixation durations

C.7 System Errors in Eye Movements Measurements

The methods used in the computer program to perform eye state classification and critical event analysis were discussed in the preceding section. The accuracy of the analysis performed by the program is affected by the accuracy of the data itself, and the setting of the various parameters in the program must take into account this accuracy. The main source of inaccuracies was in the EPR signals generated by the head and eye movement devices. Some of these sources of error are discussed below.

1. Shifting of Helmet and Spectacles. A small shift in the position of the helmet or spectacles with respect to the head after calibration has been performed results in an angular error in the EPR. This error is partially compensated for by re-calibrating the center point after each film segment, but this still leaves the possibility of the error existing for as much as a few minutes previous to the correction.
2. Squinting or Other Facial Muscular Movements. Since the vertical photosensor tracks the position of the lower eyelid, any facial muscular movement (squinting, smiling) which causes a movement in the position of the lower eyelid which is not related to the movement of the eye results in a shift in the vertical EPR voltage (and some horizontal shift due to crosstalk). This shift was observed to be as much as 6^{o}.

3. <u>Noise.</u> Random variation in the EPR voltage during a fixation were found to cause variations in visual angles of up to 0.5^{o} horizontal and 1^{o} vertical.
4. <u>Combined Calibration of Head and Eye Signals.</u> A single calibration of the EPR voltage was made as the subject looked at a sequence of nine points on the screen. The accuracy of this method is based on the assumption that the head and eye movement devices have a linear correspondence between voltage and angle; otherwise the calibration is only valid for the particular combination of head and eye movements used during the calibration sequence. Due to various non-linearities, uncorrectable crosstalk, and other factors it was not generally possible to get a linear calibration for the eye movement device.
5. <u>Non-linearity of Eye Movement Device.</u> Specifications on the eye movement device indicate that it is linear over a range of $\pm 20^{o}$ horizontal. In this experiment, the device was calibrated at $\pm 25^{o}$ horizontally, and the usable visual field extended to $\pm 35^{o}$ resulting in occasional eye movements as large as 30^{o}-35^{o}.

Tests were made to determine the cumulative error from all these sources by performing experimental runs in which subjects were first shown the nine-dot film calibration sequence, and then shown a series of calibration slides with dots at known angular positions. The EPR data for the calibration slides were run through the IBM-360 calibration program and the visual angles thus determined were compared with the known calibration slide angles. Frequent errors of 3 or 4 degrees horizontal and 6^{o} vertical were found, which are what would be expected from the error sources described above.

These errors cast extreme doubt on the ability of the analysis program to determine consistently and accurately whether the subject is looking at a given critical event, i.e., the absolute accuracy of the system is poor. However, since eye-state classification is based on an analysis of relative location of adjacent data points rather than on absolute locations, the classification analysis is fairly accurate.

C.8 Parameter Selection for Eye Movement Analysis

Table C.1 contains a summary of the parameters used in classifying eye movements and comments on their implications for data analysis. The following discussion expands the material in Table C.1.

The parameters HSLTH and VSLTH were set at 10 and 20, respectively. Thus, if the vector $EPR_{i+2} - EPR_i$ which represents ten times* the difference in the EPR angles over two sampling intervals, extends outside of an ellipse with semi-minor and semi-major axes of 10 and 20, the eye state is classified as being in a saccade. Since EPRV = 20 and EPRH = 10 correspond to visual angles of 2^o and 1^o, respectively, and two sampling intervals equal 0.02 seconds, these values correspond to slope thresholds of 100 degrees per second vertical and 50 degrees per second horizontal. The vertical threshold must be chosen larger than the horizontal because random variations due to noise in the vertical EPR voltage between sampling intervals is greater than in the horizontal. Since eye movements are primarily horizontal for a subject watching a traffic movie, the threshold on the horizontal EPR angle generally determines the eye state. Using these thresholds results in the program being able to recognize saccades of greater than 1 or 2 degrees. Because of the accuracy limitations, the thresholds could not be set any lower in an attempt to be able to recognize smaller saccades.

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*An INTEGER * 2 definition was used on the EPR data array to save storage space. Thus, to allow angles to be determined to the nearest 0.1^o, the EPR values were multiplied by 10, e.g., 15.3^o assumed the value 153. Thus HSLTH, VSLTH, HTH, and VTH all have values of visual angle times 10.

HTH and VTH were set at 4 and 8, respectively, resulting in an error ellipse with semi-minor and semi-major axes of 0.4 and 0.8 degrees. Thus, if the vector representing the difference in EPR angles over one sampling interval falls within this error ellipse when the eye state has been determined to have been in a saccade in preceding sampling intervals, the saccade is determined to have terminated and a fixation is determined to have begun. Due to noise in the EPR voltages and due to the fact that the eye state might be going into a fast pursuit, the EPR difference vector might never fall within the ellipse determined by HTH and VTH. Thus, an additional criterion is used to determine the end of a saccade using the parameter NI, which is set equal to six. When NI sampling intervals have passed after the EPR slope falls below the HSLTH and VSLTH thresholds, the saccade is assumed to be over even if the EPR difference vector is not within the HTH and VTH thresholds.

A pursuit classification is made when the EPR angles in the course of a previously assumed fixation depart from the EPR angle of the initial point of the assumed fixation by a prescribed amount determined by an error ellipse. The ellipse thresholds are determined by multiplying HTH and VTH by a factor RFAC, set equal to 7.5, resulting in thresholds of 3.0^{o} horizontal and 6.0^{o} vertical. The vertical threshold must be set higher than the horizontal because the subject's squinting during a fixation can result in an EPR variation similar to a vertical pursuit. Most pursuit movements during a traffic movie are horizontal. If the horizontal threshold is set any lower than 3^{o}, then an erroneous pursuit classification can occur by a combination of an undetected small saccade and random drifts. Thus, due to accuracy factors, pursuits of less than 3.0^{o} horizontal cannot be distinguished from long fixations, and even with a 3.0^{o} threshold, some sequences of small saccades, or fixations during which the subject squints, are classified as pursuits.

When a blink occurs, and the difference between the EPR angles at the beginning and end of the blink fall outside an error ellipse, a saccade determination is made simultaneously to the blink. The error ellipse axes are set at BFAC = 8 times HTH and VTH, resulting in axes of 3.2^{o} and 6.4^{o}. Again, sensor accuracy considerations do not permit smaller thresholds.

TLIMF, the minimum length of a fixation, was set at 0.08 seconds. Analysis of the experimental data demonstrates that fixations of this duration do occur, and other researchers have reported similar findings. TLIMP, the minimum length of a pursuit, was set at 0.5 seconds.

The problem of inaccuracy in the EPR signals was greatest in the case of setting the horizontal and vertical error boundaries around the critical events (NCEEH and NCEEV). Although manufacturers' specifications on the accuracy of the eye movement device were $\pm 1^{o}$ horizontal and $\pm 2^{o}$ vertical, extensive claibration tests showed inaccuracies occasionally as high as 3^{o} to 4^{o} horizontal and 6^{o} vertical. (A detailed discussion of the sources of these errors is given in the preceding section.) The large vertical inaccuracy essentially eliminates any vertical sensitivity in critical event determination. However, since most eye movements were horizontal, i.e., limited to a narrow horizontal strip, setting NCEEV = 6 did not too greatly inhibit critical event analysis. The horizontal error of 4^{o} was a greater problem, because to add $\pm 4^{o}$ to the horizontal critical event boundaries would result in such a large vertical strip being used to represent a critical event that a large number of fixations which were actually not on a given critical event would be counted as falling on the critical event. Thus a compromise between using a large NCEEH and counting too many fixations and using a small NCEEH and counting too few fixations had to be made, and NCEEH = 2 was used.

C.9 Accuracy of Eye State Classification

Figures C.2 and C.3 show sections of plots of horizontal and vertical EPR angle versus time for a sample experimental run. The time line of the plots is divided into segments according to the computer classification of eye states represented by the data, with S indicating a saccade, F a fixation, P a pursuit, and B a blink.

Figure C.2 shows a fairly representative segment of data (chosen so that all four types of eye states are included) in which all of the state classifications made by the computer are the same as those which would have been made by examination of the graphs. Figure C.3 shows examples of some cases in which examination of the graphs might lead to different classifications from those of the computer program. The first saccade indicated on the graph, occurring at about zero seconds, appears to include a very short fixation in between two saccades. The length of the short fixation is about .07 seconds, which is less than the minimum length parameter of .08 seconds used in the program. This is a shorter length than most researchers have reported as a minimum length for a fixation. If the fixation length threshold were set any lower, it would risk the possibility that a blink with a flat peak would be classified as a saccade followed by a short fixation followed by a saccade in the opposite direction.

Between 0.8 and 3.8 seconds in Figure C.3 the program indicates the eye state is in a long fixation. However, from the graph, at about 1.4 seconds and 2.4 seconds appear what could be small saccades which were undetected by the program. However, even by examining the graphs one can't be completely sure that these small changes are saccades rather than small variations in the noise level. If two such small saccades had occurred in the same direction, rather than in opposite directions as in the illustrated example, the program would probably have classified the long fixation as a pursuit.

Examination of many such sections of data indicate that in most cases state classification is unambiguous as in Figure C.2, and the program performs the classification accurately. Thus, in spite of the inaccuracies in the data which caused problems in the critical event analysis, the eye state classifications are fairly accurate, except that the initial angular positions of the states suffer the same possible inaccuracies discussed in section C.7, resulting in some uncertainty as to the accuracy of the spatial distribution of fixations determined by the program.

Test #	Eye State Analyzed	Test	Comment
1	Is saccade present?	Does EPR_{i+2} fall outside ellipse drawn with EPR_i as center and semi-minor and semi-major axes of 1° (horiz) and 2° (vert)? (Note 2)	Corresponds to velocity of 100 deg/sec (vert) or 50 deg/sec (horiz).
2	Is saccade terminated?	(a) Does EPR_{i+1} fall within ellipse drawn with EPR_i as center and semi-minor and semi-major axes of 0.4° (horiz) and 0.8° (vert), after saccade has been identified?	That is, has EPR settled down to within a small region at end of saccade?
		or	
		(b) Have six sampling intervals (0.06 sec) passed after EPR velocity falls below criteria used in Test 1?	This additional test used in case random noise or initiation of a fast pursuit immediately after saccade makes 2(a) inappropriate.
3	Is a dwell present?	(a) A saccade has been terminated for at least 0.08 sec. and (b) EPR remains in ellipse with center at first fixation point (first point following saccade termination) and semi-minor and semi-major axes of 3.0° (horiz) and 6.0° (vert)	Pursuits of less than 3° horiz cannot be discriminated from long fixations or from a series of short fixations. Some sequences of short saccades, or squints occurring during fixations which exceed the ellipse boundaries, are classified as pursuits.

TABLE C-1 SUMMARY OF LOGIC AND PARAMETER VALUES FOR EYE STATE CLASSIFICATIONS (Note 1)

TABLE C-1 Continued

Test #	Eye State Analyzed	Test	Comment
4	Has a pursuit been initiated?	Has the EPR moved out of the dwell error ellipse specified in 3(b), and a) the velocity of the movement is less than that specified for a saccade, and b) the movement has occurred for at least 0.5 sec.	This eliminates pursuits of short duration (less than 0.5 sec) and of short length (inside the 3(b) dwell error ellipse). Thus, some pursuits will be classified as long dwells.
5	Has a blink occurred?	Have two saccades occurred contiguous in time and of opposite directions?	EPR response to blink arises from characteristics of the sensor.
6	Has a saccade occurred during a blink?	Is the EPR at the end of the blink outside an error ellipse centered about the EPR at the beginning of the blink and with semi-minor and semi-major axes of 3.2° (horiz) and 6.4° (vert)?	
7	Is a given dwell within a critical event?	Is the EPR within an area determined by extending the vertical event boundaries 6° up and 6° down, and the horizontal boundaries 2° right and 2° left? (Note 3)	These rather large error boundaries are required because of inaccuracy in the eye movement system, particularly those due to vertical shifts. Specific values were determined partially by trial and error. The size of the vertical boundary essentially eliminated vertical movements as a factor in analyzing looks at critical events.

1) The parameter values given herein are a function of eye movement system accuracy rather than inherent in the software design.

2) EPR_{i+2} is the EPR value 2 samples (20 ms) after EPR_i.

3) The critical event boundary is the rectangle which just encloses the critical event.

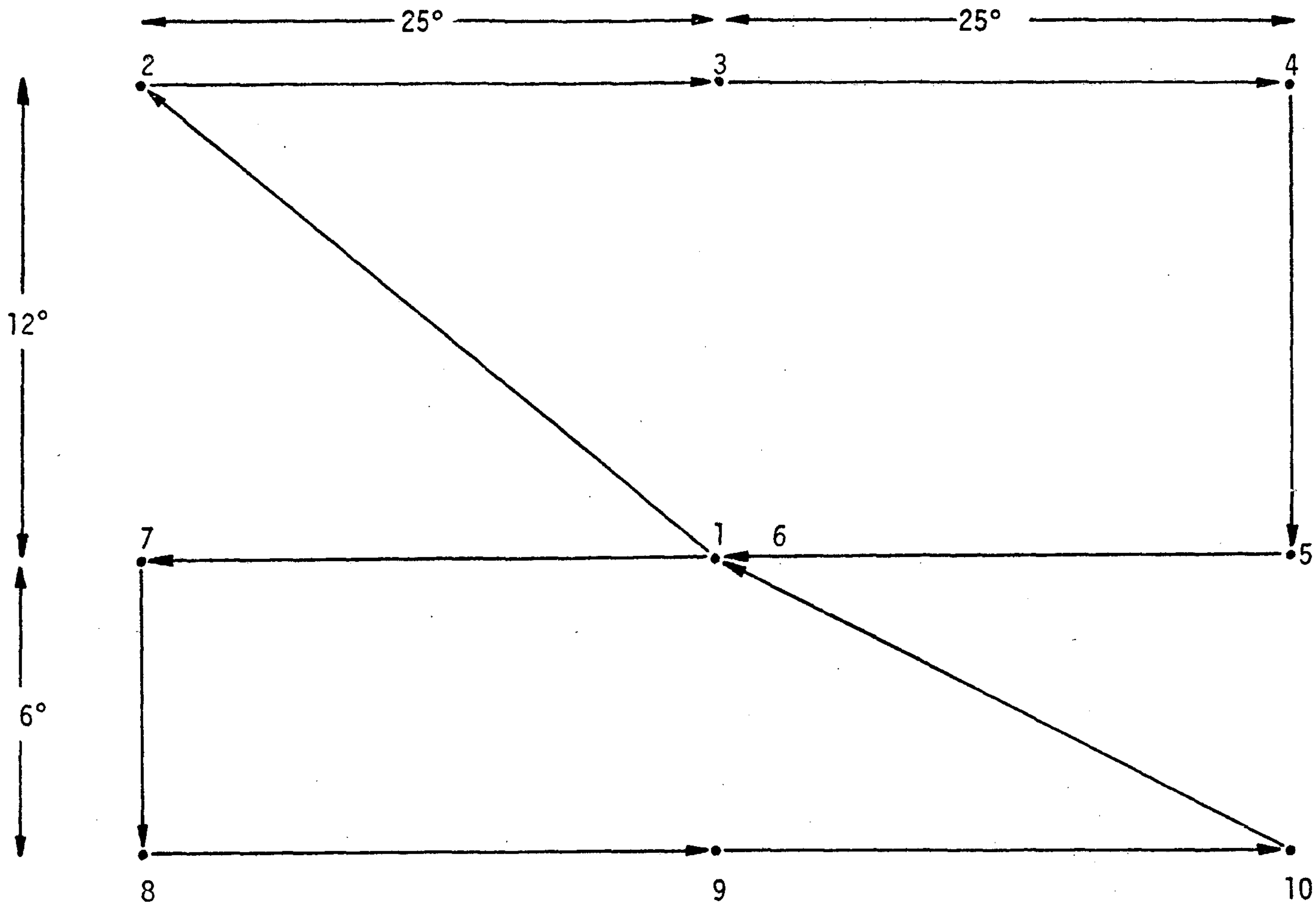


FIGURE C-1 CALIBRATION DOT SEQUENCE

The numerals next to the dots indicate the order in which they were scanned.

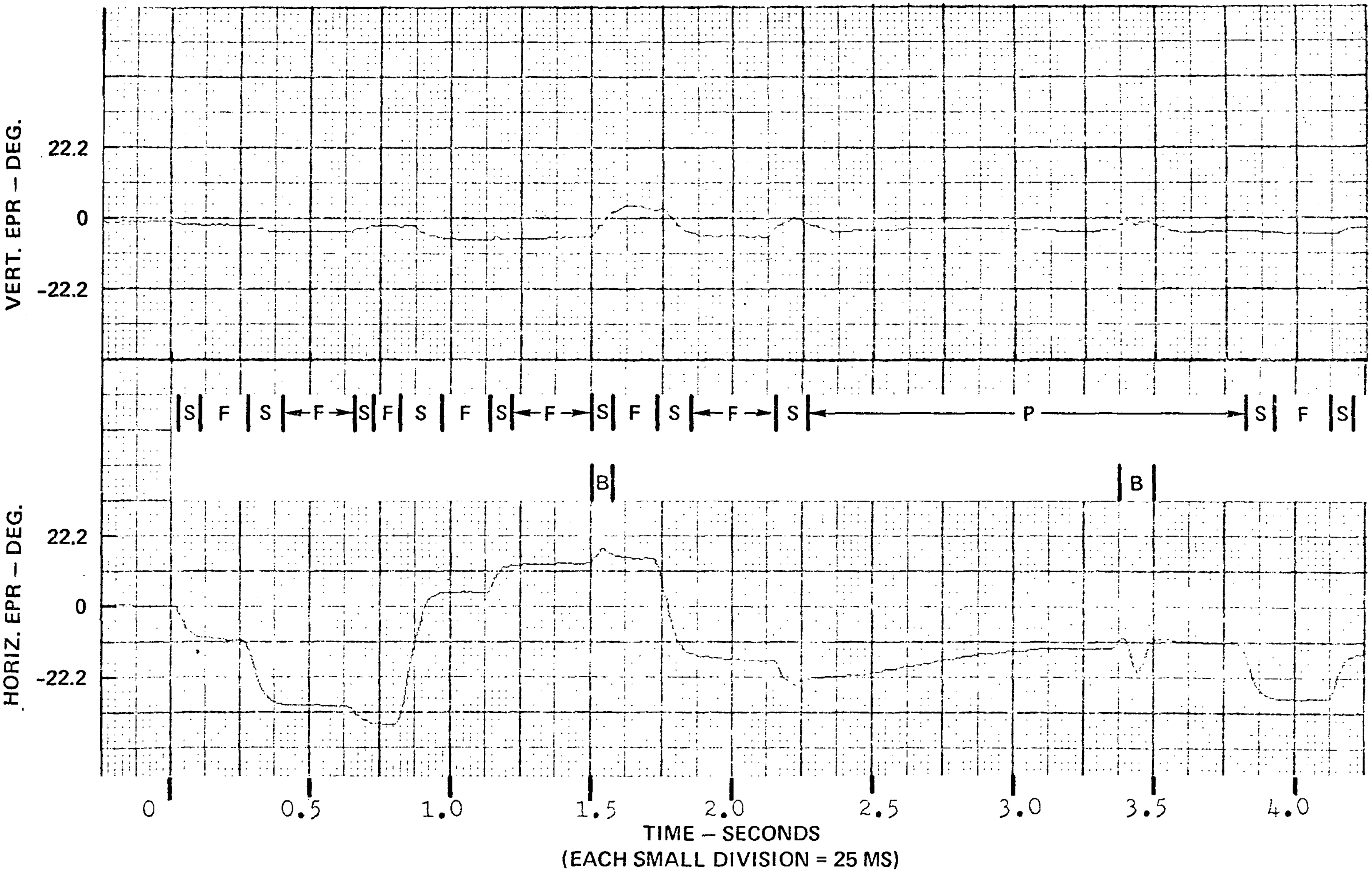


Figure C-2 Representative Sample of Eye Movement Data Where Computer and Manual Classification Generally Agree. (S = Saccade, F = Fixation, P = Pursuit, B = Blink).

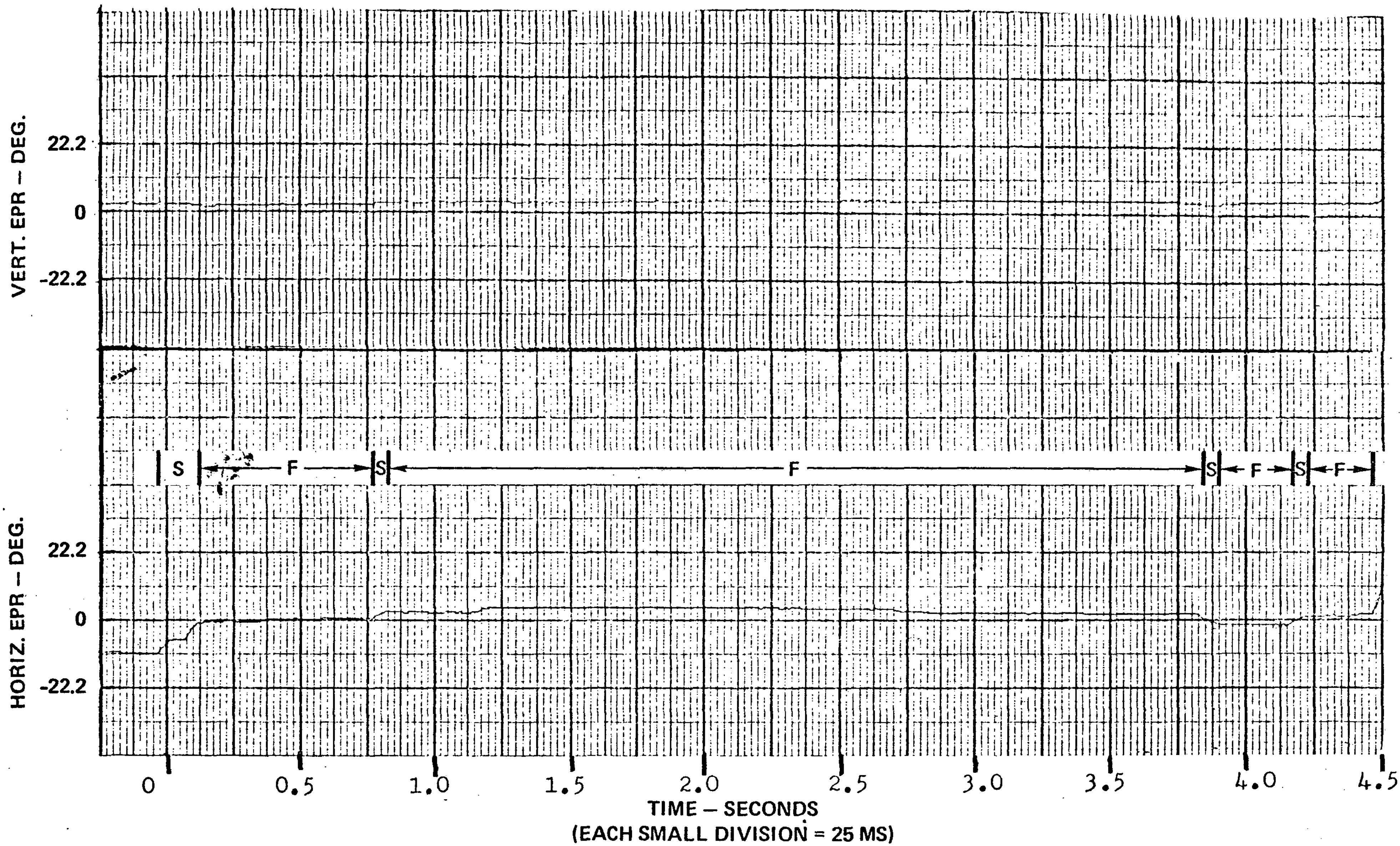
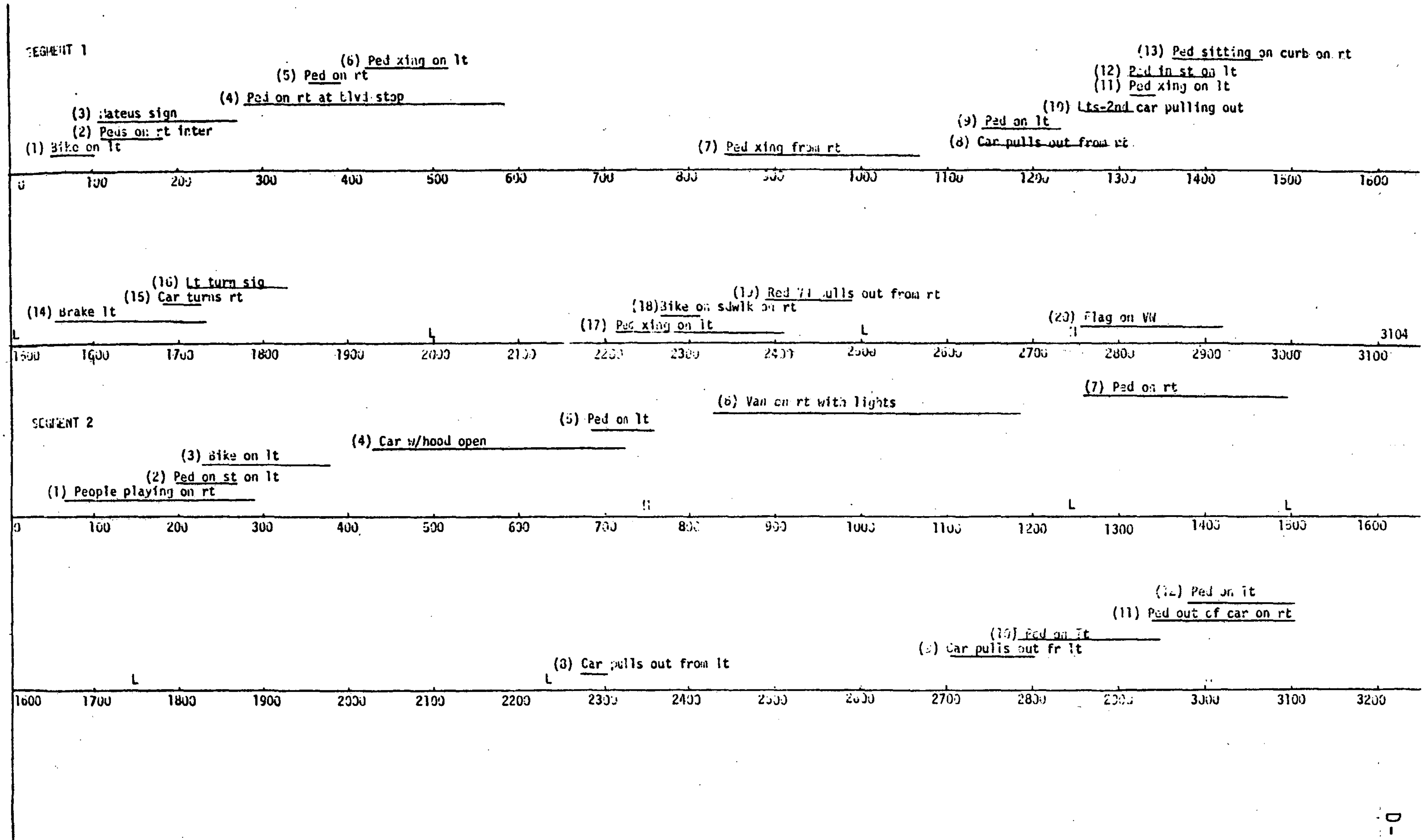


Figure C-3 **Representative Sample of Eye Movement Data Where Computer and Manual Classifications Show Some Disagreement. (S = Saccade, F = Fixation, P = Pursuit, B = Blink).**

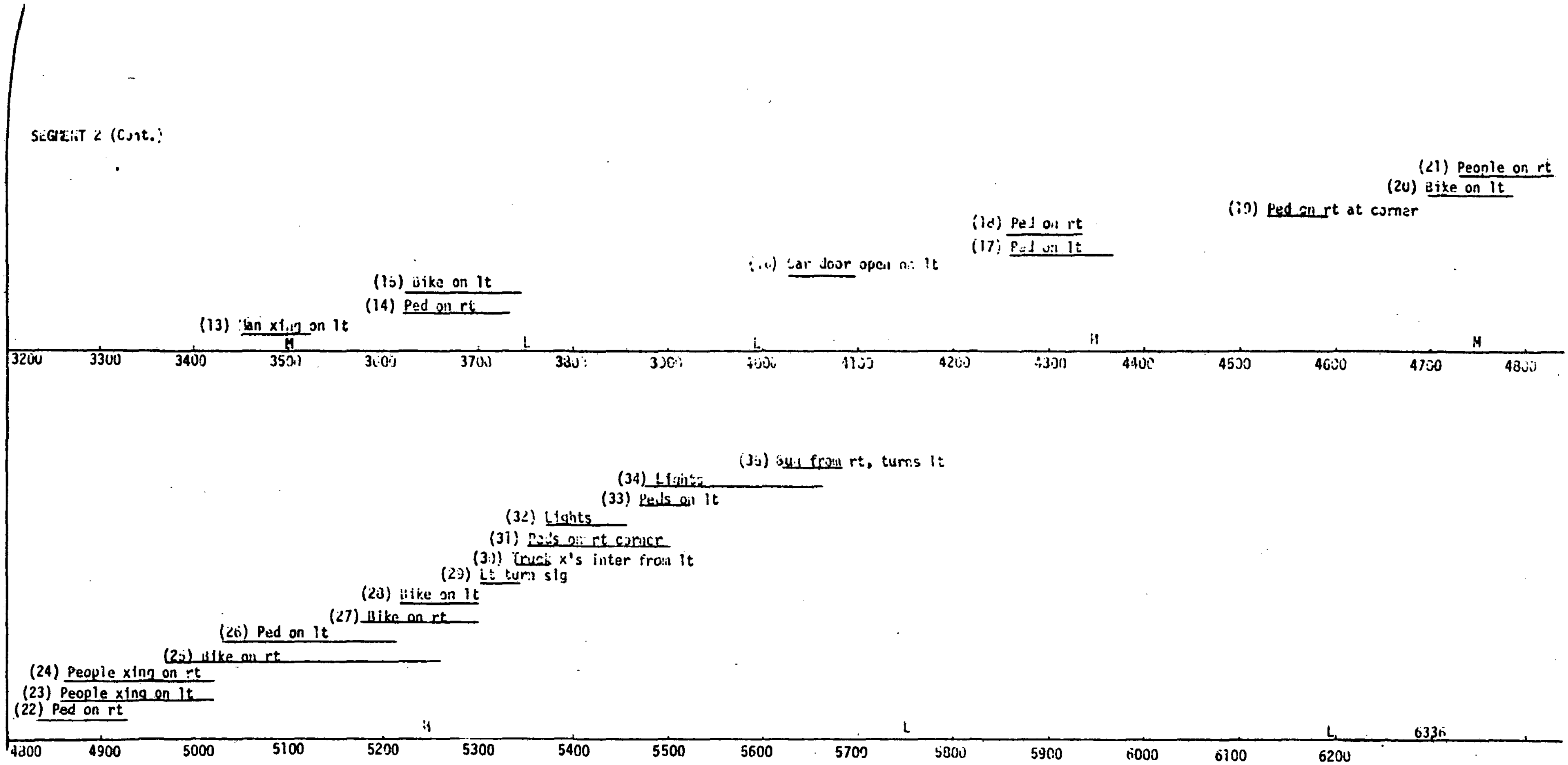
APPENDIX D

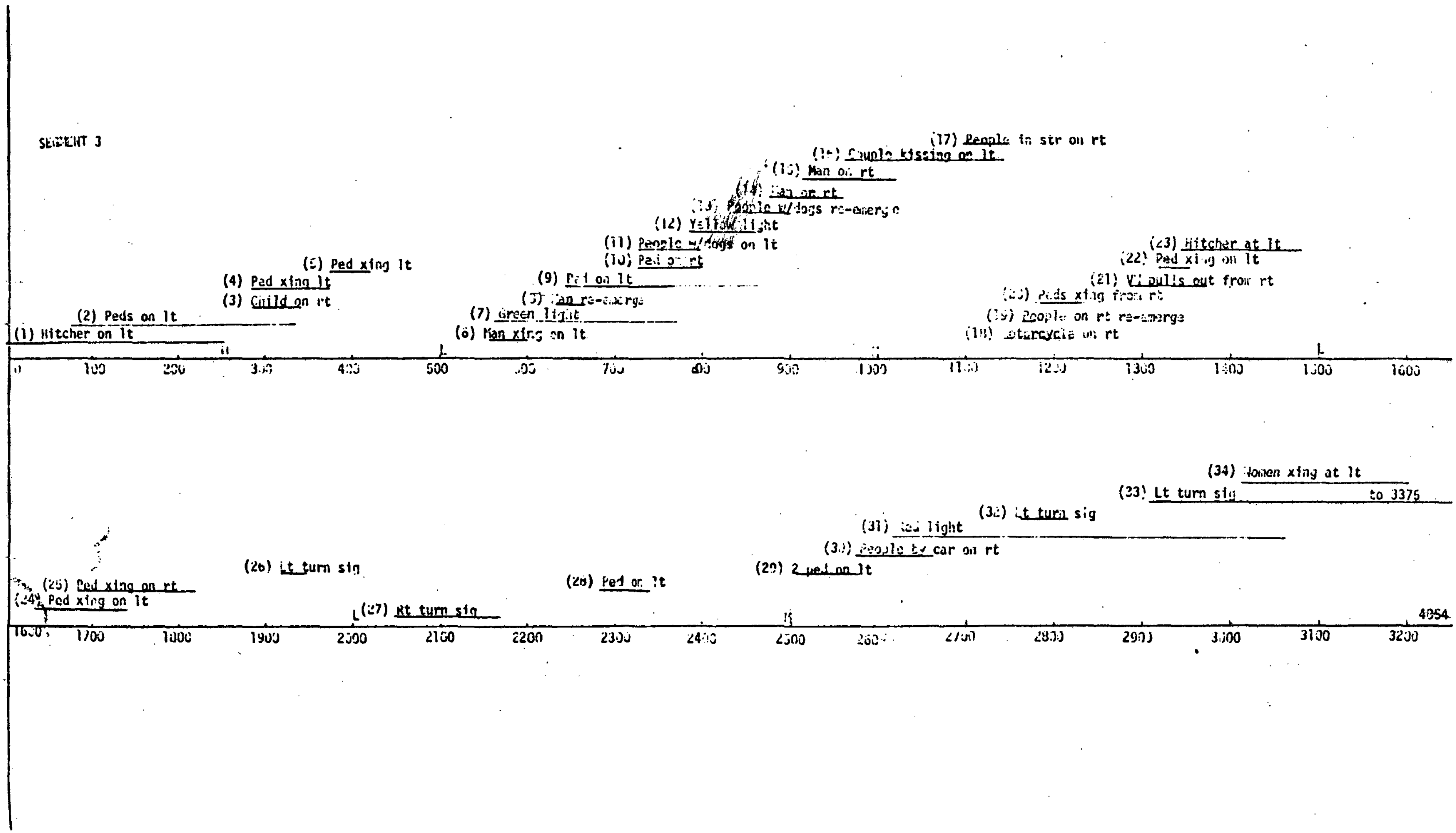
FILM TIME LINE



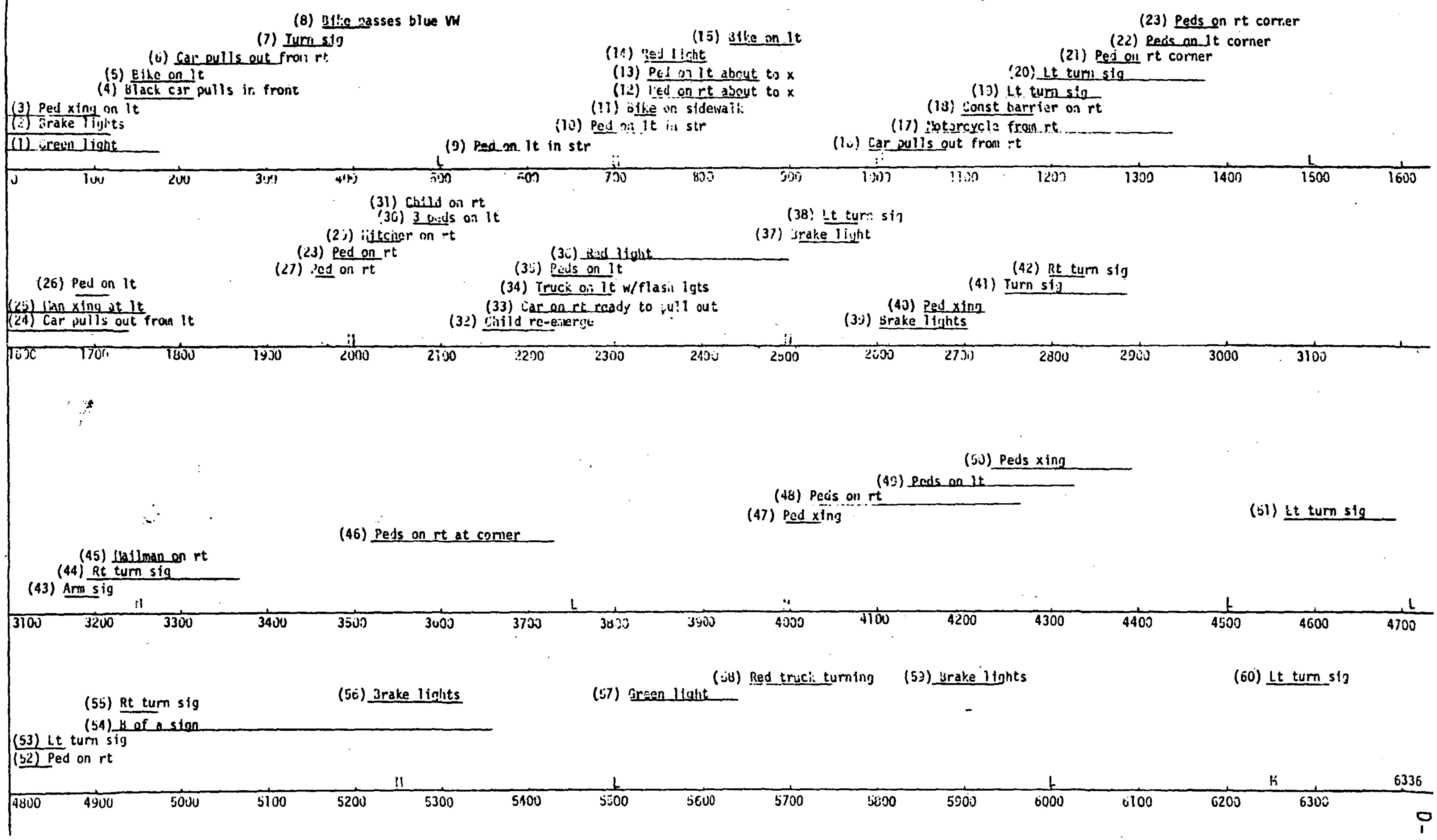
Note: Frame numbers are given from start of each segment

SEGMENT 2 (Cont.)

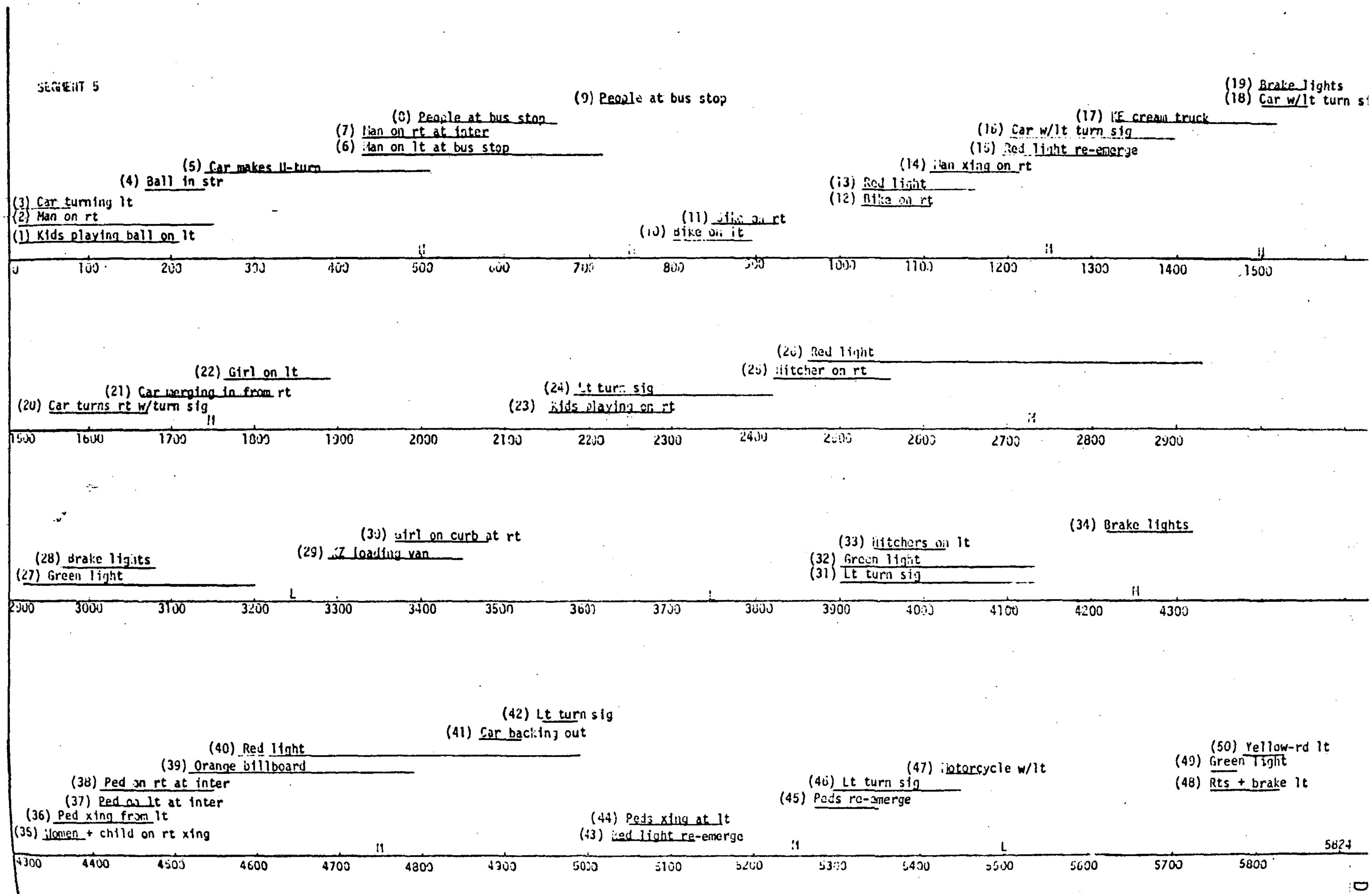



SEGMENT 3
(1) Hitcher on lt
(2) Peds on lt
(3) Child on rt
(4) Ped xing lt
(5) Ped xing lt
(6) Man xing on lt
(7) Green light
(9) Ped on lt
(10) Ped on rt
(11) People w/dogs on lt
(12) Yellow light
(15) Man on rt
(17) People in str on rt
(19) People on rt re-emerge
(21) VW pulls out from rt
(22) Ped xing on lt
(23) Hitcher at lt
(24) Ped xing on lt
(25) Ped xing on rt
(26) Lt turn sig
(27) Rt turn sig
(28) Ped on lt
(29) 2 ped on lt
(30) People by car on rt
(31) Red light
(32) Lt turn sig
(33) Lt turn sig
to 3375
(34) Women xing at lt
100
500
900
1300
1400
1600
1700
1900
2100
2200
2300
2500
2700
2800
3000
3100
3200
4054

SEGMENT 4



(1) Green light
(2) Brake lights
(3) Ped xing on lt
(4) Black car pulls in front
(5) Bike on lt
(6) Car pulls out from rt
(7) Turn sig
(8) Bike passes blue VW
(9) Ped on lt in str
(10) Ped on lt in str
(11) Bike on sidewalk
(12) Ped on rt about to x
(13) Ped on lt about to x
(14) Red light
(15) Bike on lt
(16) Car pulls out from rt
(17) Motorcycle from rt
(18) Const barrier on rt
(19) Lt turn sig
(20) Lt turn sig
(21) Ped on rt corner
(22) Peds on lt corner
(23) Peds on rt corner
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
(24) Car pulls out from lt
(25) Man xing at lt
(26) Ped on lt
(27) Ped on rt
(28) Ped on rt
(29) Hitcher on rt
(30) 3 peds on lt
(31) Child on rt
(32) Child re-emerge
(33) Car on rt ready to pull out
(34) Truck on lt w/flash lgts
(35) Peds on lt
(36) Red light
(37) Brake light
(38) Lt turn sig
(39) Brake lights
(40) Ped xing
(41) Turn sig
(42) Rt turn sig
1600
1700
1800
1900
2000
2100
2200
2300
2400
2500
2600
2700
2800
2900
3000
3100
(43) Arm sig
(44) Rt turn sig
(45) Mailman on rt
(46) Peds on rt at corner
(47) Ped xing
(48) Peds on rt
(49) Peds on lt
(50) Peds xing
(51) Lt turn sig
3100
3200
3300
3400
3500
3600
3700
3800
3900
4000
4100
4200
4300
4400
4500
4600
4700
(52) Ped on rt
(53) Lt turn sig
(54) B of a sign
(55) Rt turn sig
(56) Brake lights
(57) Green light
(58) Red truck turning
(59) Brake lights
(60) Lt turn sig
6336
4800
4900
5000
5100
5200
5300
5400
5500
5600
5700
5800
5900
6000
6100
6200
6300


SEGMENT 5
(1) Kids playing ball on lt
(2) Man on rt
(3) Car turning lt
(4) Ball in str
(5) Car makes U-turn
(6) Man on lt at bus stop
(7) Man on rt at inter
(8) People at bus stop
(9) People at bus stop
(10) Bike on lt
(11) Bike on rt
(12) Bike on rt
(13) Red light
(14) Man xing on rt
(15) Red light re-emerge
(16) Car w/lt turn sig
(17) ICE cream truck
(18) Car w/lt turn si
(19) Brake lights
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
(20) Car turns rt w/turn sig
(21) Car merging in from rt
(22) Girl on lt
(23) Kids playing on rt
(24) Lt turn sig
(25) Hitcher on rt
(26) Red light
1500
1600
1700
1800
1900
2000
2100
2200
2300
2400
2500
2600
2700
2800
2900
(27) Green light
(28) Brake lights
(29) ICE loading van
(30) Girl on curb at rt
(31) Lt turn sig
(32) Green light
(33) Hitchers on lt
(34) Brake lights
2900
3000
3100
3200
3300
3400
3500
3600
3700
3800
3900
4000
4100
4200
4300
(35) Women + child on rt xing
(36) Ped xing from lt
(37) Ped on lt at inter
(38) Ped on rt at inter
(39) Orange billboard
(40) Red light
(41) Car backing out
(42) Lt turn sig
(43) Red light re-emerge
(44) Peds xing at lt
(45) Peds re-emerge
(46) Lt turn sig
(47) Motorcycle w/lt
(48) Rts + brake lt
(49) Green light
(50) Yellow-rd lt
5824
4300
4400
4500
4600
4700
4800
4900
5000
5100
5200
5300
5400
5500
5600
5700
5800

APPENDIX E

ALCOHOL USE FORMS AND SUBJECT INTERVIEW QUESTIONNAIRE

QUESTIONNAIRE BASED ON CAHALAN STUDY (1969)

NAME________________________ DATE OF BIRTH________________________

ADDRESS________________________ TELEPHONE________________________

________________________ OTHER PHONE________________________

MARITAL STATUS________________________ HEIGHT____________ WEIGHT____________

EDUCATION________________________ OCCUPATION________________________

INCOME: BELOW $5K___ $5-7.5K___ $7.5-10K___ $10-15K___ ABOVE $15K___

CURRENT DRIVER'S LICENSE: YES_____ NO_____

AVAILABILITY FOR TESTING:

_____MON _____TUES _____WED _____THUR _____FRI

1 2 3 4 5

DO YOU EVER DRINK ALCOHOLIC BEVERAGES? YES_____ NO_____

1. Give the subject page 1 of the questionnaire and say, "On this page please put a check mark next to the answer that tells how often you usually have wine." Repeat for beer and whiskey or liquor.

FREQUENCY

Wine	1	2	3	4	5	6	7	8	9	10	11
Beer	1	2	3	4	5	6	7	8	9	10	11
Whiskey	1	2	3	4	5	6	7	8	9	10	11

2. For each category of drink (i.e., wine, beer, whiskey or liquor) for which the subject has checked a drinking frequency of "about once a month" (#8) or a higher frequency, you will ask the following further questions which are designed to determine the quantity of his consumption of that beverage. In this portion of the questionnaire you will hand the subject a card with the categories describing quantity with which he is to respond to the subsequent questions, which will be asked verbally.

WINE

1. Three or more times a day
2. Two times a day
3. Once a day
4. Nearly every day
5. Three or four times a week
6. Once or twice a week
7. Two or three times a month
8. About once a month
9. Less than once a month but at least once a year
10. Less than once a year
11. Never had drinks with wine

BEER

1. Three or more times a day
2. Two times a day
3. Once a day
4. Nearly every day
5. Three or four times a week
6. Once or twice a week
7. Two or three times a month
8. About once a month
9. Less than once a month but at least once a year
10. Less than once a year
11. Never had drinks with beer

WHISKEY OR LIQUOR

1. Three or more times a day
2. Two times a day
3. Once a day
4. Nearly every day
5. Three or four times a week
6. Once or twice a week
7. Two or three times a month
8. About once a month
9. Less than once a month but at least once a year
10. Less than once a year
11. Never had drinks with whiskey or liquor

You say, "I will be asking some questions about how often you have drunk some beverages. Please pick whichever answer on this card seems to best describe how often you drink that amount of beverage." Then ask the following questions. (Notice that if he gives a high frequency response to a large quantity of beverage, the instruction requires you to skip to the next beverage as there is no point in asking about small quantities after he tells you he always drinks large quantities.)

WINE

3. If has wine about once a month or more often, ask the following. Repeat for beer and whiskey or liquor.

3a. Think of all the times you have had wine recently. When you drink wine, how often do you have as many as five or six glasses?

1.* Nearly every time
2.* More than half the time
3. Less than half the time
4. Once in a while
5. Never

3b. When you drink wine, how often do you have three or four glasses?

1.* Nearly every time
2.* More than half the time
3. Less than half the time
4. Once in a while
5. Never

3c. When you drink wine, how often do you have one or two glasses?

1. Nearly every time
2. More than half the time
3. Less than half the time
4. Once in a while
5. Never

* If response is here, skip to next beverage.

QUANTITY

Wine 3a)	1	2	3	4	5	Beer 4a)	1	2	3	4	5	Whiskey 5a)	1	2	3	4	5
b)	1	2	3	4	5	b)	1	2	3	4	5	b)	1	2	3	4	5
c)	1	2	3	4	5	c)	1	2	3	4	5	c)	1	2	3	4	5

QUANTITY - VARIABILITY CLASS from Chart 1

Wine______________ Beer______________ Whiskey______________

QUANTITY-FREQUENCY-VARIABILITY CLASS from Chart 2

Heavy Light Moderate Infrequent Abstainer

HEALTH

1. How is your health? Poor_____ Fair____ Good____ Excellent____
2. Are you currently taking any drugs or medication? ______________________
3. Have you consulted with or been under a doctor's care within the past year?
   Reason____
4. Do you have or have you ever had:
   - Ulcers______________________
   - A heart condition______________________
   - Kidney disease______________________
   - Liver disease______________________
   - Muscular disorder______________________
   - Nervous disorder______________________

   Brief description____
5. Do you have any problems with your eyesight?
   - Yes (specify)____
   - No__________
6. Do you have any problems with your hearing?
   - Yes (specify)____
   - No__________

Chart 1.-Quantity-Variability Classifications

Quantity-Variability Class	Modal Quantity (amount drunk "nearly every time" or "more than half the time")	Maximum Quantity (highest quantity drunk)
1	5-6	5-6
2	3-4	5-6 "less than 1/2 time"
3	3-4	5-6 "once in a while"
4	no mode specified	5-6 "less than 1/2 time"
5	3-4	3-4
6	1-2	5-6 "less than 1/2 time"
7	no mode specified	5-6 "once in a while"
8	1-2	5-6 "once in a while"
9	1-2	3-4 "less than 1/2 time"
10	1-2	3-4 "once in a while"
11	1-2	1-2

Chart 2.-Q-F-V Classifications

Q-F-V Group	Frequency (of any alcoholic beverage)	Quantity-Variability Class (beverage drunk most often)
1. Heavy Drinkers 12% of weighted total		
	a.Three or more times a day	1-11
	b.Twice a day	1-9
	c.Every day or nearly every day	1-8
	d.Three or four times a week	1-5
	e.Once or twice a week	1-4
	f.Two or three times a month	1
2. Moderate Drinkers 13%		
	a.Twice a day	10-11
	b.Every day or nearly every day	9-10
	c.Three or four times a week	6-9
	d.Once or twice a week	5-9
	e.Two or three times a month	2-8
	f.About once a month	1-6
3. Light Drinkers 28%		
	a.Every day or nearly every day	11
	b.One to four times a week	10-11
	c.Two or three times a month	9-11
	d.About once a month	7-11
4. Infrequent Drinkers 15%	Drank less than once a month but at least once a year. (quantity questions not asked)	
5. Abstainers 32%	Drank none of the 3 beverages as often as once a year. (quantity questions not asked)	

QUESTIONNAIRE BASED ON OATES-McCOY STUDY (1973)

Name ______________________________ Date ______________

1. How much distilled spirits (i.e., whiskey, gin, vodka) do you generally drink on any one occasion?

   Not applicable (doesn't drink distilled spirits) ________

   One shot (1 - 1-1/2 oz.) ________

   two - three shots ________

   Four-five shots ________

   Six-seven shots ________

   Eight-ten shots ________

   One pint ________

   One pint to one fifth ________

   More than one fifth ________

2. How much beer do you generally drink on one occasion?
   Not applicable (doesn't drink beer) ________

   One bottle (12 oz.) ________

   Two-three bottles ________

   Four -five bottles ________

   One to two six-packs ________

   More than 2 six-packs ________

3. How much wine do you generally drink on any one occasion?
   Not applicable (doesn't drink wine) ________

   One glass (3-4 ounces) ________

   Two-three glasses ________

   Four-five glasses ________

   One bottle ________

   More than one bottle ________

4. How often do you drink during:
(Mark appropriate space in each column.)

	Mornings	Lunch	Afternoon	Dinner	Evenings
Never					
Monthly or less					
Several times ea.month					
Weekly					
Several times ea. week					
Daily					

5. Where do you drink most often?

Private home ________

Bar/restaurant ________

Other (specify)________________________ ________

6. When you drink, are you generally

With spouse/family members ________

With friends ________

With bar room clientel ________

Alone ________

7. How often during the past 12 months have you become physically ill as a result of drinking?

Never ________

Once ________

Twice ________

Several times or more ________

Describe drinking situation at this time(s)________________________

____

____

Related Indices

8. Have you ever been told that you have alcohol-related kidney disorders, liver trouble, or cirrhosis?

Yes__________ No__________

9. Have you ever had delirium tremens, severe shaking, or hallucinations?

Yes__________ No__________

10. Have you ever awakened the morning after drinking and found you could not recall a part of the evening?

Yes__________ No__________

11. a. Have you ever attended a meeting of Alcoholics Anonymous (AA)?

Yes__________ No__________

b. If no, has anyone ever recommended that you attend such meetings?

Yes__________ No__________

12. Have you ever seen a clergyman, social worker, doctor, etc. for help with a problem related to your drinking?

Yes__________ No__________

13. Have you ever been in a hospital because of your drinking?

Yes__________ No__________

14. Have you ever been convicted for "drunk and disorderly" or "public intoxication"?

Yes__________ No__________

If yes, how many times__________

15. Have you ever been convicted for "drunk driving", "driving while intoxicated", or "driving while under the influence of alcoholic beverages"?

Yes__________ No__________

If yes, how many times __________

SUBJECT INTERVIEW

Date ____________________

Name ____________________

Address ____________________

Phone ____________________ Driver's License : ________ Yes ________ No

Age ____________________

Alcohol	Marihuana	Other Drugs
Yes ________	Yes ________	Yes ________
No ________	No ________	No ________
Freq. ________	Freq. ________	Freq. ________
________	________	~~Specify:~~ ________
________	________	________
________	________	________
________	________	________

Willing to participate: ________ alcohol experiment

________ marihuana experiment

Appointment for

Interview, MMPI ____________________

(hour, date)

(continue from here in-person)

Verify:

Age ______________________ Driver's License ______________

Student (year) ______________ Occupation ______________

Prior Experiments: ______________ Alcohol ________ Drug ________ Sim.

(Obtain following in context of conversation, not direct questions. Record All infor. and subjective exaluation.)

Motion Sickness ______________________________

Bad "Trip" with Drug ______________________________

Experience with Acute intoxication ______________________________

____

Health Problems (note current medication) ______________________________

____

Mental Health (note therapy, tranquilizers, etc.) ______________

____

____

Alcohol Q-F-V ______________________________

Drug Use ______________________ Marihuana ______________
(Freq.)

______________________ Other ______________
(Freq.)

Available Hours, Days ______________________________

____

Interviewer Comments ______________________________

____

____

____

____

MMPI ____________________

	Alcohol	Marihuana	Vis. Search
Approved: Yes	________	________	________
No	________	________	________

Scheduled For: ____________________
(Experiment)

	Hour	Day
Training		
Exper 1.		
Exper 2.		

Date	Time Arrived	Time Arrived

APPENDIX F

PRE AND POST BAC LEVELS FOR ALCOHOL EXPERIMENT

Table 1 gives the pre- and post-simulation BAC values for all subjects in the two active treatment groups. The target values of 0.15% BAC and 0.075% BAC were closely approximated. As noted in the text,the pre-simulation BAC was measured one-half to one hour prior to the simulation run. If a subject was less than 0.16% BAC (0.15% group) or 0.08% BAC (0.075% group) at the time of the pre-simulation measurement, he was given an additional drink according to the following schedules because of the time elapsed between the BAC measurement and start of the test.

.075% group		.15% group	
Pre-reading	Additional 80 Proof Vodka (oz)	Pre-reading	Additional 80 Proof Vodka (oz)
0.05%	2 oz.	0.12%	2½ oz.
0.06%	1½ oz.	0.13%	2 oz.
0.07%	1 oz.	0.14%	1½ oz.
0.08%	0 oz.	0.15%	1 oz.
		0.16%	0 oz.

Table F-1

Pre and Post Simulation BAC Values
for 0.075% and 0.15% Groups

Subject I.D.	Pre-test BAC (%)	Post-test BAC (%)
0008	0.087	0.05
1224	0.78	0.068
0016	0.068	0.085
0024	0.082	0.070
0029	0.107	0.66
0031	0.074	0.065
0065	0.09	0.081
0069	0.081	0.066
0073	0.075	0.05
Mean	0.0824	0.0668
SD	0.0114	0.0118
JR13	0.173	0.136
0015	0.158	0.132
0018	0.149	0.150
0019	0.159	0.148
0020	0.170	0.111
0054	0.151	0.131
0056	0.164	0.126
0059	0.153	0.133
0071	0.160	0.140
Mean	0.1597	0.1341
SD	0.0082	0.0117

APPENDIX G
INSTRUCTIONS AND INFORMED CONSENT FORMS

Instructions - The instructions are in two parts: (1) Part A was read to the subject before he entered the lab to acquaint him with the general nature of the test, and (2) Part B served as a check list for the experimenter to ensure that all instructions were included when the subject was first brought into the lab and run on the training film.

Consent form - The consent forms used in the alcohol and marijuana studies are given.

Instructions - Part A

In today's session you will be familiarized with the simulation apparatus and shown a traffic movie.

You will sit in a car in the driver's seat facing a large screen. An eye-movement device and helmet will be placed on your head. This is a sensitive device and requires accurate calibration for set-up. For the calibration you will be asked to look at nine dots on the screen, one at a time. This will be further explained in the simulator. The helmet you will be wearing contains built-in earphones. When the movie is on there will be noise presented to you over the earphones. This simulates traffic noise. Your instructions when you are in the car will be delivered to you via the earphones. You can ask questions or make any comments in a normal tone of voice at any time. There is a microphone in the car which will pick up your voice.

The traffic movie which you will see was made with natural traffic scenes present, such as people crossing streets, children playing on the sidewalk, cars making left turns, etc. When viewing the movie your job is to watch it as if you were actually driving.

There are two more things that you will be required to do as you watch the movie. On the steering wheel on the right side is a button which you should keep pressed down. Whenever you see something that you feel a driver should notice, release the button and then press it down again. Remember that you are to release the button only when you see something that you think is critical or important for a driver to notice. You can release the button as many times as you wish, but only once for every important event. It is important to keep the button pressed down in-between events.

The other job that you will have to do is to detect small white arrows which will appear from time to time on the screen pointing either left or right. They can appear anywhere on the screen. When you see a left arrow you should press the turn signal down. This switch is on the steering column on the left hand side. When you see a right-pointing arrow, push the turn signal up. Since we want to know how quickly you can see these arrows, you should press down or push up on the switch as soon as you see them. You will know if you made a correct response because the arrow will disappear when you move the switch in the correct direction. The arrow will remain on if you respond incorrectly. Try to be both accurate and rapid in responding to the arrows.

Do you have any questions?

The movie which you will see is in several sections. Before the actual driving scene starts a sequence of orange dots will appear on the screen as follows:

The first dot appears in the center (#5), the next in the corner (#1) and so on around for all nine positions and then back to the center. During this period it is very important for you to look steadily at each dot as long as it is on the screen. Right after the dot sequence, the first part of the actual movie comes on and will last about 5 minutes. After the first movie part an orange dot will appear on the center of the screen. Look at the dot for as long as it is on the screen. The movie will then come on again for another 5 minutes and you should again watch it as if you were driving. At the end of the movie the sequence of nine dots that you saw at the beginning of the movie will appear again, and again you should look steadily at each one for as long as it is on the screen. The parts of the film with the dots helps us check our equipment and it is important for you to try to look at the dots as steadily as you can.

Do you have any questions?

We will now go into the lab to where you will see the movie.

Instructions - Part B

CHECKLIST FOR EXPERIMENTER:

The experimenter will show the general layout of the room to make the subject feel comfortable, and make him aware of the functions of the "awesome"-looking apparatus.

1. This is a computer which collects your eye movement data from the glasses which you will be wearing. The computer will enable us to know where you are looking when you watch the movie.

2. These are controls for calibrating the eye-movement-glasses, and for starting the computer and the film projector.

3. This and this are TV monitors. We have a camera mounted there (point to camera behind car) which takes a picture of where your eyes are fixating on the screen. This monitor will show us where you are looking on the screen.

4. This is a video tape recorder, which will record everything that comes on this TV monitor.

5. This is a rear-projection screen on which the movie will be projected. You will see the movie from the other side.

6. That is a 35-mm projector (point) which will project our movie on the screen.

7. This is our air conditioner which will keep us all cool.

8. This is the car in which you will be seated.

Open car:

1. Here is the switch you will have pressed down all the time when you are watching the movie. You will be releasing this only when you see something that is important for driving.

2. This is the signal lever which you will press up or down depending on whether the arrow which you will see is pointing left or right.

9. These are the eyeglasses that measure your eye movement.

10. And this is a motorcycle helmet which you will wear. This will measure any head movement that you will make.

11. S fitted with eyeglasses and helmet and seated in car.

SEAT ADJUSTMENT

Sit in a normal position. The seat is adjustable to allow you a comfortable sitting position.

Do you wish to adjust the seat?

SEAT BELTS

Put the seat belts on. One goes across your lap and the other goes across your chest.

Are you comfortable?

HEAD SIGHT

Look through this sight through the round hole and fixate on the center number, 5, on the screen. Use only your right eye. Adjust this screw until you are looking at number 5 in a normal viewing position.

Are you in a comfortable position when you look at number 5? Your head is not strained up or tilted down when you do this?

We will now ask you to look at the numbers which you see on the screen. Do you see all the numbers?

You will be told over the earphones which numbers you are to look at.

First, you will be asked to view the numbers as you look through the sight with your right eye. Move your head to the numbers so that you are sighting the numbers. Look at 7 moving your head. Now look at 3.

Next you will be asked to sight number 5 and to move your eyes only when you are asked to look at different numbers. Try keeping your head fixed and moving only your eyes.

Then you will be asked to look at the numbers moving your eyes and head in a natural manner.

We will then start the actual movie which will begin with the sequence of orange dots we mentioned before. These orange dots will come on one after another in the same places as the calibration slide dots. You should look steadily at each dot for as long as it is on the screen. You should move both your eyes and your head in a natural manner.

After the nine dots come on the movie will start. Press this switch down when the movie starts and keep it pressed for as long as the movie is on. Release the switch only when you see something that you feel a driver should notice.

Any questions?

You are to press this lever down if a left arrow appears, and up if a right arrow appears. The arrows can appear anywhere on the screen.

INFORMED CONSENT FORM

Please read the following carefully.

The experiment in which you will participate is an investigation of the effects of marihuana upon behavioral variables (visual capabilities and performance in a driving simulator) important to driving.

The cigarette which you will be asked to smoke may or may not be a marihuana treatment. No marihuana dose will be greater than 200 micrograms delta-9 THC per kilogram bodyweight (equivalent to about two joints). While administration of such doses to many subjects has produced no serious difficulties, there is some possibility of short-term discomfort. Use of marihuana may cause subjective "highs", changed perceptions, anxiety, nausea, lethargy, and depression.

There is nothing in our experience which would suggest long-term problems resulting from the marihuana use involved in this study. Subjects should realize, however, that marihuana is under examination as an experimental drug for which all possible subsequent effects of long-term use still are not known. The use of marihuana may produce alterations in behavior, thinking, and mood, which may range from pleasant to extremely unpleasant, and may or may not recur with, or rarely, without subsequent exposure to the drug. Acute psychotic reactions may also develop, but they are very rare.

The experiment in which you will participate will be directly supervised by one or more of the following research psychologists: Herbert Moskowitz, Ph.D., Kenneth Ziedman, Ph.D., Satanand Sharma, Ph.D., Marcelline Burns, Ph.D.

If any problem related to the experiment should arise which you or the experimenters feel requires assistance by a physician, H. Ingham, M.D., or some other medical doctor will be available.

It will be necessary for you to observe the instructions given to you pertaining to the experiment. Your participation will involve at least _____ hrs/session and you should not make appointments which will require your presence until that time has elapsed, or until the experimenter discharges you.

Our understanding is that participants are immune from prosecution for using marihuana in this experiment. The data obtained from the investigation may be used for medical and other scientific purposes and may be made available for publication, but the identity of subjects will not be revealed. You will be paid, but participation in the experiment cannot be expected to benefit you as an individual beyond the payment which you will receive.

You will be free to withdraw from the experiment at any time without prejudice. If you have any questions, please feel free to ask them before or after you consent to participate.

I have read the foregoing information.

_______________________________ Subject ________ Date

_______________________________ Witness ________ Date

4/28/75

EXPERIMENTAL PARTICIPANT AGREEMENT

Please read the following carefully

The experiment in which you will participate is an investigation of the effects of alcohol upon behavioral variables (visual capabilities and performance in a driving simulator) important to driving.

You may or may not be given alcohol in the beverage which you will be asked to drink. No alcohol dose will be greater than 1.25 grams alcohol per kilogram bodyweight.

Administration of alcohol to many subjects has produced no serious difficulties, but there is some possibility of short-term discomfort. Alcohol may cause subjective "highs", depression, speech slurring, motor incoordination, and nausea.

There is nothing in our experience which would suggest long-term problems resulting from the alcohol use involved in this study. You should realize, however, that long-term, frequent use of alcohol has been associated with physiological and psychological disorders.

The experiment in which you will participate will be directly supervised by one or more of the following research psychologists: Herbert Moskowitz, Ph.D., Kenneth Ziedman, Ph.D., Satanand Sharma, Ph.D., Marcelline Burns, Ph.D.

If any problem related to the experiment should arise which you or the experimenters feel requires assistance by a physician, H. Ingham, M.D. or some other medical doctor will be available.

It will be necessary for you to observe the instructions given to you pertaining to the experiment. Your participation will involve at least ______ hrs./session, and you should not make appointments which will require your presence until that time has elapsed, or until the experimenter discharges you.

The data obtained from the investigation may be used for medical and other scientific purposes and may be made available for publication, but the identity of subjects will not be revealed. You will be paid, but participation in the experiment cannot be expected to benefit you as an individual beyond the payment which you will receive.

You will be free to withdraw from the experiment at any time. If you have any questions, please feel free to ask them before or after you consent to participate.

I have read the foregoing information.

______________________________ __________
Subject Date

______________________________ __________
Witness Date

APPENDIX H

EFFECT OF SUBSIDIARY TASK ON SEARCH PATTERNS

H.1 Introduction

It has been amply demonstrated in the literature that the characteristics of visual search are profoundly influenced by task and stimulus variables such as instructions, costs and payoffs of detecting stimulus categories, spatial and temporal probabilities of stimulus occurrence. Although investigation of the stimulus variables influencing visual search was not a major aspect of this study, the fact that results were obtained for two types of subsidiary tasks (arrows distributed over a $\pm 15^{o}$ region for the alcohol and pilot marijuana studies and the 'C' ring tasks presented at screen center for the final marijuana study) allows a comparison of visual search results for two different spatial distributions of occurrence of the subsidiary task with the traffic scene remaining constant.

H.2 Subsidiary Task Comparisons

The three groups of subjects run in this study were:

Group	Conditions	Treatment Levels	Subsidiary Task
Alcohol	independent groups, 9 subjects per group	Placebo .075%, .15%	arrows ($\pm 15^{o}$ distribution)
Pilot marijuana	repeated measures 7 subjects	Placebo 200 mcg THC	arrows ($\pm 15^{o}$ distribution)
Final marijuana	repeated measures 10 subjects	Placebo 200 mcg THC	'C' Ring (screen center)

Comparisons were made between the three placebo groups to determine if the C ring subsidiary task significantly influenced spatial distribution of dwells as well as the other characteristics of visual search behavior. Recall that drug treatments had little or no effect on the spatial distribution of dwells for either marijuana or alcohol, although a significant alcohol effect was demonstrated for other measures of visual search behavior.

Table H.1 shows the percentage of dwells falling in the central $\pm 5^{o}$ region and the central $\pm 15^{o}$ region (horizontal axis only) for the three placebo groups.

Table H.1

Percentage of Dwells Falling in Central Screen Region for Three Placebo Groups

Group	Subsidiary Task	Percentage of Fixations $\pm 5^{o}$ Horiz Region	$\pm 15^{o}$ Horiz Region
Alcohol (N=9)	Arrows ($\pm 15^{o}$)	51.6	86.90
Pilot marijuana (N=7)	Arrows ($\pm 15^{o}$)	53.3	89.0
Final marijuana (N=10)	C-Ring (center)	62.9	93.7

A substantially higher percentage of dwells was found in the $\pm 5^{o}$ region for the C ring condition compared to the arrows. A slightly higher percentage was found in the $\pm 15^{o}$ region.

Additional comparisons were made by performing t-tests between all possible pairs of the three placebo groups for various measures of visual search behavior. That is, the comparisons examined were:

(1) alcohol - pilot marijuana (same subsidiary task)

(2) alcohol - final marijuana (different subsidiary task)

(3) final marijuana - pilot marijuana (different subsidiary task).

If the most influential factor between these groups is the nature of the subsidiary task, then comparison (1) should show no differences and comparisons (2) and (3) should show differences. The results are shown in Table H.2. The above hypothesis is generally upheld: only 4 out of 30 significant differences occur between the placebo groups of the alcohol and pilot marihuana studies. The predominant pattern is that of no difference between alcohol and pilot marijuana and significant differences between alcohol/final marijuana and pilot marijuana/final marijuana.

H.3 Conclusions

It is concluded that the nature of the subsidiary task substantially changed visual search patterns independently of drug effects. Previous studies (see Appendix B) have indicated increased attention to central areas at the expense of peripheral areas under alcohol. The fact that this was not found in the present study is attributed to the subsidiary task which forced attention over a large portion of the screen. This result has important implications for alcohol countermeasures as it indicates attention attracting displays (within the vehicle or on the road) can be useful to maintain improved search patterns under the effects of alcohol. Under marijuana, however, the degradation in information processing seems unrelated to visual search behavior and, therefore, this scheme would not be an effective countermeasure technique.

Table H.2

Comparisons Between Three Placebo Groups
(x = sig. difference)

Measure	(1) Alcohol/ Pilot Marij.	(2) Alcohol/ Final Marij.	(3) Alcohol/ Final Marij.
Mean Time per Dwell	x	x	x
Mean Time per Pursuit		x	x
Dwell Frequency		x	x (p=.06)
Pursuit Frequency		No sig. differences	
Total Time in Dwell		No sig. differences	
Total Time in Pursuit		No sig. differences	
Mean Pursuit Length		x	x
SD Pursuit Duration		x	x
SD Dwell Duration	x	x	x
Mean Total Transition Distance		x	x
Mean Horiz. Transition Distance		x	x
Mean Vert. Transition Distance	x	x	x
SD Total Transition Distance		x	x
SD Horiz. Transition Distance		x	x
SD Vert. Transition Distance	x	x	x
Mean Transition Duration		x	x
SD Transition Duration			x

APPENDIX I
DWELL TIME ANALYSIS ON ARROW TASK

In an attempt to further elucidate possible alcohol treatment effects, a manual analysis was made of dwell behavior on correct responses to subsidiary task arrows to determine the mean dwell time on arrows as a function of alcohol level. The purpose was to determine if more time was required under alcohol to reach a correct decision. (A manual analysis was required as this calculation had not been included in the original software and re-running all the data just for this information was too costly.)

The results of the placebo and 0.15% BAC groups for correct responses are given below.

Condition	Mean Number Correct Responses	Mean Frequency of Dwells on Arrows	Mean Frequency of Fixations per Response	Mean Dwell Time per Arrow (seconds)
Placebo		38.8	1.42	0.947
0.15% BAC		39.5	1.38	1.085

Note that the mean dwell time per arrow is nearly three times longer than the mean times for all dwells (Table 4.2). Further, although the difference in mean dwell time per arrow between the placebo and 0.015% BAC groups is small, and statistically non-significant due to the large inter-subject variability, it is the same order of magnitude as the differences found in mean times for all dwells (about 0.10 sec difference for all dwells, 0.14 sec differences for dwells on arrows). Thus, these data are more directly suggestive of the interpretation that information processing time is increased under alcohol as they represent looks which are associated with known decisions. (Correlated decision data were not obtained for looks at events other than the secondary task stimuli.)

APPENDIX J
CRITICAL EVENT CALCULATION PROCEDURES

Critical event data were analyzed in two ways: (1) counting all events in a given average regardless of whether the event was seen, and (2) counting only those events seen in a given average. The second method provides a comparison of looking behavior under active drug treatment to placebo. The first measure indicates a "population" effect, i.e., average looking behavior for treatment versus placebo regardless of whether each subject did or did not look at a given event. Only the second measure is reported as the two generally agreed and the second is the more meaningful. The equations used to compute the various averages are given below. (A list of all measures obtained for each event is given in Table 1.)

(A) Individual Critical Events. For each critical event each measure in Table 1 was averaged across subjects as follows (sums indicated are across subjects):

Average A - numerical averages of all subjects regardless of whether an event was looked at.

Average B -

$$\overline{\text{NLOOK}} = \frac{\Sigma\text{NLOOK}}{\text{number of subjects who looked at event one or more times}}$$

$$\left.\begin{array}{l}\overline{\text{TLOOK}}\\ \overline{\text{LKRAT}}\\ \overline{\text{TFLR}}\end{array}\right\}\quad \text{similar to } \overline{\text{NLOOK}}$$

$$\overline{\text{NFIX}} = \frac{\Sigma\text{NFIX}}{\text{number of subjects who fixated an event one or more times}}$$

$\left.\begin{array}{l}\overline{TFIX}\\ \overline{AVTFIX}\end{array}\right\}$ similar to $\overline{NFIX}$

$$\overline{NPUR} = \frac{\Sigma NPUR}{\text{number of subjects who pursued event one or more times}}$$

$\left.\begin{array}{l}\overline{TPUR}\\ \overline{AUTPUR}\end{array}\right\}$ similar to $\overline{NPUR}$

(B) Critical Event Subject Category Averages (averages for each subject across all events in a category)

Average A - averaged across all events in a category for an individual subject regardless of whether an event was seen.

Average B -

$\left.\begin{array}{l}\text{NLOOK}\\ \text{TLOOK}\\ \text{TFLR}\end{array}\right\}$ averaged only over events which were looked at at least once

$\left.\begin{array}{l}\text{NFIX}\\ \text{TFIX}\end{array}\right\}$ averaged over events which were fixated at least once

$\left.\begin{array}{l}\text{NPUR}\\ \text{TPUR}\end{array}\right\}$ averaged over events which were pursued at least once

$$\text{AVTFIX} = \frac{\text{total fixation time for all events in category}}{\text{total number of fixations on all events in category}}$$

$$\text{AVTPUR} = \frac{\text{total pursuit time for all events in category}}{\text{total number of pursuits on all events in category}}$$

(C) <u>Cross-subject Category Averages</u> (averages across subjects and across all events in a category)

Average A and Average B - Each average taken across all subjects in a given category average, excluding cases where the category average is zero.

Table J-1 Critical Event Measures

TLOOK	- Total time in seconds event was looked at while it was on the screen.
LKRAT	- Ratio of TLOOK to total time event was on the screen (LOOK RATIO in report).
NFL	- Absolute frame number at which event was first looked at.
NFLR	- Frame number event first looked at relative to frame number event first judged visible.
TFLR	- Time event first looked at in seconds relative to time event first judged visible (TIME OF FIRST LOOK in report).
ANGFL	- Horizontal angle in degrees of event location at time of first look.
NLOOK	- Total number of looks (fixations and/or pursuits) where the prior look was outside the event region (FREQUENCY OF SEPARATE LOOKS in report).
NFIX	- Total number of all fixations on event (FREQUENCY OF REPETITIVE DWELLS in report).
NPUR	- Total number of all pursuits on event (FREQUENCY OF PURSUITS in report).
TFIX	- Total time in seconds of all fixations on event (TOTAL DWELL TIME in report).
TPUR	- Total time in seconds of all pursuits on event (TOTAL PURSUIT TIME in report).
AV.TFIX	- TFIX/NFIX (secs) (MEAN TIME/DWELL in report).
AV.TPUR	- TPUR/NPUR (secs) (MEAN TIME/PURSUIT in report).

APPENDIX K

DATA TABULATIONS

Additional data tabulations are presented in this appendix. Included are results for the alcohol study, the pilot marihuana study and the final marihuana study. Tables K.1 through K.9 present complete results on spatial distributions of dwells for the three studies. Tables K.14 through K.17 present dwell, pursuit and critical event results for the pilot marihuana study and Tables K.18 through K.22 present similar data for the final marihuana study.

Table

PLACEBO	Left			Center	Right			
	$>25^{\circ}$	$15^{\circ}-25^{\circ}$	$5^{\circ}-15^{\circ}$	$\pm5^{\circ}$	$5^{\circ}-15^{\circ}$	$15^{\circ}-25^{\circ}$	$>25^{\circ}$	
Up $+12^{\circ}$ to $+6^{\circ}$	.003	.010	.026	.042	.015	.004	.001	.101
Up $+6^{\circ}$ to 0°	.002	.026	.080	.254	.076	.017	.005	.460
Down 0° to -6°	.001	.019	.063	.220	.093	.032	.008	.436
	.006	.055	.169	.516	.184	.053	.014	

0.075% BAC	$>25^{\circ}$	$15^{\circ}-25^{\circ}$	$5^{\circ}-15^{\circ}$	$\pm5^{\circ}$	$5^{\circ}-15^{\circ}$	$15^{\circ}-25^{\circ}$	$>25^{\circ}$	
Up $+12^{\circ}$ to $+6^{\circ}$	.008	.016	.026	.019	.006	.003	.003	.081
Up $+6^{\circ}$ to 0°	.012	.030	.089	.205	.060	.017	.007	.420
Down 0° to -6°	.003	.012	.055	.274	.102	.034	.021	.501
	.023	.058	.170	.498	.168	.054	.031	

.15% BAC	$>25^{\circ}$	$15^{\circ}-25^{\circ}$	$5^{\circ}-15^{\circ}$	$\pm5^{\circ}$	$5^{\circ}-15^{\circ}$	$15^{\circ}-25^{\circ}$	$>25^{\circ}$	
Up $+12^{\circ}$ to $+6^{\circ}$	.001	.009	.016	.020	.007	.006	.002	.061
Up $+6^{\circ}$ to 0°	.002	.024	.074	.221	.071	.025	.004	.421
Down 0° to -6°	.006	.022	.087	.278	.097	.020	.008	.518
	.009	.055	.177	.519	.175	.051	.014	

Table K.1 DWELL FREQUENCY DISTRIBUTIONS FOR THREE ALCOHOL LEVELS

The screen was divided into a 3x7 matrix as indicated by the angular dimensions.

Each entry is the proportion of total dwells falling in the given cell. Column and row sums are also given.

N = 9 each group.

PLACEBO	Left			Center	Right			
	>25°	15°-25°	5°-15°	±5°	5°-15°	15°-25°	>25°	
Jp +12° to +6°	.003	.008	.025	.046	.013	.003	.000	.098
+6° to 0°	.002	.020	.067	.287	.065	.012	.005	.458
)own 0° to -6°	.001	.015	.054	.260	.083	.025	.008	.446
	.006	.043	.146	.593	.161	.040	.013	

0.075% BAC	>25°	15°-25°	5°-15°	±5°	5°-15°	15°-25°	>25°	
Up +12° to +6°	.006	.011	.022	.017	.004	.002	.001	.063
+6° to 0°	.008	.019	.069	.236	.052	.011	.005	.400
Down 0° to -6°	.002	.008	.043	.360	.087	.023	.014	.537
	.016	.038	.134	.613	.143	.036	.020	

.15% BAC	>25°	15°-25°	5°-15°	±5°	5°-15°	15°-25°	>25°	
Up +12° to +6°	.001	.005	.011	.020	.005	.004	.002	.050
+6° to 0°	.001	.016	.059	.268	.062	.016	.002	.424
)own 0° to -6°	.004	.015	.076	.335	.080	.013	.006	.529
	.006	.036	.146	.623	.147	.033	.010	

Table K.2 DWELL TIME DISTRIBUTIONS FOR THREE ALCOHOL LEVELS

The screen was divided into a 3x7 matrix as indicated by the angular dimensions.

Each entry is the proportion of total time spent in the dwell state in the given cell. Column and row sums are also given.

N = 9 each group.

ALCOHOL — Left / Center / Right

Placebo

			>25°	15°-25°	5°-15°	±5°	5°-15°	15°-25°	>25°	
Up	+12° to 6°		.141	.242	.340	.347	.326	.217	.059	.239
	+6° to 0°		.326	.281	.315	.419	.310	.291	.293	.319
Down	0° - -6°		.163	.257	.316	.441	.344	.286	.301	.301
			.210	.260	.324	.402	.327	.265	.218	

0.075% BAC

			>25°	15°-25°	5°-15°	±5°	5°-15°	15°-25°	>25°	
Up	+12° to 6°		.213	.271	.305	.440	.347	.329	.156	.294
	+6° to 0°		.259	.317	.368	.547	.401	.273	.268	.348
Down	0° - -6°		.108	.306	.394	.603	.395	.307	.249	.337
			.193	.298	.356	.530	.381	.303	.224	

0.15% BAC

		>25°	15°-25°	5°-15°	±5°	5°-15°	15°-25°	>25°	
+12° to 6°		.185	.312	.324	.388	.422	.313	.167	.302
+6° to 0°		.251	.318	.391	.576	.443	.285	.193	.351
0° - -6°		.241	.331	.435	.599	.406	.311	.268	.370
		.226	.320	.383	.521	.424	.303	.209	

Table K.3 MEAN DWELL DURATION DISTRIBUTIONS FOR THREE ALCOHOL LEVELS

The screen was divided into a 3x7 matrix as indicated by the angular dimensions.

Each entry is the mean time of all dwells falling in that cell.

N = 9 each group.

Vertical Boundaries	Treatment	Horizontal Boundaries: Left >25°	Left 15°-25°	Left 5°-15°	± 5°	Right 5°-15°	Right 15°-25°	Right >25°	Vertical Distribution
Up +6° to 12°	Placebo	0.001	0.007	0.006	0.007	0.010	0.005	0.002	0.038
	200 THC	0.001	0.007	0.004	0.004	0.003	0.001	0.001	0.021
0° to 6°	Placebo	0.000	0.026	0.090	0.289	0.102	0.022	0.005	0.534
	200 THC	0.001	0.029	0.106	0.265	0.091	0.011	0.003	0.506
Down 0° to -6°	Placebo	0.000	0.010	0.058	0.237	0.092	0.022	0.010	0.429
	200 THC	0.000	0.015	0.118	0.236	0.080	0.019	0.006	0.474
Horizontal Distribution	Placebo	0.001	0.043	0.154	0.533	0.204	0.049	0.017	1.001
	200 THC	0.002	0.051	0.228	0.505	0.174	0.031	0.010	1.001

Table K.4 DWELL FREQUENCY DISTRIBUTIONS FOR PLACEBO AND ACTIVE TREATMENTS - PILOT MARIJUANA STUDY (N = 7, repeated measures)

The screen was divided into a 3x7 matrix as indicated by the angular dimensions.

Each entry is the proportion of total dwells falling in the given cell. Column and row sums are also given.

Vertical Boundaries	Treatment	Horizontal Boundaries Left				Right			Vertical Distribution
		>25°	15°-25°	5°-15°	± 5°	5°-15°	15°-25°	> 25°	
Up +6° to 12°	Placebo 200 THC	0.001 0.000	0.005 0.006	0.004 0.003	0.006 0.003	0.008 0.002	0.003 0.001	0.001 0.000	0.028 0.015
0° to 6°	Placebo 200 THC	0.000 0.001	0.018 0.019	0.072 0.087	0.334 0.306	0.083 0.078	0.013 0.007	0.003 0.002	0.523 0.500
Down 0° to -6°	Placebo 200 THC	0.000 0.000	0.007 0.013	0 46 0.120	0.294 0.270	0.081 0.063	0.015 0.013	0.005 0.004	0.448 0.483
Horizontal Distribution	Placebo 200 THC	0.000 0.001	0.030 0.038	0.122 0.210	0.634 0.579	0.172 0.143	0.031 0.021	0.009 0.006	0.998 0.998

Table K.5 DWELL TIME DISTRIBUTIONS FOR PLACEBO AND ACTIVE TREATMENTS - PILOT MARIJUANA STUDY (N = 7, repeated measures)

The screen was divided into a 3x7 matrix as indicated by the angular dimensions.

Each entry is the proportion of total time spent in the dwell state in the given cell. Column and row sums are also given.

Vertical Boundaries	Treatment	Horizontal Boundaries Left $>25^{0}$	$15^{0}-25^{0}$	$5^{0}-15^{0}$	$\pm5^{0}$	$5^{0}-15^{0}$	Right $15^{0}-25^{0}$	$>25^{0}$	Vertical Distribution
Up $+6^{0}$ to 12^{0}	Placebo 200 THC	.159 .101	.300 .381	.398 .198	.372 .317	.320 .243	.160 .274	.148 .111	.265 .232
0^{0} to 6^{0}	Placebo 200 THC	.075 .196	.308 .307	.364 .365	.536 .501	.388 .367	.286 .257	.250 .272	.315 .323
Down 0^{0} - -6^{0}	Placebo 200 THC	.057 .150	.293 .346	.363 .413	.567 .521	.387 .332	.304 .284	.155 .327	.304 .339
Horizontal Distribution	Placebo 200 THC	.097 .149	.300 .345	.375 .325	.492 .446	.365 .314	.250 .272	.184 .237	.295 .298

Table K.6 MEAN DWELL DURATION DISTRIBUTIONS FOR PLACEBO AND ACTIVE TREATMENTS - PILOT MARIJUANA STUDY (N = 7, repeated measures)

The screen was divided into a 3x7 matrix as indicated by the angular dimensions.

Each entry is the mean time of all dwells falling in that cell.

Vertical Boundaries	Treatment	Horizontal Boundaries Left > 25°	15°-25°	5°-15°	± 5°	Right 5°-15°	15°-25°	> 25°	Vertical Distribution
Up +6° to 12°	Placebo	0.000	0.004	0.008	0.010	0.006	0.002	0.001	0.031
	200 THC	0.002	0.008	0.015	0.016	0.006	0.003	0.001	0.051
0° to 6°	Placebo	0.002	0.016	0.093	0.360	0.076	0.010	0.002	0.559
	200 THC	0.001	0.014	0.082	0.271	0.058	0.008	0.001	0.435
Down 0° to -6°	Placebo	0.004	0.014	0.062	0.259	0.063	0.005	0.002	0.409
	200 THC	0.002	0.015	0.097	0.314	0.063	0.018	0.005	0.514
Horizontal Distribution	Placebo	0.006	0.034	0.163	0.629	0.145	0.017	0.005	0.999
	200 THC	0.005	0.037	0.194	0.601	0.127	0.029	0.007	1.000

Table K.7 DWELL FREQUENCY DISTRIBUTIONS FOR PLACEBO AND ACTIVE TREATMENTS - FINAL MARIJUANA STUDY (N = 10, repeated measures)

The screen was divided into a 3x7 matrix as indicated by the angular dimensions.

Each entry is the proportion of total dwells falling in the given cell. Column and row sums are also given.

Vertical All Boundaries	Treatment	Horizontal All Boundaries Left				Right			Vertical Distribution
		>25°	15°-25°	5°-15°	± 5°	5°-15°	15°-25°	>25°	
Up + 6° to 12°	Placebo	0.000	0.002	0.005	0.010	0.004	0.001	0.000	0.018
	200 THC	0.001	0.004	0.010	0.012	0.004	0.002	0.001	0.034
0° to 6°	Placebo	0.001	0.008	0.069	0.422	0.051	0.005	0.001	0.557
	200 THC	0.001	0.007	0.060	0.335	0.038	0.004	0.001	0.446
Down 0° to -6°	Placebo	0.002	0.010	0.052	0.314	0.041	0.003	0.001	0.423
	200 THC	0.001	0.008	0.080	0.383	0.041	0.008	0.002	0.523
Horizontal Distribution	Placebo	0.003	0.020	0.126	0.746	0.092	0.009	0.002	0.998
	200 THC	0.003	0.019	0.150	0.740	0.083	0.014	0.004	1.003

Table K. 8 DWELL TIME DISTRIBUTIONS FOR PLACEBO AND ACTIVE TREATMENTS - FINAL MARIJUANA STUDY (N = 10, repeated measures)

The screen was divided into a 3x7 matrix as indicated by the angular dimensions.

Each entry is the proportion of total time spent in the dwell state in the given cell. Column and row sums are also given.

Table K.9 Mean Dwell Durations for Placebo and Active Treatments - Final Marijuana Study (N=10, repeated measures)

Vertical All Boundaries	Treatment	Horizontal Boundaries: Left 25°	Left 15°-25°	Left 5°-15°	± 5°	Right 5°-15°	Right 15°-25°	Right 25°	Vertical Distribution
Up +6° to 12°	Placebo 200THC	0.082 0.000	0.314 0.120	0.212 0.251	0.516 0.585	0.260 0.250	0.239 0.000	0.064 0.000	0.562 0.402
0° to 6°	Placebo 200 THC	0.110 0.000	0.306 0.235	0.400 0.360	0.665 0.558	0.364 0.345	0.220 0.205	0.163 0.000	0.743 0.568
Down 0° to -6°	Placebo 200 THC	0.050 0.000	0.244 0.380	0.442 0.395	0.673 0.639	0.369 0.314	0.255 0.237	0.145 0.157	0.726 0.707
Horizontal Distribution	Placebo 200 THC	0.081 0.000	0.288 0.245	0.351 0.335	0.618 0.594	0.331 0.303	0.238 0.147	0.124 0.052	

The screen was divided into a 3 x 7 matrix as indicated by the angular dimensions. Each entry gives the mean dwell time of all dwells in the given cell. Column and row means are also given.

Table K.10 STANDARD DEVIATIONS AND RANGES OF DWELL AND PURSUIT RESULTS - ALCOHOL STUDY (N = 9 each group)

The variability measures in this table refer to the distribution of individual subject means and therefore represent estimates of "between subjects" variability.

Measure	Placebo	.075% BAC	.15% BAC
Mean Time per Dwell (sec)	0.37	0.47 (+27%)	0.48 (+30%)
SD	0.046	0.073	0.082
Range	0.310-0.441	0.405-0.592	0.385-0.632
Mean Time per Pursuit (sec)	1.23	1.48 (+20%)	1.36 (+11%)
SD	0.17	0.26	0.11
Range	1.01-1.55	1.10-1.81	1.18-1.54
Dwell Frequency	1753	1290 (-26%)	1297 (-26%)
SD	332	288	122
Range	1025-2201	790-1650	1109-1534
Pursuit Frequency	157	189 (20%)	192 (+22%)
SD	75	44	44
Range	105-347	126-260	147-276
Total Time in Dwells (sec)	653	601 (-8%)	628 (-4%)
SD	104	83	76
Range	395-733	468-707	488-707
Total Time in Pursuits (sec)	196	281 (+43%)	259 (+32%)
SD	103	98	54
Range	117-457	187-461	195-340
Mean Pursuit Length (deg)	5.9	5.5 (-7%)	5.3 (-10%)
SD	0.95	0.49	0.82
Range	5.0-7.6	4.6-6.1	4.3-7.0

Table K.11 CENTROID LOCATIONS AND STANDARD DEVIATIONS OF DWELL DISTRIBUTIONS - ALCOHOL STUDY (N = 9 each group)

	Centroid of Dwell Distribution (deg. from straight ahead)	
BAC	Horiz	Vert
Placebo	0.27	0.895
0.075%	0.29	0.397
0.15%	-0.07	0.077

	Standard Deviations of Dwell Distribution (deg.)	
BAC	Horiz	Vert
Placebo	9.27	4.01
0.075%	10.56	3.49
0.15%	9.47	3.78

Table K.12 SACCADIC TRANSITION DURATION AND ANGULAR DISTANCE - ALCOHOL STUDY (N = 9 each group)*

	Placebo	0.075%	0.15%	Kruskal-Wallis Sig. Level
Mean Total Transition Distance (Deg)	9.05	8.74	8.16	NS
Mean Horizontal Trans. Distance (Deg)	8.25	8.24	7.66	NS
Mean Vertical Trans. Distance (Deg)	2.48	1.94	1.83	NS
S.D. Total Trans. Distance (Deg)	6.01	7.13	6.45	NS
S.D. Horizontal Trans. Distance (Deg)	6.69	7.64	6.93	NS
S.D. Vertical Trans. Distance (Deg)	2.57	2.20	2.08	NS
Mean Trans. Duration (sec)	0.0867	0.0830	0.0829	NS
S.D. Trans. Duration (sec)	0.0573	0.0574	0.0572	NS

*Due to the 60 Hz low pass filter incorporated in the eye movement circuitry the transition times do not accurately represent actual saccadic times.

Table K.13 DISCRETE RESPONSE DATA

Alcohol Study (N=8 each group)[1]

BAC	Arrow Horizontal Location -15°	-10°	-5°	+5°	+10°	+15°
0%	4.1	3.2	1.8	1.6	2.4	3.0
0.075%	5.0	2.6	1.8	1.6	2.0	2.6
0.15%	2.5	3.5	2.3	1.5	2.3	4.2

Table 4A: Mean Response Time in Secs for 1st Time Correct Responses as a function of Horizontal Location of Subsidiary Task Arrow

BAC	Arrow Horizontal Location -15°	-10°	-5°	5°	+10°	+15°
0%	1.6	4.8	5.1	5.5	5.9	3.9
0.075%	1.9	5.4	5.5	5.6	5.6	4.4
0.15%	1.3	4.3	4.6	5.4	5.6	4.0

Table 4B: Mean Number 1st Time Correct Responses versus Horizontal Location of Subsidiary Task Arrows

BAC	Response Time (secs)	Number Correct	% Correct out of 35
0%	2.5	26.75	76.4
0.075%	2.3	28.38	81.1
0.15%	2.6	25.13	71.8

Table 4C: Mean Response Times and Total Number Correct (both for 1st time correct responses) for all Arrow Presentations

BAC	Movie Segment 1	2	3	4	5	Mean Over Entire Movie
0%	10.1	15.5	13.5	12.8	16.9	69
.075%	8.4	12.1	7.8	10.8	12.0	51
.15%	7.3	13.5	11.6	13.5	17.1	63

Table 4D: Mean Number 'Critical Event' Switch Responses for Movie Segment

Note: [1]Due to equipment malfunctions discrete response data were lost for one subject.

Table K.14 PILOT MARIJUANA STUDY (N = 7, repeated measures)

Allocation of Viewing Time (Absolute Values in Seconds - Percentages Relative to Total Movie Duration in Parentheses)[1]

Treatment	Dwells	Pursuits	Saccades	Total (Dwells, Pursuits and Saccades)	Blinks[3]
Placebo	661.77 (65)	223.92 (22)	113.801 (11)	999.491 (98)	22.509 (2)
200 mcg THC	660.11 (65)	207.22 (20)	126.881 (12)	994.211 (97)	27.789 (3)

1. Total time for traffic portions of movie = 1022 sec.
2. Total saccadic time estimated by taking the product of total number of fixations and the mean interdwell times.
3. Blink durations were not measured. The blink times are based on the difference between the sum of dwell, pursuit and saccadic time from the total movie time.

Table K.15 STATISTICAL SUMMARIES - PILOT MARIJUANA STUDY*
(N = 7, repeated measures)

Measure	Treatment: Placebo	Treatment: 200 mcg THC/kg BW
Mean Total Dwells	1460.86	1689.86
SD	304.34	311.20
Range	1219-2071	1278-2161
Mean Total Dwell Time (sec)	661.77	664.38
SD	71.44	43.86
Range	536.94-747.68	621.63-733.53
Mean Total Pursuit	160.57	152.00
SD	41.32	31.10
Range	100-225	102-187
Mean Total Pursuit Time (sec)	223.92	195.66
SD	83.45	51.69
Range	114.99-368.54	113.12-266.36
Mean Dwell Time (sec)	0.46	0.40
SD	0.07	0.08
Range	.347-.541	.334-.560
Mean SD Dwell Time (sec)	0.45	0.36
SD	0.10	0.09
Range	.317-.553	.297-.541
Mean Pursuit Duration (sec)	1.36	1.29
SD	0.19	0.26
Range	1.04-1.64	1.01-1.68
Mean Pursuit Length (deg)	5.77	6.24
SD	0.71	1.89
Range	4.5-6.5	4.3-10.0
Mean Total Blinks	158.14	302.29
SD	107.56	263.94
Range	76-319	65-861
Mean Saccade Duration	0.08	0.08
SD	0.01	0.01
Range	0.0697-.0922	.0687-.1019

*None of the differences were statistically significant as measured by a paired measures t-test.

Table K.15 Continued

Measure	Treatment	
	Placebo	200 mcg THC/kg BW
Mean Horizontal Dwell Transition Length	7.72	7.75
SD	1.29	1.26
Range	6.28-9.88	6.06-9.88
Mean Vertical Dwell Transition Length	1.53	1.51
SD	0.37	0.33
Range	1.06-2.18	1.15-2.13
Mean Total (Horizontal and Vertical) Dwell Transition Length	8.08	8.08
SD	1.28	1.28
Range	6.66-10.18	6.33-10.18

Table K.16 DWELL TRANSITION DISTANCES - PILOT MARIJUANA STUDY
(N = 7, repeated measures)

	Placebo (O/D)	200 mcg THC (O/D)
Mean total transition distance (deg.)	8.08	7.59
Mean horizontal transition distance (deg.)	7.72	7.28
Mean vertical transition distance (deg.)	1.53	1.44
S.D. total transition distance (deg.)	5.82	5.37
S.D. horizontal transition distance (deg.)	6.44	6.01
S.D. vertical transition distance (deg.)	1.77	1.55
Mean transition duration (sec.)	0.0779	0.0794
S.D. transition duration (sec.)	0.0454	0.0521

Table K.17 Event Switch and Arrow Responses - Pilot Marihuana Study

(N = 7, repeated measures)

Treatment	Mean Event Switch Responses per Movie Segment				
	1	2	3	4	5
Placebo	9.86	20.4	16.29	20.57	20.43
SD	8.51	17.64	16.41	27.63	21.06
200mcg THC	14.29	30.29	19.57	24.00	26.14
SD	9.38	22.54	15.59	26.78	20.91

Treatment	Mean Response Times for Arrows and Number of Responses (in Brackets)			
	First Time Correct Response	All Correct Responses	Total False Alarms to Left Arrows	Right Arrows
Placebo	2.28 (26.14)	2.29 (26.43)	1	2
SD	0.56 (6.99)	0.57 (7.14)		
200mcg THC	2.26 (28.14)	2.28 (28.57)	1	5
SD	0.52 (3.53)	0.53 (3.36)		

Table K.18 FINAL MARIJUANA STUDY (N = 10, repeated measures)

Allocation of Viewing Time (Absolute Values in Seconds
Percentages Relative to Total Movie Duration in Parentheses)[1]

Treatment	Dwells	Pursuits	Saccades[2]	Total (Dwells, Pursuits and Saccades)	Blinks[3]
Placebo (new)	668.09 (65)	235.80 (23)	84.014 (8)	987.904 (96)	34.096 (3)
200mcg THC (new)	666.91 (65)	220.43 (22)	88.732 (9)	976.072 (96)	45.928 (4)

1. Total time for traffic portions of movie = 1022 sec.

2. Total saccadic time estimated by taking the product of total number of fixations and the mean interdwell times.

3. Blink durations were not measured. The blink computations are based on the difference between the sum of dwell, pursuit and saccadic times and the total movie time.

Table K.19
Final Marihuana Study: Dwell Results . N = 10, repeated measures
(percent changes in mean values relative to
placebo indicated in parentheses)

Measure	Placebo	200 THC	Matched-pair t-test
Total Number Dwells	1207.1	1234.1 (+2)	0.27
SD	210.8	261.0	
Range	928.0-1520.0	753.0-1520.0	
Total Time in Dwells (sec)	668.1	666.9 (0)	-0.06
SD	55.0396	45.8031	
Range	567.7 -748.2	587.4 -748.3	
Mean Time per Dwell (sec)	0.565	0.569 (-2)	0.09
SD	0.086	0.157	
Range	0.426-0.677	0.386-0.886	
Mean SD of Dwell Time (sec)	.607	0.642 (+6)	0.42
SD	0.138	0.271	
Range	0.369 - 0.855	0.334 - 1.302	
Mean Dwell Frequency (dwell/sec)	1.18	1.20 (+2)	0.27
SD	0.21	0.25	
Range	0.91 -1.48	0.73 -1.48	

Table K.20

Pursuit Results for Marihuana
(percent changes in mean values relative to placebo
indicated in parentheses (N=10))

Measure	Placebo	200 THC		Matched t-test
Mean Total Pursuits	149	146.2	(-2)	-0.38
SD	37.2	46.2		
Range	80.00-197.00	60.0 -215.0		
Mean Total Pursuit Time (sec)	235.8	220.4	(-7)	-0.83
SD	56.9	43.7		
Range	130.9 -301.1	147.9 -269.2		
Mean Pusuit Duration (sec)	1.59	1.60	(1)	0.09
SD	0.21	0.40		
Range	1.38-1.97	1.22 - 2.50		
Mean Pursuit Length (deg)	4.8	5.5	(15)	1.10
SD	0.7	2.0		
Range	4.0 - 6.5	3.8 - 11.2		

Table K.21 Final Marihuana Study:
Dwell Transition Distances and Transition Durations

N = 10, repeated measures

	Placebo (new)	200mcg THC (new)
Mean Total Transition Distance (Deg.)	5.96	6.30
Mean Horizontal Transition Distance (Deg.)	5.60	5.96
Mean Vertical Transition Distance (Deg.)	1.37	1.41
S.D. Total Transition Distance (Deg.)	4.29	4.87
S.D. Horizontal Transition Distance (Deg.)	4.91	5.42
S.D. Vertical Transition Distance (Deg.)	1.43	1.51
Mean Transition Duration (sec.)	0.0696	0.0719
S.D. Transition Duration (sec.)	0.0545	0.0514

Table K.22 Final Marihuana Study:
Number and Percentage Seen
for Each Critical Event Category
N = 10, repeated measures

Category	Total No.	Placebo	200mg THC	T
Pedestrians	95	60.10(63.26)	61.90(65.16)	-0.43
Vehicles	23	20.50(89.13)	19.90(86.52)	0.51
Turn Signals	34	27.70(81.47)	26.90(79.12)	-0.94
Traffic Lights	13	12.10(93.07)	11.80(90.77)	-0.54
Bicycles	15	8.50(56.67)	9.10(60.67)	-0.82
Motorcycles	2	2.00(100)	2.00(100)	0.60
Billboards	4	3.20(80.0)	2.70(67.5)	0.00
Other	3	2.60(86.67)	2.50(83.34)	-1.86
TOTAL	189	136.70		