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# THE EFFECTS OF ALCOHOL ON THE DRIVER'S VISUAL INFORMATION PROCESSING

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16. Abstract


Twenty-seven male subjects were tested in a driving simulator to study the effects of alcohol on visual information processing and allocation of attention. Subjects were required to control heading angle, maintain a constant speed, search for critical events, and respond to route signs while viewing a 15 minute film of a drive along a rural roadway. Visual information processing demand was manipulated by testing one subgroup (N=13) on a familiar roadway and route and another subgroup (N=14) on unfamiliar roadways and routes. Eye movements and task performance scores were measured. Subjects were tested under blood alcohol concentrations of 0% (placebo), 0.085% and 0.125%. Alcohol generally impaired performance on all subtasks, but the level of impairment on visual tasks was related to the information processing demand. The route familiar group was less impaired on perceptual tasks then the route unfamiliar group. A shift in allocation of attention was also found under alcohol. Eye dwell duration was sensitive to information processing load as well as BAC level. The results suggest two possible types of countermeasures for further study: (1) consideration of impaired driver states in design of highway signing and delineations, and (2) driver training and education directed towards self-awareness of impairment.


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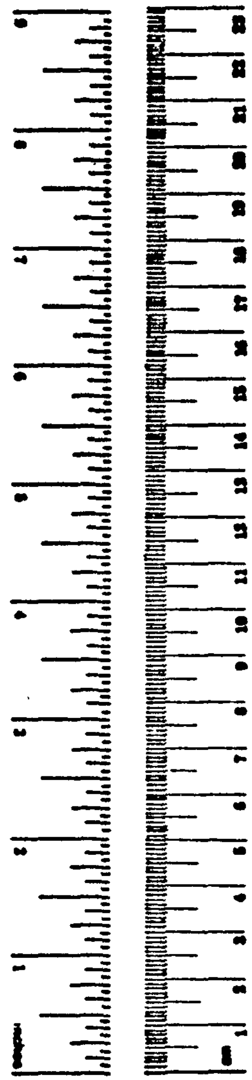
# METRIC CONVERSION FACTORS

## Approximate Conversions to Metric Measures

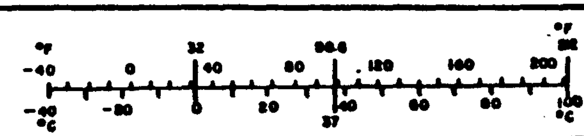
| Symbol | When You Know | Multiply by | To Find | Symbol |
|---|---|---|---|---|
| | | **LENGTH** | | |
| in | inches | *2.5 | centimeters | cm |
| ft | feet | 30 | centimeters | cm |
| yd | yards | 0.9 | meters | m |
| mi | miles | 1.6 | kilometers | km |
| | | **AREA** | | |
| $in^2$ | square inches | 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 |



# ADDENDUM

The purpose of this driver simulator study was to determine whether alcohol alters or impairs a driver's ability to allocate his attention among critical driving tasks. Specifically, the objectives were to determine whether alcohol produces: (1) a shift in attention among steering, speed control, roadway sign and hazard recognition; and (2) more deterioration in some tasks than in others. Another objective was to suggest possible countermeasures for reducing impairment due to attentional and/or performance shifts under alcohol.

Driver simulator data collected during the study under sober and drinking (0.085%, 0.125% BAC) conditions showed that: (1) shifts in attention toward speed control and away from the roadway increased with BAC level; and (2) performance on selected tasks (steering and speed control) was degraded as BAC level increased. Also, under alcohol, the time needed to process visual information increased when the demands on the driver increased, e.g., when the simulated drive was on an unfamiliar rather than familiar roadway.The study results support and extend findings of past NHTSA research concerning alcohol's impairing effects on visual information processing during various driving situations.

It should be pointed out that testing conditions used in this study were less complex than might be expected under real-life driving. Additionally, drivers used in the study were heavy (chronic) drinkers. Therefore, one must be cautious in generalizing the findings to real-world driving situations and to other drinker groups, i.e., social drinkers. The present study results are being used to support: (1) development and testing of alcohol countermeasures directed at reducing behavioral errors which result in specific alcohol-related accidents; and, (2) selection and testing of alcohol roadway countermeasures (e.g., lane delineators) under a NHTSA on-going research project entitled--"Identification and Testing of Countermeasures for Specific Alcohol Accident Types and Problems."

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# 1.0 SUMMARY

## 1.1 Introduction

It is well known that alcohol increases the probability of traffic accidents. The purpose of this study was to advance understanding of the deficits in driver performance that occur under alcohol. Such information is pertinent for understanding the causal elements in alcohol-related accidents and for providing countermeasure indications.

Laboratory studies of the effects of alcohol on perceptual-motor tasks have shown impairment in skills required for driving. A slowing of the speed at which visual information can be processed occurs under alcohol. Division of attention or ability to allocate attention among several subtasks is impaired. Tasks emphasizing motor response, such as steering, also show impairment.

A previous NHTSA study (DOT-HS-150-3-668) examined the effects of alcohol on visual allocation of attention and visual search performance of subjects viewing a traffic film in a driving simulator. The results showed that at an elevated blood alcohol concentration (BAC):

1. An increased time was used to examine or look at each point of the visual field;

2. The time spent examining highly conspicuous objects, such as turn signals and traffic lights increased disproportionately; and

3. Subjects switched attention less often between different areas of the roadway scene.

It was inferred from the results, although not conclusively demonstrated, that the longer looking times under alcohol and the decreased attention switching reflected a slowed visual information processing speed. Such performance impairments, if typical in driving under alcohol, could likely be an important causal factor in accidents.

Although the previous NHTSA study supported and extended prior work in emphasizing the impairing effects of alcohol on visual information processing and allocation of attention, the effects of elevated BACs are known to be dependent on task demand or difficulty level, and, on the relative demands of subtasks composing a total task. For instance, the relative demands of steering control versus route guidance can vary greatly depending on the driving situation. Thus, it can be misleading to draw conclusions as to the specific nature of alcohol-induced impairments in driving, without taking into account the relative demands of various driving tasks.

The present study, therefore, was intended to extend the results of the previous NHTSA study to a situation including several component tasks of driving as well as variation in task difficulty levels. Confirmation of the inference that longer looking times are a consequence of slowed information processing speed was also sought.

The specific objectives were:

1. To determine if alcohol produces a shift in a driver's allocation of attention among: steering control, speed maintenance, route sign recognition, and hazard recognition tasks;

2. To determine if alcohol selectively impairs performance on the above tasks;

3. To determine if an alcohol-induced slowing of information processing rate is exhibited in the task situation;

4. To determine if familiarity with the roadway and route (i.e., reduced information processing load) reduces the impairing effects of alcohol; and

5. To identify countermeasures for overcoming or reducing alcohol-related performance deficits.

## 1.2 Methodology

### 1.2.1 Design

As shown below in Figure 1-1, two separate groups of 15 subjects were each tested at three target BAC levels of: 0%, 0.10%, and 0.15%. Each subject was tested at one of the three alcohol levels on three different occasions. One group (FAMILIAR) was tested at each occasion on a route (roadway plus sequence of route signs) with which they were familiar; the other group (UNFAMILIAR) was tested on each occasion on a route which had not been seen before. Treatments were administered in a counterbalanced order.

| | TARGET BLOOD ALCOHOL CONCENTRATION (BACs) | | |
|---|---|---|---|
| | 0% | 0.075% | 0.15% |
| ROUTE FAMILIAR GROUP | N= 15 → | → | → |
| ROUTE UNFAMILIAR GROUP | N= 15 → | → | → |

FAMILIAR - SAME ROADWAY AND ROUTE SIGNS ON TEST TRAILS AS TRAINING

UNFAMILIAR - DIFFERERNT ROADWAY AND ROUTE SIGNS ON TEST TRAILS AS TRAINING

Figure 1-1 Experimental Design

### 1.2.2 Performance Task

The simulator task configuration was selected so as to require a driver to divide his attention among several subtasks. A critical event recognition task required searching the roadway scene for two types of potential hazards: pedestrians on the shoulders or cars on intersecting roads. A route recognition task required the subject to detect the occasional occurrence of city names on a fixed route sign and to respond when his preselected "destination" city name appeared on two occasions out of 18 five-second city name presentations. Steering control required maintenance of apparent car alignment in the lane, to correct the effects of random wind disturbances. A final task, which was used to further increase task loading, required the subject to keep the speedometer needle at 40 mph by use of the accelerator pedal.

The simulation laboratory is shown in Figure 1-2. A 15 minute movie of a simulated drive along a rural, two lane roadway was rear projected onto a screen in front of the subject seated in the car cab. The turntable on which the car cab was mounted randomly oscillated about the indicated vertical axis requiring compensatory steering control by the subject to keep the car pointed straight down the road.

### 1.2.3 Performance Measures

Several types of performance measures were used to evalute performance on the various subtasks used in the study. Steering control was measured by the standard deviation of heading angle (angle between car axis and "straight ahead"). The standard deviation provides a measure of variability of control, the most important aspect of performance with regard to accident potential. Similarly, speed maintenance was evaluated by the standard deviation of actual speed about the command speed of 40 mph.

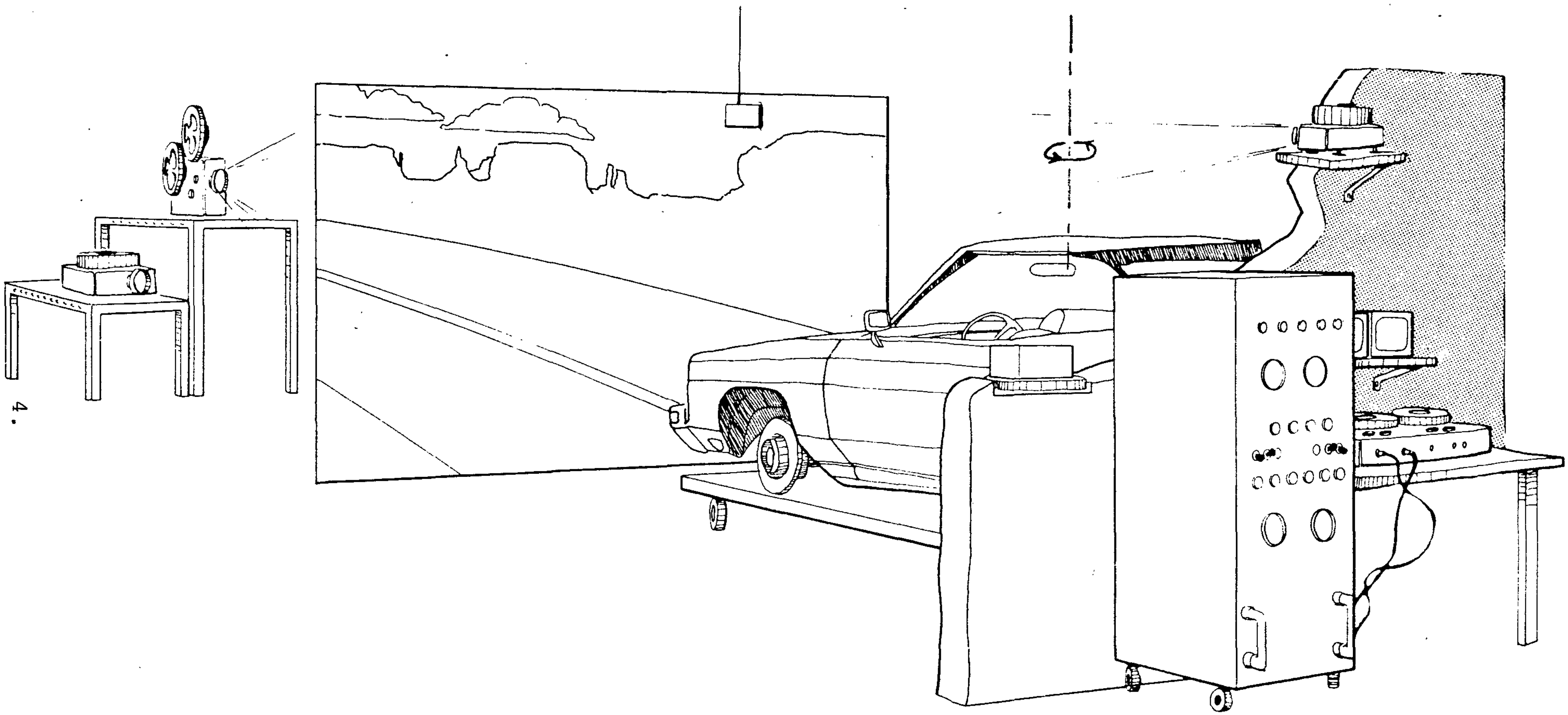


Figure 1-2. Simulation Laboratory

The mean number of correct turn signal responses to the two destination city presentations provided a measure of route sign recognition performance. Horn preses were correlated with occurrence of the critical events to provide a measure of event detection.

An important class of measures was based on analysis of eye movements, which were measured by sensors mounted on spectacle frames worn by the subjects. Two types of eye movement measures are of interest: (a) a dwell is a condition in which the eye is fixated (relatively motionless) at a given point in the visual scene; and (b) a pursuit is a condition in which the eye is tracking a moving object (as it flows past the driver) with a smooth following movement. Information is input to the visual system during pursuits and dwells. Both mean durations (in seconds) and number (or frequency) of dwells and pursuits were measured.

Allocation of attention among roadway, route sign and speedometer was measured by the frequency of dwells at each area, relative to the total frequency of dwells during the drive. Time to acquire visual information was measured by the mean durations of dwells and pursuits.

### 1.2.4 Subjects

Subjects were male, 21-55 years of age, had uncorrected vision and at least three years driving experience. A heavy drinker population was used as defined by the highest two categories of the heavy drinker category in the Cahalan, Cisin and Crossley (1969) Quantity-Frequency-Variability scale. The subject population represented the top 8% to 10% of the drinking population in terms of either the quantity normally consumed or the frequency of consumption, or both.

### 1.2.5 Procedures

After screening and selection, subjects were given four training sessions, each on a separate day. Before training, subjects were randomly assigned to either the roadway FAMILIAR group or to the roadway UNFAMILIAR group. The FAMILIAR group viewed the same roadway and route sign sequence during training on which they would be tested; whereas the UNFAMILIAR group were trained on a roadway and route signs different from any of the test drives.

After training, each subject was tested on each of the three treatments (placebo or 0.0% BAC, 0.075% BAC and 0.15% BAC). Tests were separated by one week. Alcohol was administered as an orange juice/vodka mixture in three equal drinks over an hour and one-half period. BACs were measured with an Intoximeter.

## 1.3 Results

### 1.3.1 Obtained Ns and BACs

Due to subject dropouts the final Ns were 13 in the FAMILIAR group and 14 in the UNFAMILIAR group. The 0.075% BAC target was overshot somewhat (mean BAC: 0.085%; range: 0.05% to 0.112%) and the 0.15%

BAC target was undershot (mean BAC: 0.13%; range: 0.098% to 0.163%).

### 1.3.2 Shifts in Allocation of Attention

Changes in attention to the roadway speedometer and route sign were evaluated by analyzing the proportion of dwells falling in each of these areas. The FAMILIAR and UNFAMILIAR groups each shifted attention from the roadway to the speedometer as BAC increased (Figure 1-3). In both cases the shifts were statistically significant (i.e., $p<0.05$). At all BAC levels, the UNFAMILIAR group looked more often at the roadway and less often at the speedometer, compared to the FAMILIAR group. These differences were also statistically significant. However, neither the BAC nor the route familiarity effects showed statistically significant differences on route sign dwells.

Thus, both BAC and route familiarity effects were found on allocation of attention, as measured by dwell proportions.

### 1.3.3 Selective Impairment of Performance

The issue of whether performance on the different subtasks is differentially affected by alcohol was evaluated by examining performance on each subtask.

Speed and Steering Performance. Variability of speed maintenance increased significantly as BAC increased ($p < 0.001$) as did variability of steering control ($p < 0.02$). See Figure 1-4. No statistically significant difference was found between the familiar and unfamiliar groups on these measures. Thus, performance on both tasks decreased as BAC increased but was unaffected by route familiarity.

Recognition of Destination City. A trend towards decreased probability of destination city recognition as BAC increased is shown in Figure 1-5.

Recognition of Critical Events. As shown in Figure 1-6, elevated BACs did not affect critical event detection, but the FAMILIAR group detected significantly more events than did the UNFAMILIAR. In spite of greater attention to the roadway scene by the UNFAMILIAR group, as shown by dwell allocation, they still performed more poorly than did the FAMILIAR group on this task.

### 1.3.4 Visual Information Processing Rate and Task Demand

Mean Dwell and Pursuit Durations: A significant increase in mean dwell duration (of all dwells) was found under alcohol. A similar result was found for pursuit duration. These results confirm findings from the previous NHTSA study.

Effect of BAC and Task Demand on Visual Information Processing. Dwells on the route sign were analyzed separately from all other dwells to assess the combined influence of BAC and task demand on

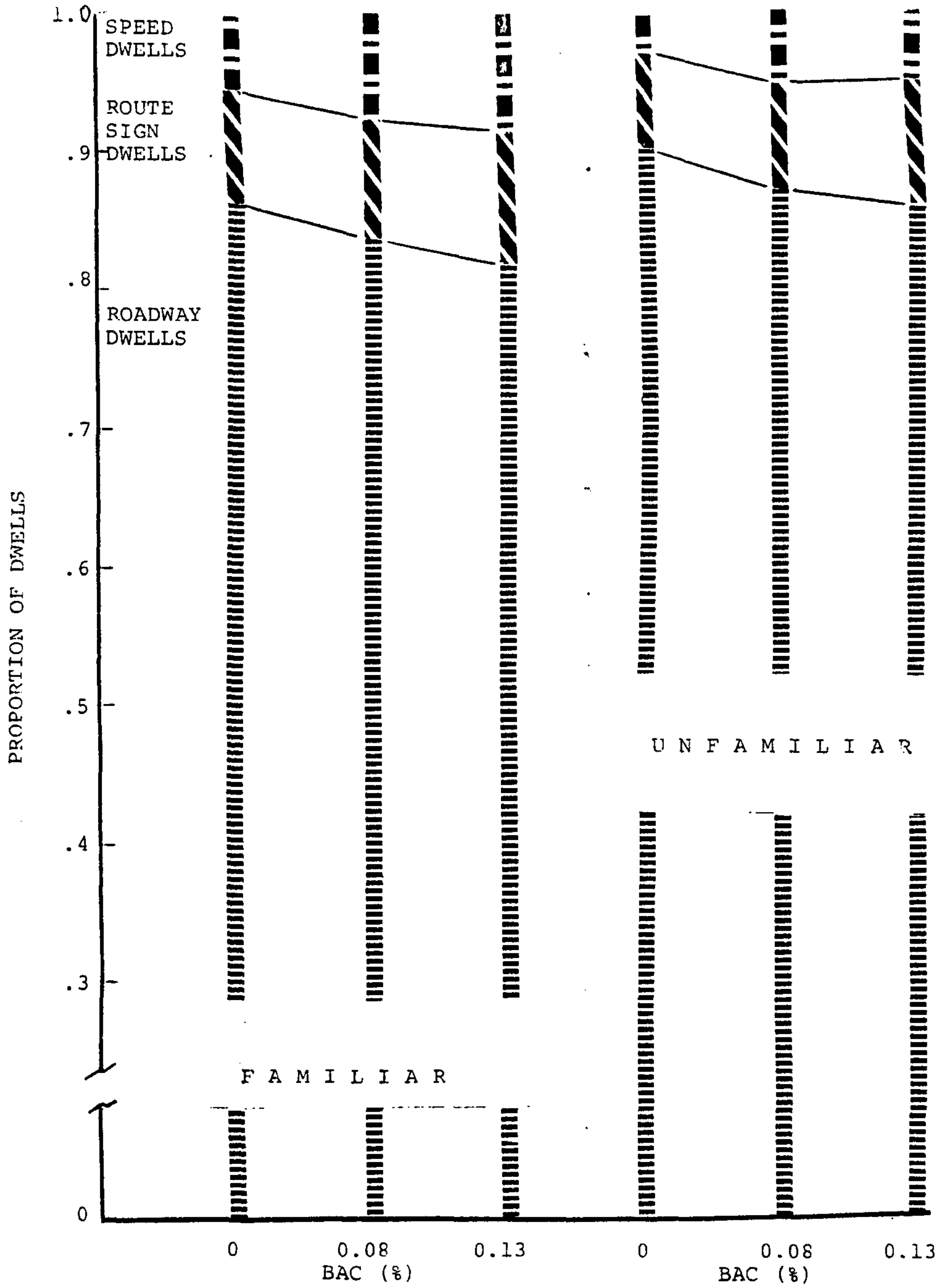
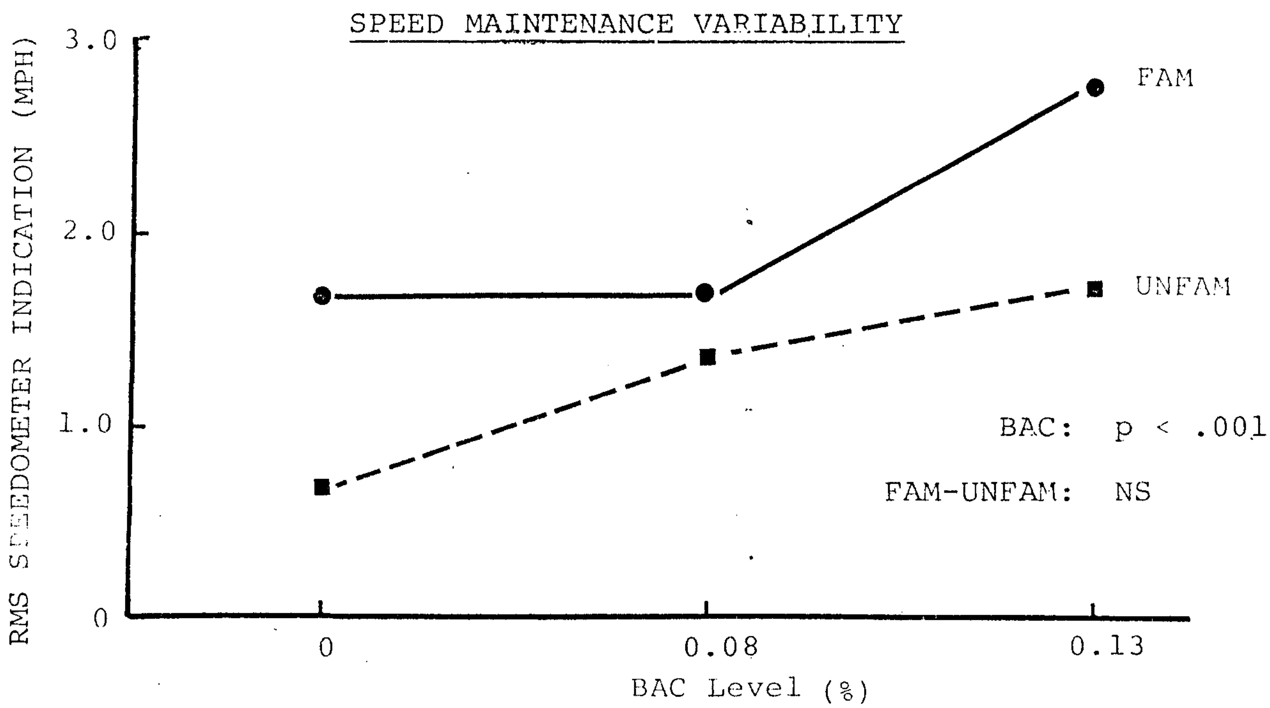



Figure 1-3. Allocation of Attention Among Speedometer, Route Sign and Roadway for Route Familiar and Route Unfamiliar Groups



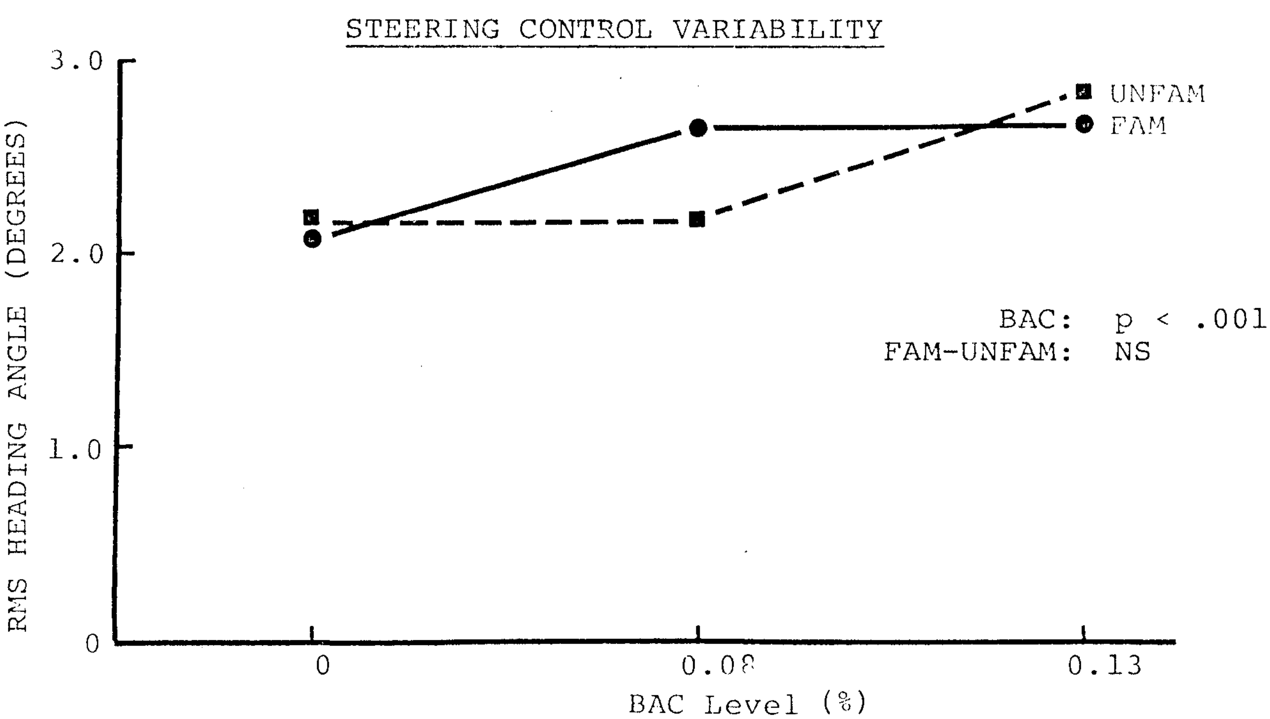




Figure 1-4. Speed Maintenance (top) and Steering Control (bottom) versus BAC

RECOGNITION OF DESTINATION CITY PRESENTATIONS

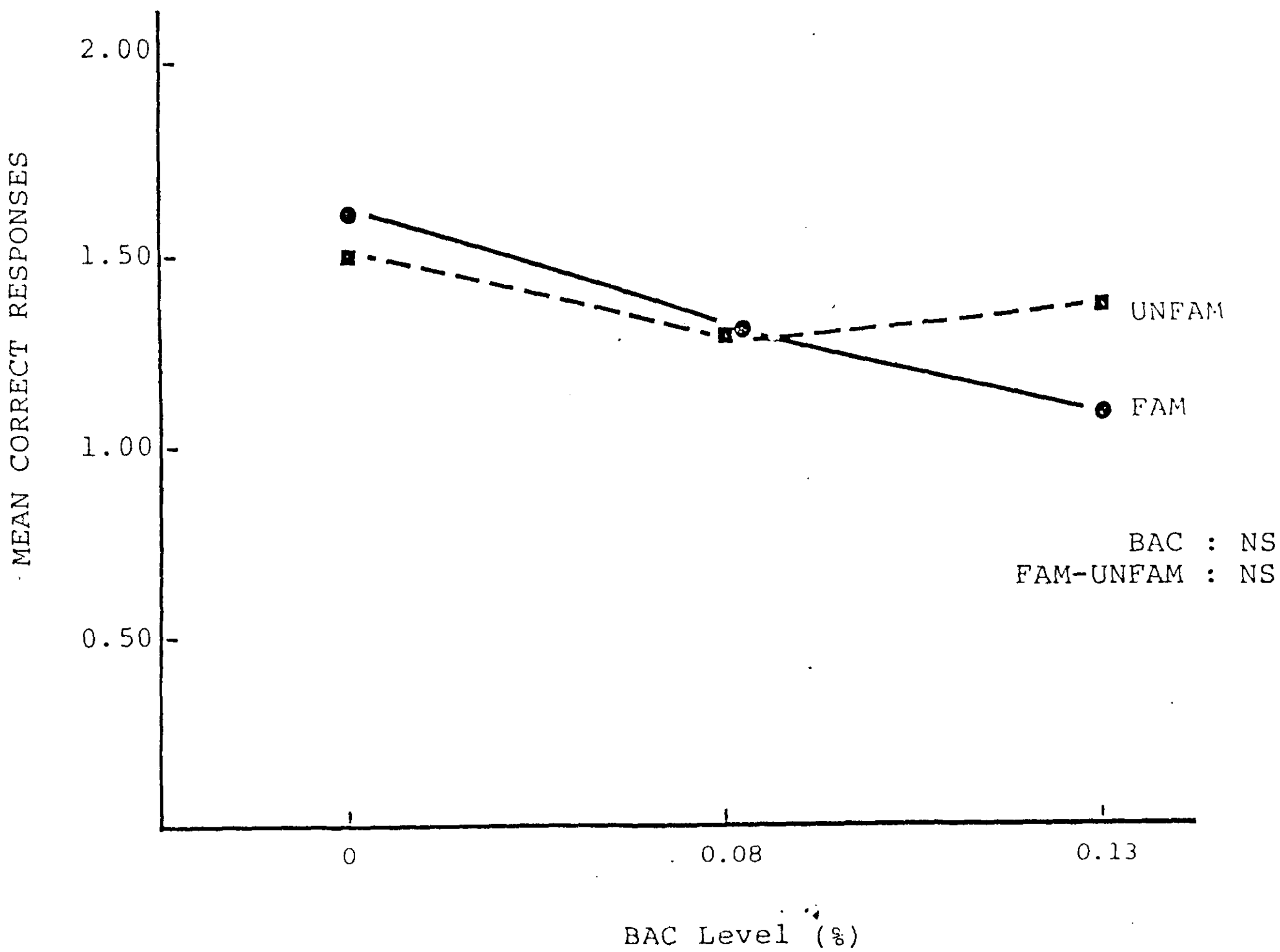



Figure 1-5. Mean Correct Responses to Destination City Presentations versus BAC

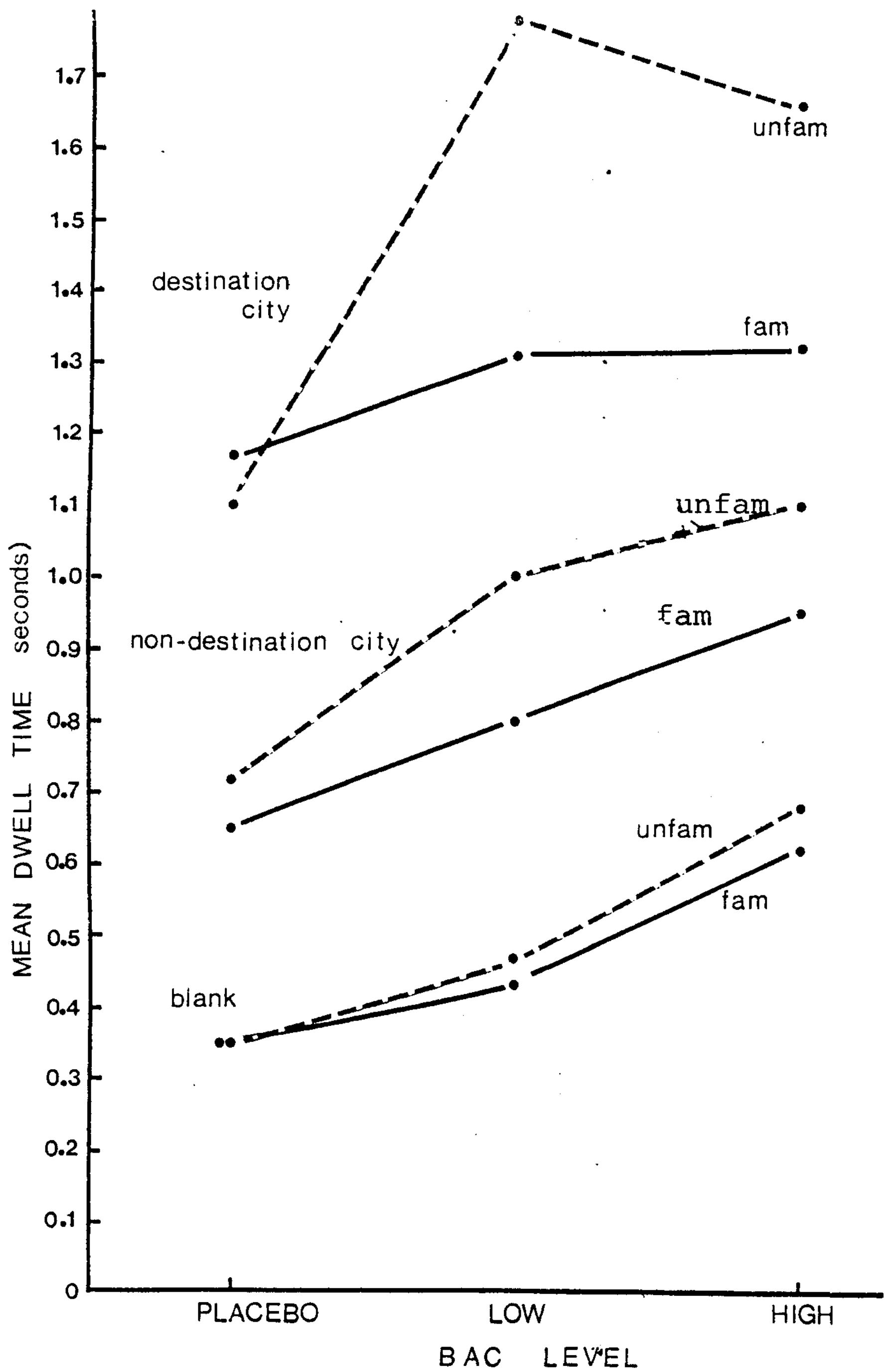



Figure 1-7. ROUTE SIGN DWELL TIMES AT THREE LEVELS OF INFORMATION PROCESSING DEMAND

perceptual performance. Figure 1-7 shows that the effect of elevated BACs on dwell duration was dependent on the amount of visual information demand: the highest level of information load (UNFAMILIAR group, destination city presentation) shows the most prounounced increase in dwell time under alcohol.

Various analyses were performed to examine the statistical significance of the route sign dwells. The analysis was complicated by three problems: (1) the small N involved in the destination city dwell data (the total number of dwells for all subjects for each familiarity/BAC category varied from 19 to 27), (2) the large differences in the N between the blank, non-destination city and destination city dwells (the total Ns varied from a maximum of 27 for destination city dwells to over 1000 for dwells on the blank sign), and (3) the large variability and lack of normality typically found in eye fixation data, which is accentuated for small Ns. Based on these considerations, Friedman two-way non-parametric analyses (subjects x BAC) were applied separately to the FAM and UNFAM groups at each information demand level. A significant alcohol effect on mean dwell time was found for all levels of information demand for the UNFAM group. However, for the FAM group significance is only reached for dwells on the blank sign, i.e., alcohol did not have a significant effect on non-destination and destination city dwell time. Thus, the magnitude of impairment due to alcohol is jointly dependent on the level of route familiarity and the information demand level. Apparently, the FAM group had sufficiently overlearned the recognition task so as to partially compensate for the effect of BAC on information processing rate. The 0.5 second increase in dwell duration shown by the UNFAMILIAR group over that of the FAMILIAR group in reading destination city displays is of obvious practical importance in driving at highway speeds, in spite of the fact that the small Ns involved in the destination city dwells preclude a direct test of the statistical significance of the difference.

## 1.4 Conclusions

At elevated BACs, a decreased visual information processing rate is clearly exhibited in the driver's perceptual performance in the simulated driving situation that was studied. The magnitude of alcohol-induced impairment in visual information processing rate was shown to depend on a task variable (familiarity level) for both allocation of attention and route sign dwell durations. Eye dwell time was found to be related to both information processing demand and BAC, eye movement measures were thus shown to be a sensitive measure of the driver's information processing performance. Finally, allocation of attention shifts and selectivity of performance do occur under alcohol but may be dependent on relative demand of the various component tasks in driving.

Thus, it is concluded that a complete analysis of the impairing effects of alcohol on driving performance requires understanding of the relative information processing demands of component tasks in a given driving situation. It should also be noted that a heavy drinker group was chosen for this study because this population is substantially overrepresented in driving accidents. Substantial impairment under alcohol was shown for this group at 0.08% BAC, which is below the typical legal limit in the United States. Even greater impairment could be expected for moderate and light drinkers at equivalent BACs.

## 1.5 Countermeasures

The above findings indicate two types of countermeasures: (1) including alcohol-impaired drivers' characteristics in criteria for signing and delineation design; and (2) consideration of driver training techniques and public information and education programs designed to develop resistance to impairing effects of alcohol.

## 1.6 Recommendations

1. The dependence of alcohol impairment on other task variables (such as fatigue and vigilance) should be studied to extend understanding of the dependence of alcohol-related impairment on driving task variables.

2. The study of alcohol effects on the driver's visual information should be extended to light and moderate drinkers.

3. An examination of traffic situations most susceptible to alcohol-related accidents should be made to examine possibilities for improved signing and delineation treatments.

4. Continue the development of eye-movement analysis as a tool for studying driver visual information processing.

5. Identify the driving tasks which may be amenable to impairment resistance through training or self-correction.

# 2.0 BACKGROUND

## 2.1 Introduction

Driving under the influence of alcohol greatly increases the probability of an accident (Borkenstein, 1964). Various hypotheses as to the failures in driver performance that occur under alcohol have been advanced, based on research into the nature of alcohol-induced impairment. For instance, it has been shown that visual information processing rate is slowed under alcohol. This finding led to an inference that tasks requiring division of attention would be particularly sensitive to elevated BACs, and, conversely, that tasks allowing concentrated attention would be less affected by alcohol (Moskowitz, 1973). The purpose of the present study was to examine further the nature of alcohol-induced impairment in perceptual and information processing behaviors of the driver.

## 2.2 Driver Performance and Alcohol

Two sources of data are relevant to an examination of performance deficits when driving under the influence of alcohol. These are: (1) accident analysis studies in which accidents are analyzed to determine causitive factors, and (2) experimental studies in which performance is measured after administration of alcohol. Experimental studies have the advantage of allowing control over testing conditions and permit clear specifications of performance measures. However, quantitative predictions of actual accident rates or levels of risk from such studies are difficult. While epidemiological and accident studies give actual accident probabilities, such investigations are expensive and subject to numerous methodological problems. Such problems include the difficulties presented by a post-hoc behavioral analysis of accident causation and the inadequacies of accident reporting procedures (Treat and Shiner, 1976). A brief review of results from accident and laboratory investigations is given below.

### 2.2.1 Accident Investigations

Studies of automobile accidents have clearly implicated driver behavior as the major cause of accidents. Joscelyn and Treat (1976, Fig. 3-1, p. 34) report that human factors were definite or probable causes of accidents in 92% of 318 accidents (in-depth analysis) and 95% of 1364 accidents (on-site analysis).* Based on police reports of 1653 accidents, Perchonok (1977) determined that drivers were primarily culpable in about 75% of the accidents studied and to some extent culpable for a proportion of the remaining 25% (Table 6, p.29). In an earlier study Mackay (1967) found that in 84% of accidents studied the driver was partially or fully responsible.

In those accidents for which the driver was to some extent responsible, errors of perception and decision making were predominant. Joscelyn and Treat (1976) found that recognition errors

*In the Joscelyn and Treat study, a subsample of the total accidents studied on site were also subjected to additional in-depth analysis.

were definitely implicated in 44.7% (in-depth analysis) and 38.9% (on-site analysis) of the accidents for which the driver was responsible. Decision errors accounted for 32.7% (in-depth) and 36.7% (on-site) of the driver-caused accidents. Perchonok (1977) found that "information failures" accounted for 66% of driver-culpable accidents. Clayton (1972) in a study of 158 accidents in which the driver was responsible found that 47% of driver errors were errors of perception and another 28% were errors of decision.

Thus, the evidence is clear that errors related to perceptual and decision behavior are responsible for a large proportion of driver-culpable accidents. When accident data are categorized with respect to alcohol involvement, a large increase in driver culpability is found. For instance, Perchonok (1977) found that the proportion of cupable drivers increased from 43% (normal) to 80% (had been drinking, HBD) and to 85% (driving while intoxicated, DWI). However, the proportion of information failures to control failures decreased under alcohol (Perchonok, 1977, p. 37), although, in an earlier study, Perchonok (1972), the incidence of information failures was found to increase relative to control failures. Perchonok (1977) did not suggest a reason for this discrepancy except for the inherent unreliability of a small data base (e.g., only 216 of the total 1653 accidents studied were alcohol-related in his 1977 study). The use of police reports as a primary data base also placed limitations on the accuracy of the data. Joscelyn and Treat (1976) did not provide a breakdown of difference in causal factors between alcohol and non-alcohol involved accidents. In the 158 driver-responsible cases in Clayton's (1972) study, of 10 drivers with significant blood alcohol levels, seven showed perceptual or decision failures.

### 2.2.2 Experimental Studies

Experimental studies on the nature of the alcohol-related performance deficits show that one primary effect is on the rate at which information can be processed by the driver. Perceptual and decision-making tasks, e.g., reading a sign, evaluating a traffic situation, making a decision as to an appropriate maneuver, etc., require time for the driver to process information. The rate at which the information necessary for such activities can be processed by the driver has been shown to be slowed under alcohol (Moskowitz and Murray, 1976) using a backward visual masking technique. A slowed information processing rate implies that the ability to divide attention among several inputs will be impaired. Division of attention is a necessity for driving, in that the driver must attend to several subtasks including steering, route planning, sign recognition, obstacle detection and avoidance, speed maintenance, and so forth. Performance of divided attention tasks has been shown to be much more sensitive to alcohol than is performance of concentrated attention tasks (Moskowitz, 1973).

As discussed above, accident data show perceptual failures to be a major cause of driver-culpable accidents. Experimental studies demonstrate that alcohol impairs performance of perceptual tasks; therefore, a basis exists for hypothesizing that perceptual deficits, an important factor in accidents in general, are also important in alcohol-related accidents. The latter hypothesis is the basis for examining the effects of alcohol on the driver's allocation of attention and visual information processing capabilities.

## 2.3 Eye-Point-of-Regard Measurements, Allocation of Attention and Visual Information Processing in Driving

### 2.3.1 Use of Eye-Point-of-Regard-Data to Study the Effects of Alcohol

The experimental situations that have commonly been used to study the effects of alcohol on visual information processing have not generally included the specific behaviors used in driving, e.g., steering control, route finding, visual search, critical event or hazard recognition, etc. Previous studies of alcohol, information processing and division of attention have not included a sufficiently representative range of driving tasks to show how alcohol effects are actually exhibited in the driving situation. In addition, definition and measurement of the "focus of attention" presents methodological and practical problems. Generally, shifts in allocation of attention in multi-task situations are inferred by measuring performance on each of the component tasks. A decreased performance on one task relative to others would indicate less attention to the first task. In some cases, however, use of performance measures to examine attention shifts is undesirable. For instance, detection of events in the peripheral visual field is important for safe driving. However, in order to obtain a reliable measure of detection it is necessary to introduce many such events in any practical testing situation. A high rate of occurrence of a given type of event can influence visual search patterns and thus produce results not applicable to all driving situations. Thus, a means of measuring attention is required which does not, in itself, alter patterns of attention.

Eye movements have been used by several investigators as a means of measuring the focus of attention during driving or simulated driving (Rockwell and Zwahlen, 1977). When the human observer is scanning a visual scene, the eye can be thought of as a searchlight with a narrow beam pointing in the direction of gaze, surrounded by a dimmer area of illumination peripheral to the narrow beam. The eye typically moves in rapid, jerky movements called <u>saccades</u>, which successively position the "searchlight beam" at various locations of interest on the visual scene. The small central area covered by the "searchlight beam" is seen at high resolution compared to the peripheral area, which is seen less clearly than the central area. The period between two saccades during which the eye position is relatively fixed is termed a <u>fixation or dwell</u>. Visual information is acquired during fixation periods, which typically comprise 80% to 90% of the total time in visual scanning or search.

The point of intersection of the "searchlight beam" (actually optical axis of the eye) with the visual scene is termed the Eye-Point-of-Regard (EPR). As an observer must look directly at an object to bring it to the central (or foveal) area of the eye for best resolution. Measuring the locations of successive dwells during performance of a visual task provides valuable data on an individual's information-seeking strategy. This is especially true for driving in which nearly all of the information required by the driver is visual.

If visual attention is directed towards a moving object, then the eye may follow or track the object by a smooth following movement called a pursuit. Pursuits only occur in the presence of a moving target and represent a "locking-on" of the eye's "searchlight beam" on the target. As saccadic and pursuit movements are controlled by different parts of the oculomotor control system, they can be differentially affected by drugs.

In addition to providing information as to where an observer is looking, EPR measurements are used to provide data on the duration of each look. Look duration information indicates the time required to acquire and process information (Shebilske, 1975). In general, EPR measurements have been found to be a valuable technique for studying driver behavior data and were a primary source of data in the present study.*

2.3.2 Previous Studies

A brief review of previous studies concerned with effects of alcohol on allocation of attention and information processing in driving is given below. The review emphasizes simulator and on-the-road studies as the focus of the present study is on situations in which a representative range of driving tasks were studied.

Belt (1969) measured visual search patterns of two subjects under three levels of alcohol for three different driving conditions. The nominal blood alcohol concentrations (BAC) were 0%, 0.037% and 0.075%. The three on-the-road tasks were car following, short interval open road driving, and long interval open road driving. Only about one or two minutes of data were analyzed per test session.

The results showed no effect of alcohol level on mean eye travel distance (distance between successive fixations). An increased amount of fixation time in the most populous 3 x 3 visual angle block was shown under alcohol indicating that subjects looked less often outside a central region under alcohol. Mean fixation duration increased under alcohol under the open road mode but not under the car-following mode. The results of this study must be taken as tentative due to the small amount of data collected.

Mortimer and Jorgenson (1972) studied visual scan patterns of two experienced drivers for three BAC levels: 0, 0.05%, and 0.10%. Driving on a two-lane road at 35 mph and driving on an expressway at 60 mph were compared, as were car following and open road driving.

The results showed an increase in mean fixation durations at the 0.10%

* Visual information acquired in peripheral vision, of course, would not be directly measured by knowing the EPR. In addition, information at a given point in the visual scene may not be processed by the perceptual system even if the eyes are directed towards that point (dubbed the "looking without seeing" phenomenon).

alcohol level and an indication (not statistically significant) that preview distances were decreased under alcohol (viewing was closer to the vehicle). Contrary to Belt, no alcohol effects were found on the horizontal distribution of fixations.

Kabayashi (1974), also found indications of longer fixation durations in two subjects while driving a test course under alcohol but did not report on the spatial pattern of fixations.

Buikhuisen and Jongman (1972) conducted a laboratory study in which subjects' eye movements were measured when viewing 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 potentially hazardous events that should be noticed by a driver. In all, 86 such "critical events" were selected for analysis. Fifty-five subjects at 0% BAC were compared to 50 subjects at 0.08% BAC.

The results indicated that under alcohol subjects looked at 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 the roadway scene, 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 is the finding that subjects under alcohol shifted their focus of attention towards the right side of the road. In Holland the vehicle 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 concentrated attention on those areas which were (1) most sensitive to the basic task of driving (straight ahead) and (2) to areas emphasized by learned reinforcement of critical events (a traffic citation or accident due to not giving another driver the right of way).

Schroeder, Ewing and Allen (1974) examined the combined effects of alcohol and methapyrilene and chlordiazepoxide on performance of a simulated driving task. Male subjects viewed a six-minute 10 second 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 to decrease the proportion of saccades greater than 5 compared to those less than 5 , i.e., more attention was paid to central visual regions under alcohol. The frequency of driving errors did not increase under alcohol.

Beideman and Stern (1976) examined visual search behavior in a Link Driver Simulator at 0% and 0.075% BAC. Twenty subjects operated brake, steering and accelerator while viewing two films in succession

(49 minute total viewing time). A variety of visual search measures as well as measures of control performance were recorded. Under the intoxicated conditions subjects demonstrated (1) a decrease in the frequency of saccades, (2) an increase in the percentage of long duration fixations, (3) a decrease in large amplitude saccades, (4) an increase in the duration of saccadic eye movements and (5) a decrease in the peak velocity of saccades. On motor performance tasks alcohol increased the amplitude, velocity and variability of responses on the accelerator, brake and steering wheel. A tendency for subjects to "stare into space" was noted. Beideman and Stern concluded that their results support the hypothesis that alcohol affects information processing capability as exhibited by a less efficient division of attention in the complex simulation task.

Moskowitz, Ziedman and Sharma (1976a,b) examined visual search behavior in 27 subjects while watching a 17 minute traffic movie (congested, urban scene) at 0%, 0.075%, or 0.15% BAC. Subjects were required to watch the movie for potentially hazardous events and also performed a secondary task requiring turn-signal responses to "right" or "left" arrows projected on the screen.

The results showed an 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. An analysis of the various categories of traffic events looked at by subjects indicated differential effects of alcohol on different categories of events (duration of looks for flashing lights and traffic lights increased under alcohol whereas look duration decreased or remained the same for pedestrians). A "fixation of gaze" phenomenon apparently similar to the tendency to "stare into space" reported by Biedeman and Stern (1976) was also found.

Moskowitz, Ziedman and Sharma (1976a,b) concluded that the longer dwell times found under alcohol were the consequence of a decreased information processing rate and that visual search efficiency decreased as the need to examine each area for a longer time resulted in a decrease of the amount of the visual field that can be examined.

An increase in fixation duration under alcohol was reported in all of the above studies. This finding is consistent with laboratory work showing that alcohol slows information processing rate (e.g., Moskowitz and Murray, 1976). Thus, the longer fixation times found in the studies reported above could be attributed to the additional time needed for processing data during each fixation.

Less consistent findings were reported regarding whether allocation of attention is changed under alcohol. Belt (1969), Buikhuisen and Jongman (1972), Beideman and Stern (1976), and Schroeder et al. (1974) found indications of increased attention to central areas, whereas Mortimer and Jorgeson (1972) and Moskowitz, et al. (1976a,b) did not. This apparent inconsistency could be related to differences in the task demands between studies and to the strategies adopted by the subjects towards their tasks. Note that a possible shift in attention when driving under alcohol need not only be a shift in the focus of visual scanning from the peripheral scene towards the central area, but could be increased attention on any subtask to the exclusion of others. The specific aspects of a shift in attention would be determined by the driver's "set" as influenced by previous experience and the reward/penalty structure of the current situation.

In some of the above studies the subjects were primarily "observers" of a traffic scene and demands for performing a control task were non-existent or minimal. The effects of alcohol on allocation of attention might be different between situations in which attention to vehicle control was required (in the sense that an accident or simulated accident would occur if steering were neglected) and situations in which it was not required. Also, in on-the-road studies, vehicle control and guidance performance were often not reported even when it was a required task. Thus, correlation between changes in attention as measured by EPR data, visual task performance, and vehicle control/guidance performance could not be examined.

Finally, in order to study visual information processing in connection with allocation of attention, visual tasks must be included which allow changes in visual task performance under alcohol to be related to changes in measures of attention. For instance, knowledge that a given point in the visual scene received a fixation does not, in itself, indicate that information at that point was processed and acted upon. (For instance, Sharma and Moskowitz (unpublished study) found that under marihuana the eye tracked stimulus location well, but subjects often did not report signals even when they were looked at.) Thus, it is essential not just to measure distributions of eye fixations, but to require responses to specific perceptual tasks.

Although not involving alcohol treatments, a study by Bhise and Rockwell (1973) provides pertinent data illustrating the effects of task context on the driver's allocation of attention during periods of driving involving highway sign reading and route decisions. Eight on-the-road studies were conducted in which eye movements were measured under various sign reading tasks and traffic situations. Typical results were that less time was allocated to sign reading (1) under heavy as compared to light traffic, (2) when the sign was less relevant to the driving tasks, and (3) when the driver was familiar rather than unfamiliar with the route. This study confirms the usefulness of eye movements for studying allocation of attention and information processing when driving and shows the influence of several factors on allocation of attention.

It is concluded that available studies do not adequately specify the nature of alcohol effects on allocation of attention and visual information processing in driving. Studies employing EPR measurements have generally neglected to include visual tasks specifically designed to examine relationships between EPR characteristics and visual task performance. Other studies are lacking in that the range of subtasks used was not sufficiently representative of driving to evaluate changes in allocation of attention among typical driving tasks.

Finally, it can be expected that various other factors such as the driver's familiarity with the route, nature of the visual scene (e.g., day/night, rural/urban), and various environmental factors (e.g., traffic flow) will all influence allocation of attention.

## 2.4 Study Objectives

The present study was designed to remedy some of the deficiencies discussed above. The objectives of the study were:

1. To determine if alcohol produces a shift in a driver's allocation of attention among: steering control, speed maintenance, route sign recognition and hazard recognition tasks;

2. To determine if alcohol selectively impairs performance on the above tasks;

3. To determine if an alcohol-induced slowing of information processing is exhibited in the task situation;

4. To determine if familiarity with the roadway and route (i.e., reduced information processing load) reduces the impairing effects of alcohol; and

5. To identify countermeasures for overcoming or reducing alcohol-related performance deficits.

## 3.0 METHOD

### 3.1 Introduction

The testing instrument used for this study was a laboratory-based driving simulator. The driving scene was generated by a motion picture presentation. The subject's tasks included detection and recognition of "critical events" in the film, recognition of destination city names on a route sign, steering control and speedometer monitoring. The task configuration was chosen so as to require a reasonable range of driving skills, although emphasizing visual search performance over vehicle control and guidance. Descriptions of the simulator, roadway films, subject tasks and performance measures are given in the following sections.

### 3.2 Driving Simulator and Task Description

#### 3.2.1 Simulator Description

An overview of the driving simulator laboartory is shown in Figure 3-1. Subjects sat in a car cab located 264 cm (104 inches) in front of a rear-projection screen. A 35mm motion picture projector was used to present the 15 minute driving films. The horizontal field-of-view of the driving scene subtended 70 degrees. A small projection screen located in the upper right quadrant of the main screen (subtending about 3 degrees vertically by 5 degrees horizontally) was used to project route names from a 35mm slide projector located above the car cab (see Figure 3-1).

A steering control task was implemented by rotating the car cab about its yaw (vertical) axis on a hydraulically driven turntable. This produced an apparent change in heading angle (pointing angle of the car with respect to the road) which could be corrected by use of the steering wheel. Although changes in lateral lane position corresponding to the heading angle change were not generated, the steering task provided a realistic simulation of the steering control necessary to compensate for disturbances such as road irregularities and mild wind gusts. A random appearing disturbance function was used consisting of the sum of four sine waves.

The speedometer indication was controlled by the accelerator pedal. Although the movie speed and thus apparent driving speed was held constant, the accelerator-speedometer linkage provided for a secondary monitoring task requiring attention to a region outside the roadway scene.

#### 3.2.2 Data Recording and EPR Measurement

Analog and digital response signals were sampled at 100/sec and recorded on nine-track tape with a PDP-8 computer. The computer also provided an experimental control and sequencing function. In addition, a video record was made of the movie scene with a superimposed eye mark spot. The video record was used for real-time monitoring and for qualitative analysis. Documentation of the data recording and simulator system is given in Burger, Kemmerer, and

Moskowitz (1977) and Ziedman, Sharma, and Niemann (1975).

Eye point-of-regard (EPR) was recorded with photoelectric sensors mounted on spectacle frames (Narco Bio-Systems) which sensed a variation in reflected light as a function of eye rotation. Horizontal movements were recorded from the right eye by measuring the light reflected at the iris-sclera boundary. Vertical movements were sensed at the left eye by measuring the light reflected at the eyelid-eyeball boundary.

Head movements were recorded with a two-axis gonimeter mounted on an adjustable helmet worn by the subject. A view of the eye and head movement sensors mounted on a test subject is shown in Figure 3-2. The head and eye movement signals were input to an EPR analog computer (Systems Technology, Inc.), which provided variable gain and offset controls for calibration. The EPR computer outputs were routed to the PDP-8.

Calibration of the EPR signals was accomplished before beginning a run by asking the subject to visually fixate on each point of a nine-point dot matrix projected on the screen, and adjusting the EPR computer controls as appropriate. Before the traffic portion of the film started, the film displayed a sequence of dots which appeared one at a time at the same locations as the calibration dots. Subjects were instructed to fixate on these dots, and data recorded during this period were used to obtain a calibration correction function which was applied to all subsequent data points during analysis.

### 3.2.3 Roadway Films

Seven 15 minute 35mm color films were made depicting a drive along a straight, rural road in daytime. The films were made in the vicinity of Lancaster, California, a desert area having flat terrain in front and to the sides of the road, with low mountains in the distance. Typical roadside objects or scenes were farmhouses, fields, cross-roads, groves of trees and occassional traffic. Two typical frames are shown in Figure 3-3. A rural scene was chosen so as to provide a fairly monotonous drive to simulate the typical conditions under which the single car driving-off-the-road accident occurs.

The films were edited and spliced such that each of the seven films was composed of:

1. A sixty-second eye movement calibration sequence at the beginning,

2. Six driving sequences of exactly two minutes duration, with a 10 second eye movement calibration sequence occuring in-between each two minute sequence, and

3. A sixty-second eye movement calibration sequence at the end.

Two of the films were used in training and five were used in testing under alcohol. (An eighth film, of similar composition but of only

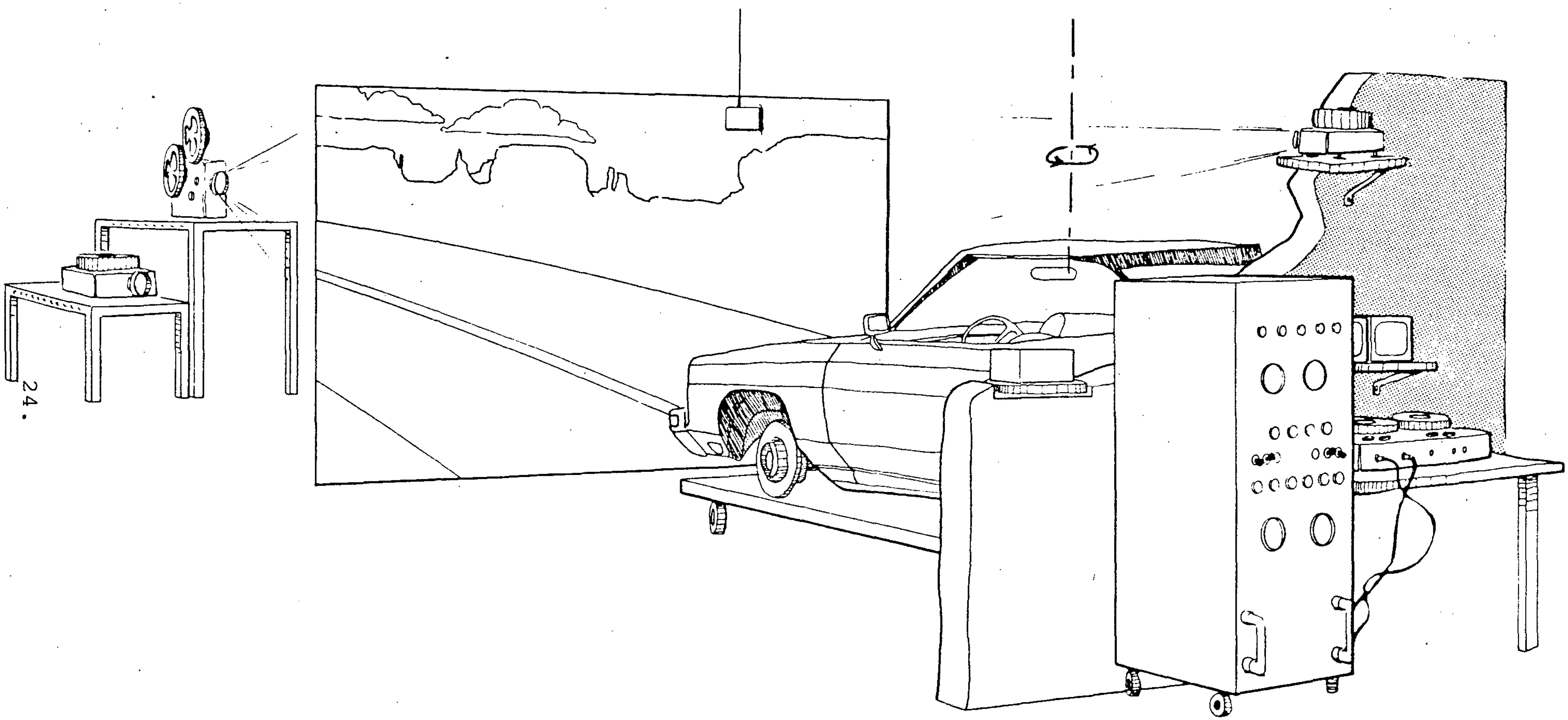


Figure 3-1. Simulation Laboratory

Figure 3-2. Subject in Simulator Showing Head and Eye Movement Sensors

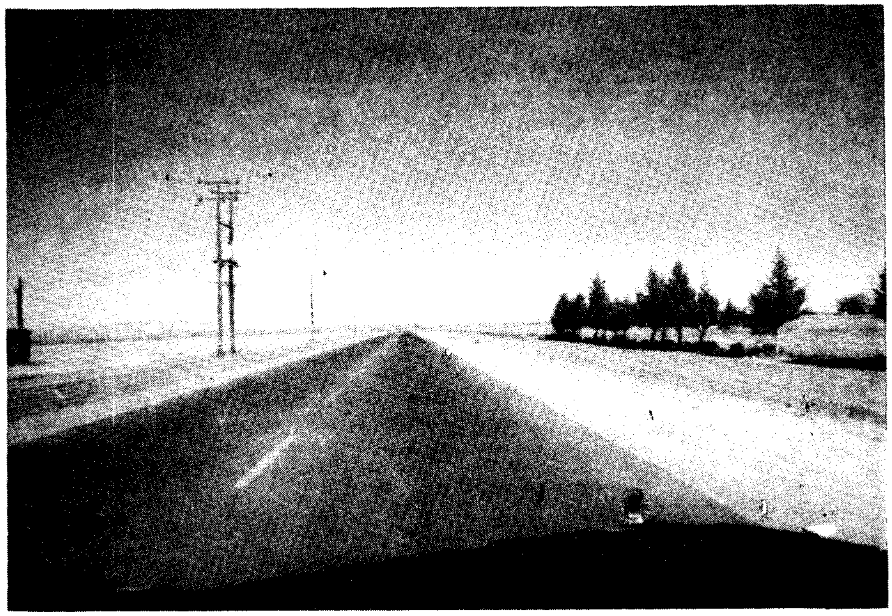


Figure 3-3. Typical Roadway Scenes

eight minutes duration, was used for an initial familiarization session.) In addition to events of opportunity, two kinds of staged events (pedestrians and cross traffic) were included such that each film would have a reasonably balanced frequency of similar events which subjects could be required to detect and recognize.

### 3.2.4 Simulation Tasks

The simulator task configuration was selected so as to require a driver to divide his attention among several subtasks. A critical event recognition task required searching the roadway scene for two types of potential hazards. A route recognition task required the subject to detect the occasional occurrence of city names on the fixed route sign and to respond when his preselected "destination" city name appeared. Steering control required maintenance of apparent car alignment in the lane to correct the effects of random wind disturbances. A final task, which was used to further increase task loading, required the subject to keep the speedometer needle at 40 mph by use of the accelerator pedal. These tasks are described below.

Critical Event Recognition:

Subjects were instructed to watch the visual scene for two types of potentially hazardous situations: (a) pedestrians standing or walking on the shoulders, and (b) cross-traffic on intersecting roads. Drivers were required to press the horn button as soon as any such event was seen. The horn button was a standard center-steering wheel press-to-acurate control. This task was included to provide additional visual information processing demand and as typical of potentially hazardous situations for rural driving.

Route Recognition:

During the drive, city names were presented for five second exposures on 18 occasions on the route sign located in the upper right screen quadrant (right 10 degrees from center, up 9 degrees from center). As noted, the route sign was at a fixed location in front of the rear-projection screen and was above the horizon of the roadway scene. The route sign appeared as a stationary dark rectangle in front of the blue/sky background. The projected image appeared as light letters on a dark background.

Six-letter names were used, subtending 0.54 degrees vertically and 3.2 degrees horizontally. Below each city name the legend "next right" or "next left" appeared, subtending 4.8 degrees and horizontally, 0.54 degrees vertically. Each city name presented during a given session was different from all others, except that a "destination city" name was displayed on two of the 18 occasions. Each subject was given the name of his destination city before a given session and was instructed to watch for its appearance on the sign. When a destination city was detected, a right or left turn signal was required, as appropriate.

The route sign task was designed to require three levels of information processing, depending on the nature of the display on any given look at the sign. It was hypothesized that the least information processing was necessary to determine if the sign was blank, more processing was required to evaluate a non-destination city display and the most to evaluate a destination city display. (This hypothesis is based on studies of eye movements and visual information processing, e.g., Shebilske, 1975). Thus the route sign task enabled an analysis of looking behavior as a function of the level of displayed information processing demand.

Steering Control:

As described previously, the subject was required to operate the steering wheel in order to compensate for continuous random disturbances of heading angle. (During the eye position calibration segments of the film, the car was locked in a straight-ahead position and the subject was instructed not to steer.)

Speedometer Monitoring:

The subject was required to maintain a speedometer indication of 40 mph by keeping a constant pressure on the accelerator pedal. A random disturbance was not used. This task provided additional loading which required visual attention away from the roadway scene.

## 3.3 Performance Measures (Dependent Variables)

The dependent variables examined in this study can be considered in two general categories: (a) eye state characterisitics, and (b) discrete and continuous performance measures such as steering error and route sign recognition responses.

As several measures were based on eye movement and eye state characteristics, these are defined first, followed by a discussion of the specific dependent variables used in the analysis.

### 3.3.1 Definitions of Eye State Measures

The eye position data were analyzed to determine whether, at any given instant, the subject's eyes were (a) in a state of fixation, (b) in a pursuit or smooth following movement, or (c) in a saccade or rapid movement that occurs when the eyes move from one fixation point to another. For the purposes of the present study, the fixation and pursuit states are the most important, as the threshold for visual information is substantially raised during saccades (visual stimuli are not sensed during the movement from one fixation to another). That is, fixation and pursuit characteristics (e.g., dwell or pursuit duration) are more related to the nature of the visual stimuli and information processing demands of the moment than are saccadic characteristics. (Saccadic characteristics reflect the state of the oculomotor control system more than they do the perceptual and cognitive demands of visual stimuli.)

Discrimination between the three eye states was performed by a series of logical tests in the eye movement analysis program (Niemann, 1974,1977). A saccade was considered initiated if the velocity of any eye movement exceeded a threshold value. The saccade was considered terminated and a fixation initiated when the eye position stabilized. A movement outside a small region around an initial point of stabilization indicated initiation of another saccade, if the velocity of the eye exceeded the saccadic threshold. The movement was classified as a pursuit if the EPR moved outside the initial point of stabilization and if the velocity was lower than the saccadic threshold velocity.

Particular attention is directed to the definition of a fixation. As stated above, once a fixation is initiated, it is assumed to last as long as the eye position remains in a small "cell" around the initial fixation position. The cell boundaries used in the study were ± 3 degrees of visual angle around the initial fixation position. The procedure was required because of artifacts in the eye position signal induced by eyelid droop, squinting, etc. Thus, small eye movements, including saccades and pursuits, could occasionally be occurring during the period when a single "fixation" is recorded. For this reason the term "dwell" is used instead of the term "fixation." Thus, "dwell" refers to maintenance of an EPR within a spatial region of dimensions on the order of a few degrees of arc as opposed to a strict definition of fixation, which implies eye position stability to within minutes of arc.

### 3.3.2 Visual Search Performance Measures

Table 3-1 presents the measures used to analyze visual search and eye movement characteristics. The spatial distribution of dwells across the driving scene and between driving scene, speedometer and route sign were examined to determine possible changes in allocation of attention. Durations and frequencies of all dwells, pursuits, and saccades were examined to determine overall effects of the independent variables on eye movement and visual search characteristics.

### 3.3.3 Route Sign Performance Measures

The characteristics of looks (dwells) on the route sign were analyzed separately from other dwells. In addition, the frequency of correct responses to the destination city and turn-signal response time to the destination city were recorded.

### 3.3.4 Critical Event Recognition Measures

Four critical events (two instances of vehicles stopped at cross-streets and two instances of pedestrians walking on the right or left shoulder) were selected for scoring from each film. Detection of each event was scored on the basis of the horn response. The initial positions of the events ranged from 3 degrees to 23 degrees from screen center (both to the right and left).

### 3.3.5 Speedometer Monitoring Measures

The mean and standard deviation of the speedometer indication maintained by the subjects were scored.

Table 3-1 Summary of Performance Measures

| General Category | Specific Dependent Variables or Comparisons | Principal Relevance |
|---|---|---|
| 1. Visual Search and Allocation of Attention | a. Distribution of dwells over roadway area | a. Functional "tunnel vision" |
| | b. Distribution of dwells over roadway, route sign, speedometer | b. allocation of attention |
| | c. Relative performance changes or component tasks | |
| 2. Eye State Characteristics | a. Dwell duration and frequency | a-b. Visual search efficiency and information processing |
| | b. Pursuit duration and frequency | |
| | c. Saccadic duration | c. Oculomotor system |
| 3. Route Sign Performance | a. Dwell duration and frequency for route sign looks | a. Information processing rate |
| | b. Correct responses to destination city presentations | b-c. Detection, recognition performance and search efficiency |
| | c. Response times to destination city presentations | |
| 4. Critical Event Recognition | a. Event detection (horn response) | a. Search efficiency |
| 5. Speedometer Monitoring | a. Mean and standard deviation of speedometer indication | a. Subsidiary task performance and allocation of attention |
| 6. Steering Control | a. Mean and standard deviation of heading angle | a. Control peformance and allocation of attention |

### 3.3.6 Steering Control Measures

The mean and standard deviation of heading angle were scored.

## 4.0 PROCEDURES

### 4.1 Experimental Design

A 2 x 3 design diagrammed in Figure 4-1 was used in which two levels of route familiarity were examined in combination with three levels of Blood Alcohol Concentration (BAC). A separate group of subjects was tested at each of the two familiarity levels. These were designated: (a) FAM group-subjects were tested on familiar roadways, and (b) UNFAM group-subjects were tested on unfamiliar roadways. A nominal goal of 15 subjects per group was planned; due to dropouts the final Ns were 14 in the UNFAM group and 13 in the FAM group.

Each subject was tested on three occasions; at each occasion he received one of the three alcohol doses: placebo (0.0% BAC), 0.075% BAC target dose, or 0.15% BAC target dose. Thus, alcohol treatment was a within-subjects variable and route familiarity was a between-subjects variable.

### 4.2 Establishing the Familiarity Levels

The FAM group was exposed to four films during the course of the experiment (one training film and three test films). All four films presented the identical roadway and route sign sequence, but were filmed on different days. Thus, during testing under alcohol each FAM subject viewed a familiar FAM route with constant fixed scenery (buildings, signs, etc.), but different events of opportunity (traffic, clouds, etc.). It should also be noted that the critical events, as events of opportunity, were also different in each of the four FAM films.

The UNFAM group was trained on a different training film than was the FAM group and tested on three different test films at each BAC level. Each of these four films were different in both roadway and route sign content. Thus, an UNFAM subject's experience was that of driving a completely new route on each occasion. Note that not only was the roadway different on each occasion for the UNFAM subjects, but the sequence of route sign names and the destination city were changed each time.

### 4.3 Counterbalancing, Film/BAC Administration Orders

A counterbalancing scheme was used in which each subject received a different order of film presentation and BAC treatment combination.

### 4.4 Training Procedures

Each subject was scheduled for sessions on four days during the first week of the study. This week was devoted to familiarization with all tasks, including EPR calibration procedures. No alcohol was administered during this period.

#### 4.4.1 Sequence of Events During Training

Day 1: Subjects were run singly in the simulator, including set-up

| | TARGET BLOOD ALCOHOL CONCENTRATION (BACs) | | |
|---|---|---|---|
| | 0% | 0.075% | 0.15% |
| ROUTE FAMILIAR GROUP | 15 → | → | → |
| ROUTE UNFAMILIAR GROUP | 15 → | → | → |

FAMILIAR - <u>SAME</u> ROADWAY AND ROUTE SIGNS ON TEST TRIALS AS TRAINING

UNFAMILIAR - <u>DIFFERENT</u> ROADWAY AND ROUTE SIGNS ON TEST TRAILS AS <u>TRAINING</u>

Figure 4-1. Experimental Design

and calibration of the eye movement apparatus. All tasks were practiced. The purpose of this session was to familiarize the subject with the apparatus, tasks, and eye movement calibration procedures. A separate procedural training film was shown to both the FAM and UNFAM subjects and provided eight minutes of roadway scenes. The film contained a different route and road sign sequence than that used in any of the other training and test films.

Days 2 and 3: During these two days each subject received six exposures to either the FAM training film or the UNFAM training film, as appropriate to his group assignment. Subjects were run in pairs, one in the driver's seat, the other in the passenger's seat, for three viewings each day. Subjects alternated driver and passenger positions so that each received three runs in each place during these two days. The eye movement apparatus was not used, but subjects were requested to perform all tasks which could be performed in each seat position and to memorize as much as possible about the film and route sign sequence.

Day 4: Subjects received individual runs in the simulator using the eye movement apparatus. The FAM or UNFAM training film was shown, as appropriate. Runs on Day 4 were identical in procedure and timing to the actual test runs. Thus, FAM subjects received a total of seven exposures to the same roadway and route sign sequence on which they would be tested under alcohol; UNFAM subjects received identical amounts of exposure to a single route which was different from the FAM training film and different from any of the films they would see on the test sessions. In addition, two of the training sessions (one with the procedural film, one with the route training film) provided complete exposure to all tasks, including the eye movement calibration procedures. Data were not recorded during the training week; however, subjects were not informed of this, and the experimenters performed all operations as if data were being recorded.

### 4.4.2 Training Instructions

Instructions were read to each subject on each training day before entering the simulator. A final series of instructions were read just before each run started. Subjects were asked to read the instructions from a handout at the same time as the experimenter read them. The instructions reminded the subjects of each task (steering, speedometer, critical event detection, and destination city recognition) and encouraged good performance on all tasks without stressing one task above the others. Appendix E contains the actual instructions used for each day of training.

## 4.5 Testing Procedures

After the training week each subject returned three times, one week apart, to be tested under the three BAC conditions. Alcohol administration procedures and instructions are discussed below.

### 4.5.1 Alcohol Administration/Testing Protocol

Subjects were instructed not to drink or use other drugs 12 hours before their appointments and not to eat breakfast on the morning of test runs. (If a breakfast was eaten, then the target BAC could not be reached within the allocated dose.) BAC was measured (by gas chromatography of breath samples using an Intoximeter Inc., Mark IV breath analyzer) when the subject first entered in the morning to ensure an initial level of 0% BAC.

Drinks were administered in three equal volume doses at one-half hour intervals, with instructions to complete each drink during that time period. A dose administration time line is shown in Table 4-1. One-half hour after the last drink, the subject was requested to wash out his mouth, and a BAC reading was taken just before the subject was escorted to the simulator. Set-up and calibration of the EPR sensors required about 15 minutes and about five minutes were needed after the run to disconnect. Thus, including the 15 minute film, about 35 to 40 minutes elapse between entering and leaving the simulator. After the run another BAC reading was taken. BAC was monitored until it reached 0.03% or lower, at which time the subject was released.

The alcohol doses used are given in Table 4-2. Drinks were composed of one part 80 proof vodka mixed with one-and-one quarter parts orange juice. The placebo dose consisted of a teaspoon of vodka floated on top of a volume of orange juice equal to the liquid volume in the low dose.

4.5.2 Testing Instructions

Instructions regarding task performance were read to each subject before drink administration on each testing day. In addition, the subjects were informed of their destination city for that day and were given a short multiple-choice test three times during drinking to help equalize exposure to and rehearsal of the destination names. Final instructions regarding task performance were given just prior to the start of a run. Finally, each subject was also asked to state his destination city prior to each run. Subjects were again reminded of each task and were encouraged to do their best on all tasks. Performance feedback was not given. Testing instructions are given in Appendix F.

## 4.6 Subject Selection

### 4.6.1 Recruitment and Screening

Subjects were voluntarily recruited through ads placed in local college newspapers and placement offices, the California State Human Resources Department and daily newspapers. The ads stated only that subjects were needed for an alcohol experiment, the rate of pay ($4/hour + completion bonus of $50) and age, vision and driving history requirements. As a minimum the following criteria were required: (a) male, (b) had been driving for at last three years, (c) heavy drinkers, (d) 21-55 years old, (e) had uncorrected vision of at least 20/25 (Snellan chart), and (f) absence of medical problems that could be aggravated by alcohol.

Applicants were initially screened by phone. A general screening

Table 4-1

Alcohol Dose Time Line

| Time (min) | Event |
|---|---|
| 0 | Start 1st drink |
| 30 | Finish 1st drink/start 2nd drink |
| 60 | Finish 2nd drink/start 3rd drink |
| 90 | Finish 3rd drink |
| 120 | BAC Test/Enter Simulator |

Notes: Each drink was 1/3 of total dose.

Table 4-2

Alcohol Dose Levels in ml of 80 Proof Vodka and grams 100% Alcohol (200 proof) per Kilogram Bodyweight

| Target BAC | ml 80 proof/kg. B.W. | g 100% alcohol/kg. B.W. |
|---|---|---|
| 0.15% | 5.87 | 1.85 |
| 0.075% | 3.36 | 1.06 |

Notes:

1) All doses were calculated for 1½ hour drinking time.
2) Doses were calculated to reach slightly higher BAC peaks than the target dose to allow subject preparation time prior to start of run.
3) All doses were mixed using 1 part 80 proof alcohol to 1¼ parts orange juice.

questionnaire, including drug use and medical history, was administered. In addition, the Quantity-Frequency-Variability (Q-F-V) alcohol use scale (Cahalan, Cissin and Crossley, 1969) was administered to determine drinking practices. Applicants who met the criteria given above were asked to come in for an interview for which they were paid $4.00, regardless of whether they were used in the study.

The screening questionnaire and the Q-F-V scale were again administered at the in-person interview as a check on consistency of responses. The general nature of the experiment, schedules, and payment were explained. A visual acuity test was also given at this time. Applicants were accepted only if they fell at the high end of the heavy drinker category, and if the responses obtained on both drinking scales and during the interview were consistent with the phone interview results.

Acceptance by the applicant was strictly voluntary. An informed consent was read to each subject who agreed to participate (with the subject simultaneously reading his own copy). Both copies of the informed consent were signed by the subject and witnessed by the experimenter (the subject kept one copy).

The screening questionnaire and alcohol use scales are given in Appendix G.

Subjects were randomly assigned to the FAM and UNFAM groups as they were accepted with the constraint of balancing age distribution between groups and equalizing the Ns. Mean age was 30.15 years (SD = 7.74; RANGE = 21,45) for the FAM group and 31.14 (SD = 9.96; RANGE = 23,54) for the UNFAM group. (As age is known to be correlated with driving performance, the constraint of balancing ages between each group avoided a potential source of bias.)

4.6.2 Human Use Review

All experimental procedures, including the informed consent form, were approved by the SCRI Human Use Committee. The informed consent form is reproduced in Appendix H.

4.7 Data Handling and Analysis Procedures

All data were recorded on nine track magnetic tape by the PDP-8 computer. Analysis was performed off-line on the PDP-8. A single pass through the analysis program provided both the eye-point-of-regard scores and other performance scores for individual subjects. The data were then transferred to the UCLA Biomedical Computing Facility for statistical analysis. Complete documentation of the software used for the eye movement analysis and performance measure scoring performed on the PDP-8 is given in Niemann (1974, 1977).

Statistical analyses were performed using the BMDP P-series Biomedical Computer Programs. Statistical procedures used included two-way analyses of variance (ANOVA), the non-parametric Friedman two-way analysis of variance, and paired-comparison tests in cases where the ANOVA's indicated significant effects. Unless otherwise indicated, all references to ANOVA's refer to a BAC x Familiarity analysis using repeated measures for the BAC factor and independent groups for the Familiarity factor.

Due to subject dropouts, all analyses are based on 13 subjects in the FAM group and 14 in the UNFAM group. However, for some measures (e.g., mean time for destination city dwells) cases with zero scores were dropped from the analysis resulting in a smaller N in statistical tests for those measures.

## 5.0 RESULTS

### 5.1 Introduction

Obtained BAC levels are presented in Section 5.2. The relationship between the independent variables (BAC and familiarity level) and dwell, pursuit and saccadic characteristics are discussed in Section 5.3. These results provide an overview of the effects of the experimental treatments on visual search behavior, EPR characteristics, and visual information processing.

Distribution of dwells over the roadway scene and among roadway, route sign and speedometer are discussed in Section 5.4, and results for critical event recognition are present in Section 5.5. These data pertain to the effects of the experimental treatments on allocation of attention, as measured by looking behavior and recognition performance.

Route sign looking behavior and recognition performance results are presented in Section 5.6. These results are particularly germane to understanding the combined effects of BAC and visual information processing demand level on performance of a perceptual task.

Finally, results for the two subsidiary tasks, steering control and speedometer monitoring, are given in Section 5.7.

### 5.2 Obtained BAC

Measured BACs for the two active dose groups are given in Table 5-1. As shown, the FAM and UNFAM groups were closely matched on mean BAC at both dose levels. However, the target BAC for the low dose (0.075%) was overshot slightly (mean BAC for FAM and UNFAM combined = 0.084%) and that for the high dose (0.15%) was undershot (mean BAC for FAM and UNFAM combined = 0.125%). For convenience, placebo (i.e., 0.0% BAC), low alcohol dose and high alcohol dose will be used hereafter to refer to the above dose levels.

### 5.3 Effect of BAC and Familiarity Level on Dwell, Pursuit and Saccadic Characteristics

#### 5.3.1 Dwell Characteristics

Dwell Duration: Mean dwell durations for all dwells on the roadway scene (excluding route sign and speedometer dwells) are shown in Figure 5-1. Increased dwell times were found at the low and high BAC doses, compared to placebo, for both the FAM and UNFAM conditions. In addition, the UNFAM group showed slightly larger mean dwell times than did the FAM group. The ANOVA showed a significant BAC effect ($p < .001$) but the familiarity differences were not significant.* Mean durations were 0.49 sec. (FAM) and 0.50 sec. (UNFAM) for the placebo case, 0.66 sec. (FAM) and 0.68 sec. (UNFAM) for the low dose, and

*Because of the large number of ANOVA's performed, all summary tables and data tabulations are given in Appendix E

Table 5-1. Obtained BAC Levels (% BAC) for Combined Data for Before Run and After Run Measurements

| | High Dose | | Low Dose | |
|---|---|---|---|---|
| | FAMILIAR | UNFAMILIAR | FAMILIAR | UNFAMILIAR |
| Mean | .123 | .129 | .085 | .085 |
| Standard Deviation | .014 | .022 | .009 | .011 |
| Range | .098-.151 | .101-.163 | .059-.094 | .070-.112 |

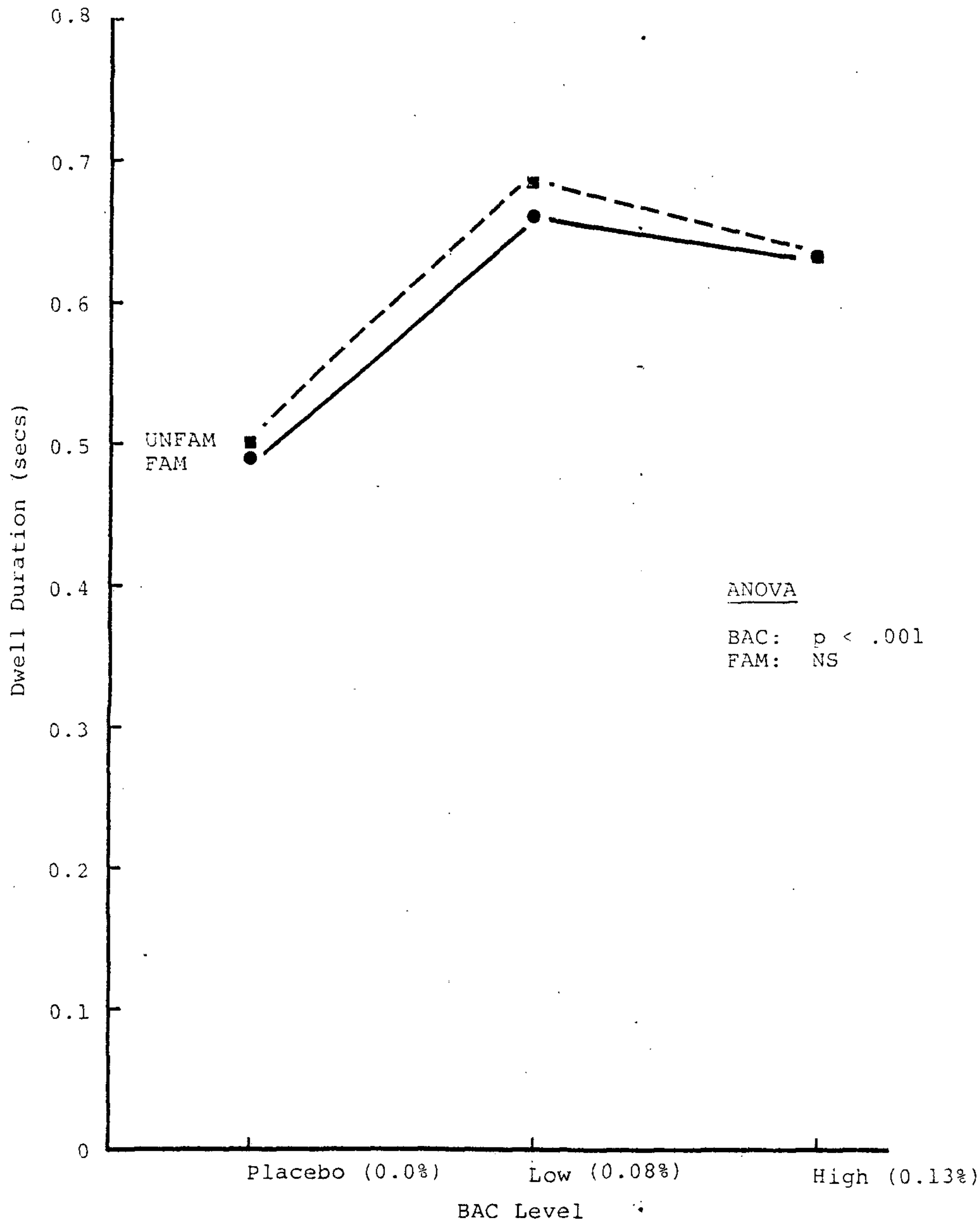



FIGURE 5-1: Mean Dwell Durations for All Dwells

0.63 sec. (FAM and UNFAM) for the high dose. The relative increases in mean dwell duration ranged from 26% to 36%, comparing placebo to the low and high BAC doses.

Examination of the frequency distributions of dwell times showed a substantial proportion of very long dwells (> 1 sec.) are shown for both the FAM and UNFAM groups. Dwells longer than one second comprise 9% to 18% of all dwells, across the various treatments. As previous studies (Beideman and Stern, 1976; Moskowitz, Ziedman and Sharma, 1976 a,b) had concluded longer dwells might indicate a "starring" phenomena, dwells were further analyzed into two categories: (1) dwells < 1 sec. in duration and (2) dwells > 1 sec. in duration. The ratio of long dwells (> 1 sec.) to short dwells (< 1 sec.) was found to vary from about 1:10 for the placebo case to about 1:6 to 1:7 for the low and high BAC levels. That is, about 30% to 40% more long dwells were found under alcohol treatment. An ANOVA using the ratio of long to short dwells as a dependent variable showed that the alcohol effect was significant ($p < .001$). Mean durations for all dwells, dwells < 1 sec. duration and dwells > 1 sec. duration are given in Table 5-2. Mean dwell duration increased for each category, comparing the placebo to the low and high alcohol doses. An ANOVA showed that the alcohol effect on mean dwell duration was statistically significant for both subcategories of dwells ($p < 0.05$ for dwells > 1 sec. and $p < 0.001$ for dwells < 1 sec.) but that the familiarity effect was not, although a trend towards longer dwell durations for the UNFAM group was shown.

<u>Dwell Frequency</u>: The increase found in mean dwell duration necessarily resulted in corresponding decrease in dwell frequency, as shown in Figure 5-2 (over a fixed duration drive or viewing period, a longer dwell duration allows fewer possible dwells). An ANOVA indicated BAC was a significant effect ($p < .001$), but that the familiarity factor was not.

5.3.2 Pursuit Characteristics

<u>Pursuit Durations</u>: Mean pursuit durations are shown in Figure 5-3. The ANOVA indicated a significant BAC effect on pursuit durations ($p < .001$) but the familiarity factor was not significant. T-tests indicated no significant differences between the low and high BAC levels, but each was significantly different from placebo.

<u>Pursuit Frequency</u>: Pursuit frequency shows a nearly linear dose-response relationship, as seen in Figure 5-4. A doubling of pursuit frequency was found between the high dose and placebo treatments. In spite of the large mean difference between the FAM and UNFAM groups (Figure 5-4), the ANOVA only showed significance for the BAC effect ($p < .001$); however, the familiarity factor approached significance ($p < .082$).

<u>Total Pursuit Time</u>: The combined increase in pursuit duration and pursuit frequency resulted in an increase of total viewing time in the pursuit state from about 13% under the placebo treatment to about 30% at the high BAC condition. An ANOVA performed on total pursuit time indicated BAC to be a significant effect ($p < .001$) and that

Table 5-2: Mean Durations in Seconds for all Dwells, for Dwells < 1 sec Duration and for Dwells >1 sec Duration

| | BAC Treatment | | |
|---|---|---|---|
| | Placebo | Low | High |
| FAM | | | |
| All Dwells | 0.49 | 0.66 | 0.63 |
| Dwells <1 sec. | 0.34 | 0.39 | 0.36 |
| Dwells <1 sec. | 1.83 | 2.02 | 1.96 |
| UNFAM | | | |
| All Dwells | 0.50 | 0.68 | 0.63 |
| Dwells <1 sec. | 0.35 | 0.40 | 0.40 |
| Dwells >1 sec. | 1.83 | 2.03 | 1.92 |

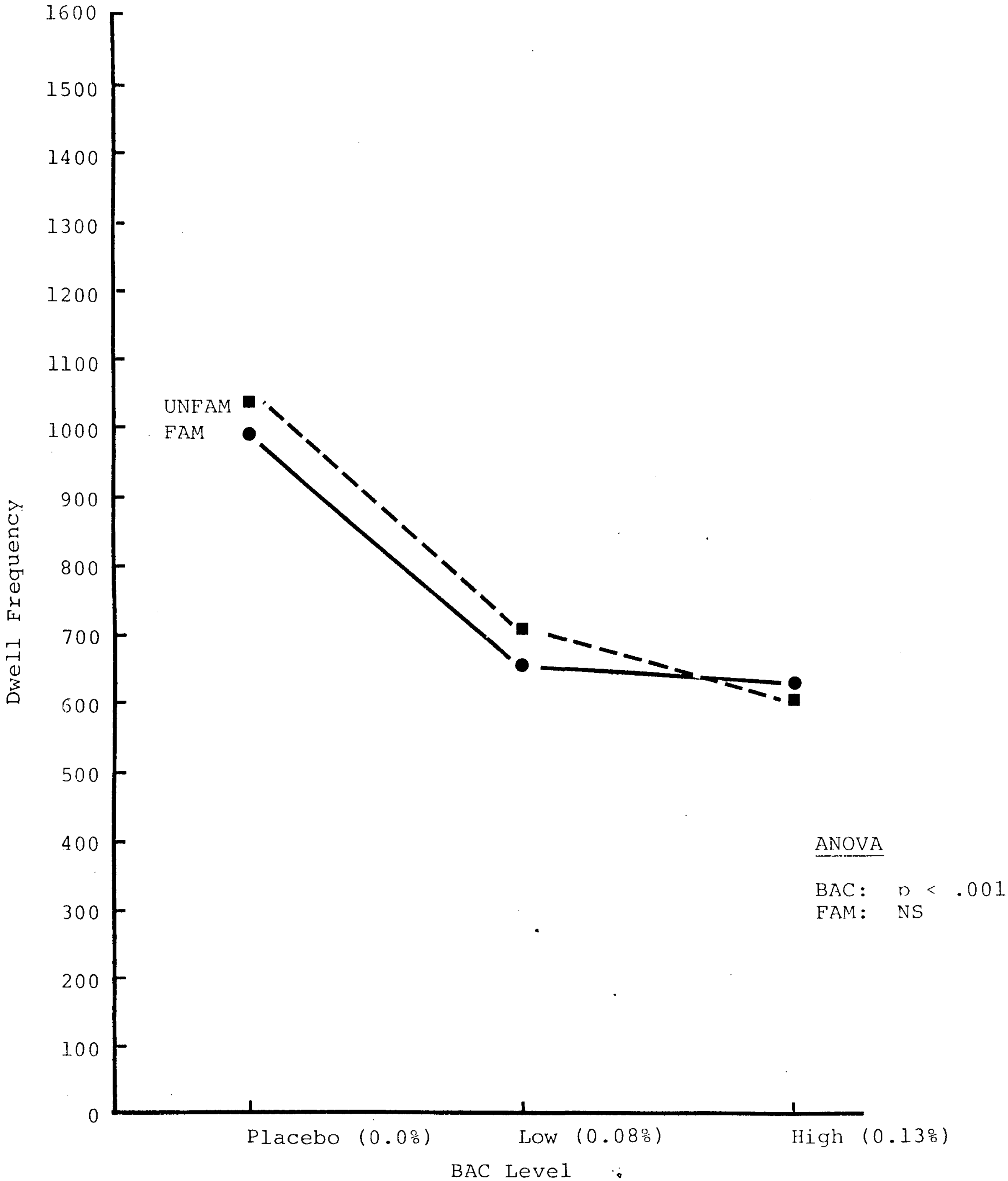



FIGURE 5-2: Dwell Frequency for All Dwells

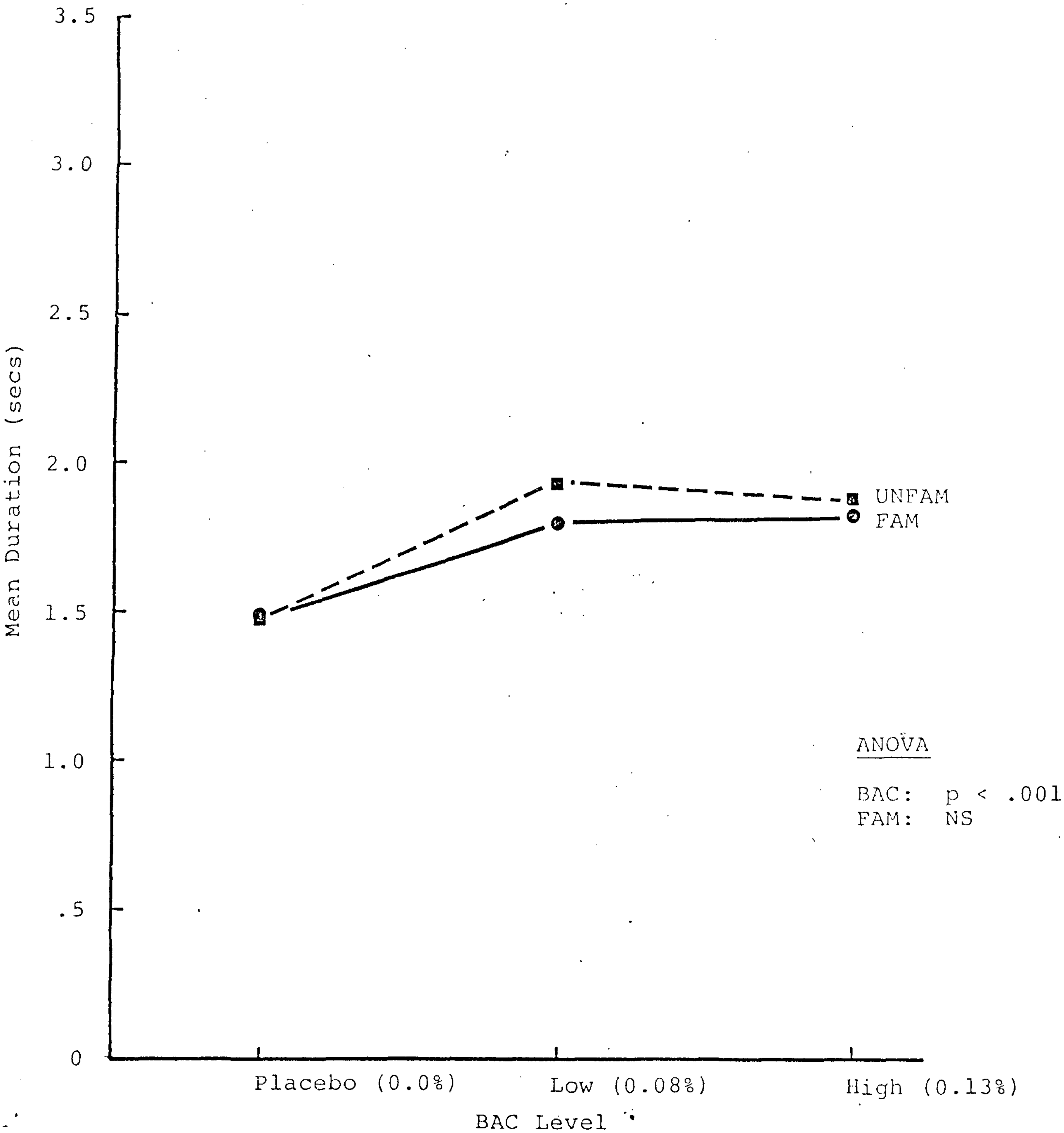



FIGURE 5-3: Mean Pursuit Durations

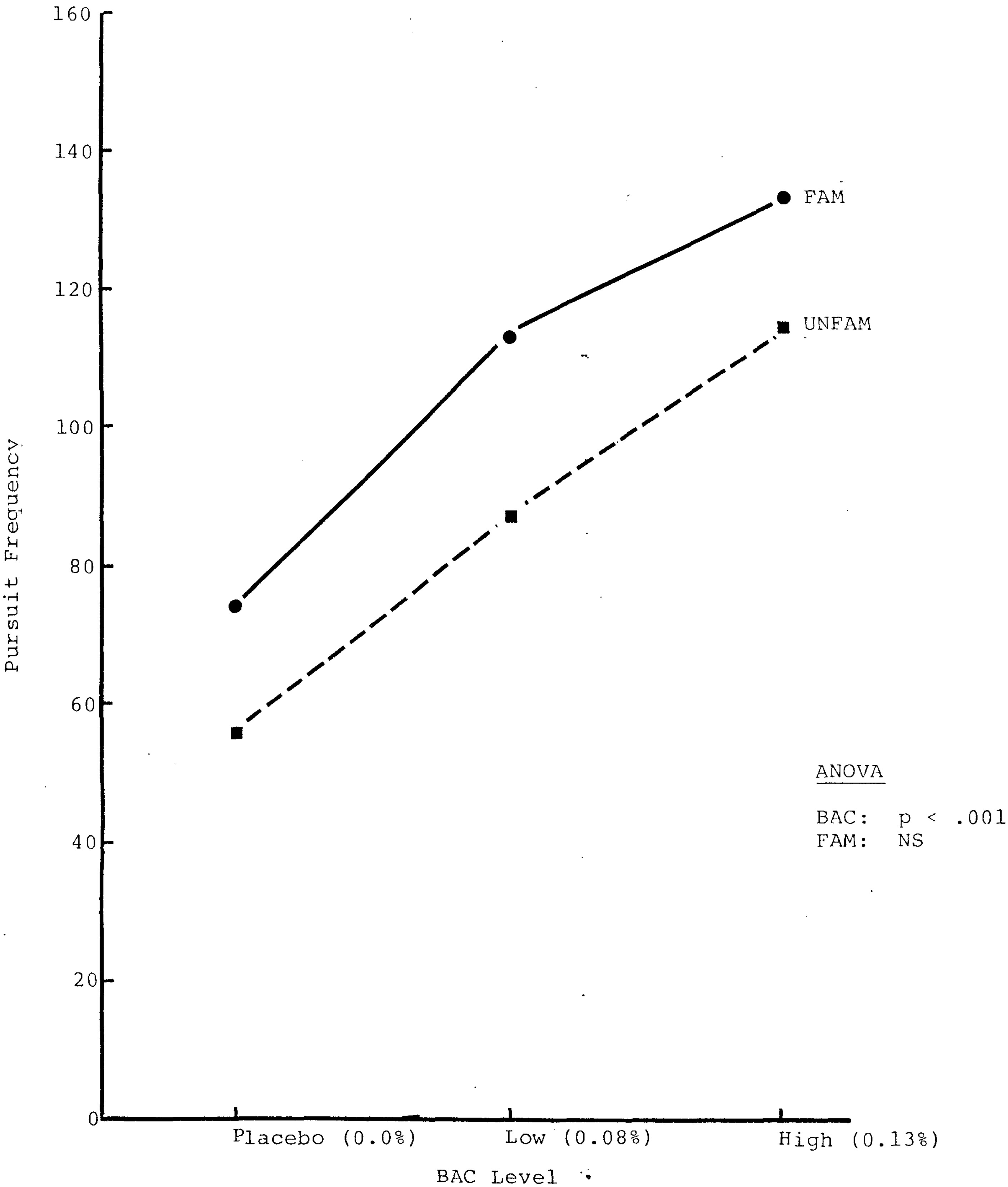



FIGURE 5-4: Pursuit Frequency

familiarity approached significance ($p < .075$).

### 5.3.3 Saccadic Characteristics

Mean saccadic duration (eye movement time between successive dwells) shown in Figure 5-5 also significantly increased under alcohol ($p < .01$) but no familiarity effect was found. T-tests indicated significant differences between placebo and high BAC and between low and high BAC but not between placebo and low BAC levels.

The increase in saccadic duration under alcohol was much smaller than the increases in dwell and pursuit durations. For instance, the maximum increase in saccadic duration was about 0.04 sec., whereas dwell duration increased by about 0.15 sec., and pursuit duration increased about 0.3 sec.

### 5.3.4 Comparisons of Total Time in Dwell, Pursuit and Saccadic States

Proportions of time spent in dwell, pursuit and saccadic states are shown in Figure 5-6. The increasing time in the pursuit state and the decreasing time in the dwell state with increasing alcohol dose is evident from Figure 5-6. Time spent in the saccadic state remained approximately constant, as the increase in mean saccadic time was compensated for by the decreased saccadic frequency (saccadic frequency is identical to dwell frequency, because there is one saccade for each dwell).

## 5.4 Allocation of Attention to the Visual Scene and Critical Event Detection

### 5.4.1 Distribution of Dwells over the Roadway Scene

Mean transition distance (mean distance between successive dwells) is shown in Figure 5-7. This quantity provides a convenient summary measure of the extent of visual search, i.e., the larger the mean transition distance the more "spread out" is the distribution of dwells. The FAM group shows a wider distribution of dwells than the UNFAM at all BAC levels. The ANOVA indicated a significant familiarity effect ($p < .003$) but not a BAC effect.

### 5.4.2 Allocation of Observations to Route Sign, Speedometer and Roadway Scene

Dwell frequencies were tabulated separately for the route sign, the speedometer and the roadway. The same data displayed in terms of the proportion of dwells allocated to each region relative to all dwells at each BAC level are given in Figure 5-8. For both FAM and UNFAM groups, the proportion of dwells allocated to the roadway decreased under both low and high BAC conditions compared to placebo, and the proportion of speedometer dwells increased under low and high BAC doses. Route sign dwell proportion did not appear to change consistently with BAC. In addition, the UNFAM group, compared to the FAM group, looked more often at the roadway, and less often at the route sign and speedometer at all BAC levels.

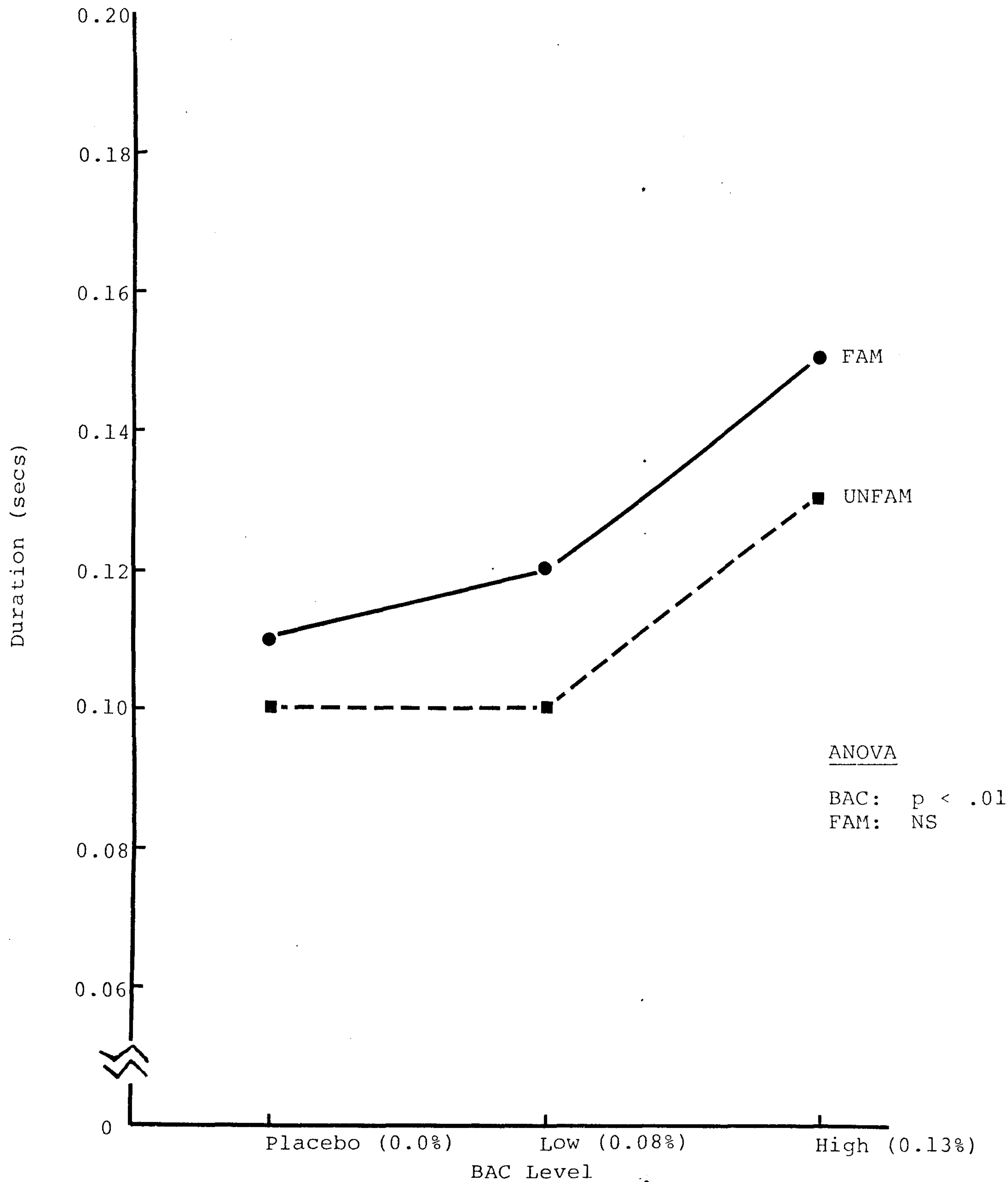



FIGURE 5-5 Mean Saccadic Duration

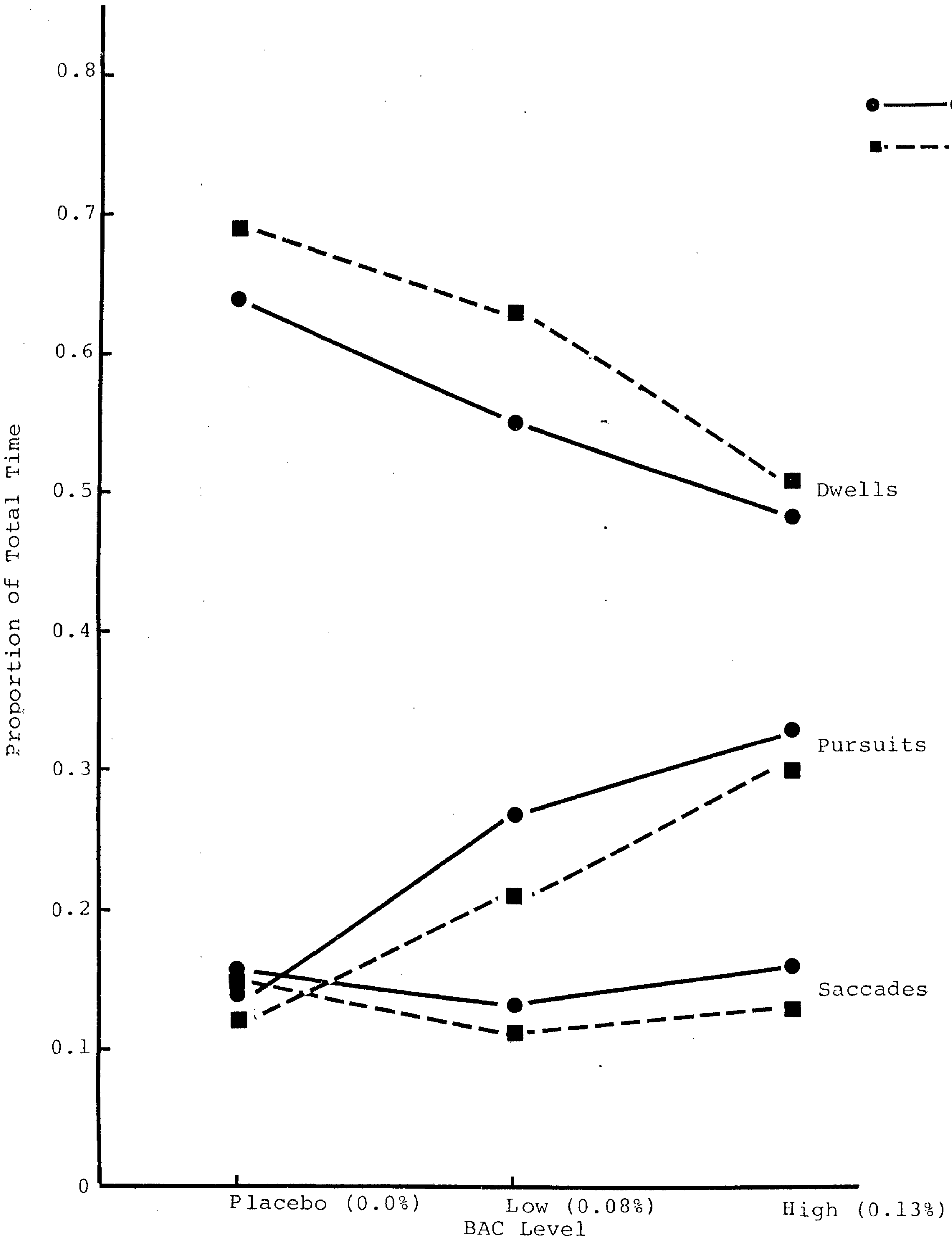



FIGURE 5-6: Proportion of Total Time Spent in Saccadic, Dwell and Pursuit States

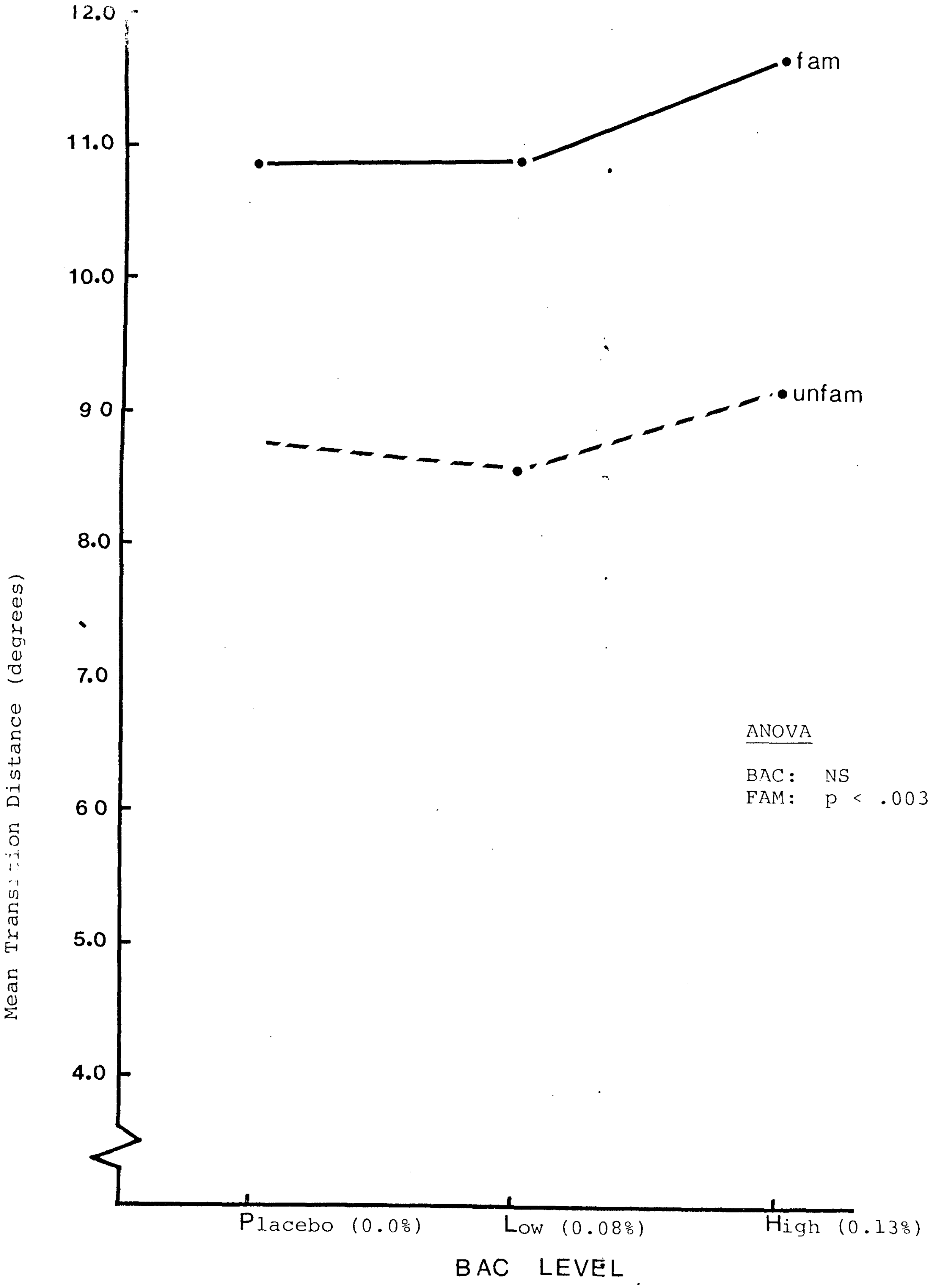
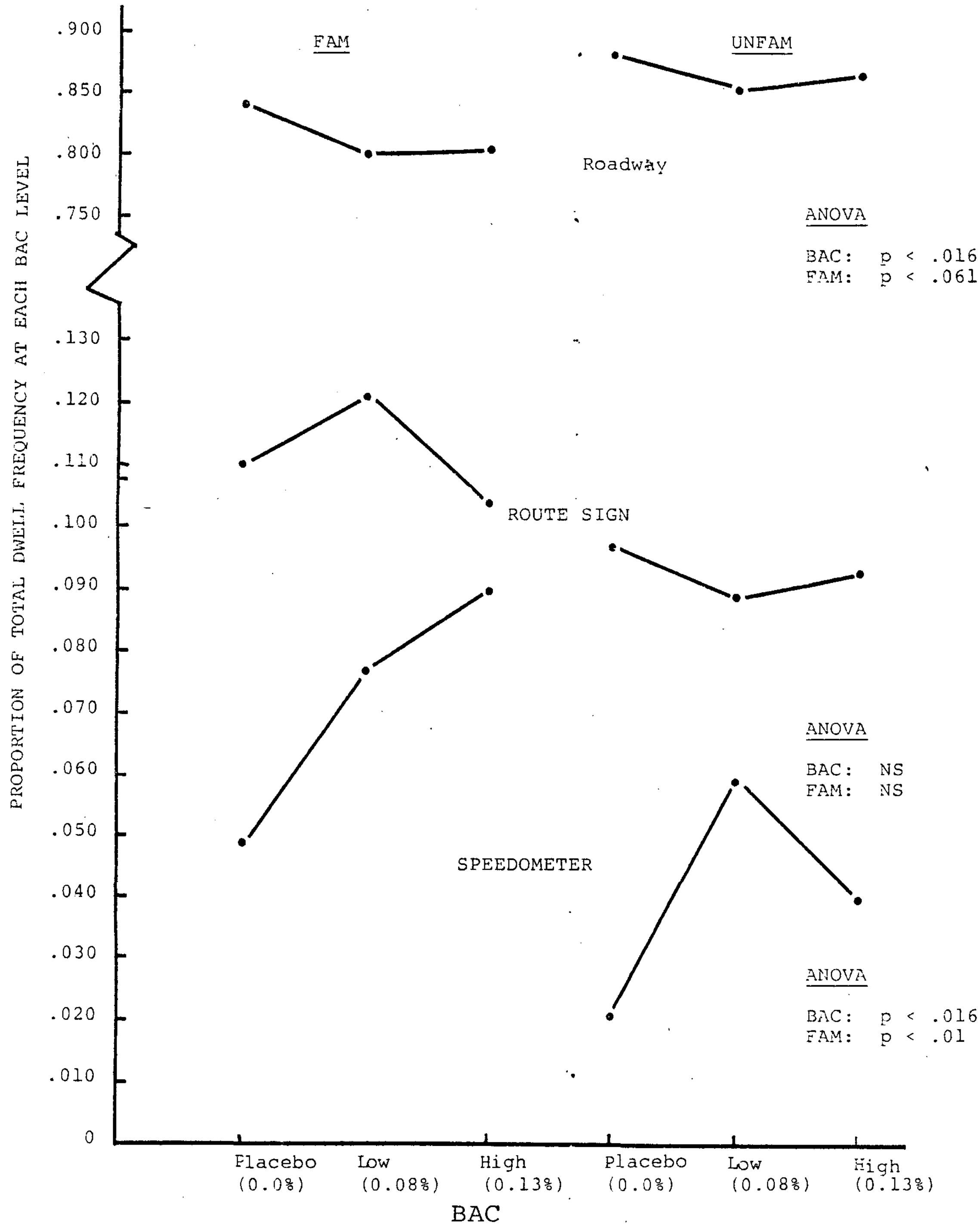



FIGURE 5-7: Mean Saccadic Transition Distance versus BAC

FIGURE 5-8: Proportions of Total Dwell Frequency Allocated to Roadway, Route Sign and Speedometer



Separate two-way ANOVAs were run to test the change in relative allocation of dwells to each area in the visual scene. That is, three BAC x familiarity ANOVAs were performed, one each for the proportions of dwells allocated to the speedometer, to the road sign, and to the roadway. No significant differences were found for proportion of dwells allocated to the route sign. However, an alcohol effect was found for proportion of speedometer dwells ($p < .016$) and for proportion of roadway dwells ($p < .016$). The effects of alcohol were to increase the proportion of speedometer looks and decrease the proportion of roadway looks, without affecting relative attention given to the route sign. In addition, the familiarity effect was significant for speedometer looks ($p < .01$) and approached significance for roadway looks ($p < .061$). Decreased familiarity resulted in a greater proportion of looks at the roadway and relatively fewer at the speedometer.

## 5.5 Critical Event Observations

Critical event detections were measured by recording horn presses (subjects were instructed to press the horn whenever a critical event was recognized) during the period such an event was potentially visible in the film. Four events were selected for scoring per run. Results are shown in Figure 5-9. An ANOVA indicated that BAC was not significant, but that the FAM group performed significantly better than the UNFAM group ($p < .05$). The FAM group responded to 2.3 out of 4 events, whereas the UNFAM group responded to 1.7 out of 4 events.

## 5.6 Route Sign Observations and Recognition Performance

### 5.6.1 Route Sign Information Level and Mean Dwell Times

Route sign dwells were analyzed for the three categories of information demand level discussed in Section 3.2.4 (recognition of blank sign, recognition of non-destination city, and recognition of destination city). Mean dwell time, combining data from all three alcohol levels, is shown plotted versus route sign information demand in Figure 5-10. A strong effect of route sign information category on mean dwell time is shown: the shortest dwell times occurred for the blank sign (0.47 to 0.5 sec.), the next longest for the non-destination city (0.8 to 0.95 sec.) and the longest for the destination city (1.22 to 1.44 sec.). In addition, the UNFAM group shows longer mean dwell times compared to the FAM group for all cases. However, only the alcohol effect was significant ($p < .001$).

### 5.6.2 Alcohol Level and Mean Dwell Times

The route sign dwell data are replotted in Figure 5-11 with mean dwell duration for all route sign dwells shown versus BAC level. Mean dwell duration increased by about 70% as the BAC level increased from placebo to high. A significant alcohol effect was found ($p < .001$) and the familiarity effect approached significance ($p < .089$). Note that the smallest effect of familiarity was found for the placebo case.

### 5.6.3 BAC, Information Processing Load and Dwell Times

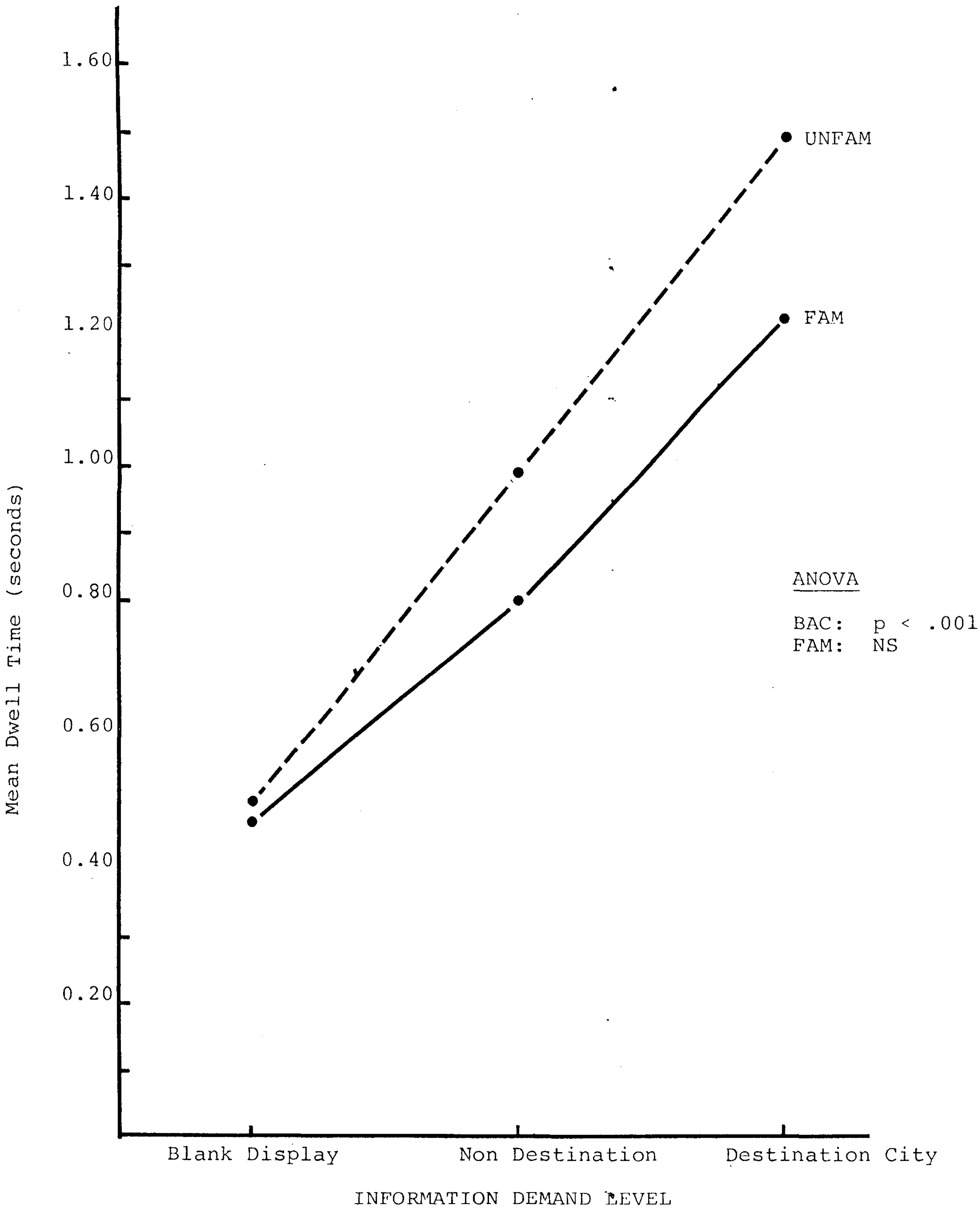



FIGURE 5-10: Route Sign Mean Dwell Times Versus Information Demand Level

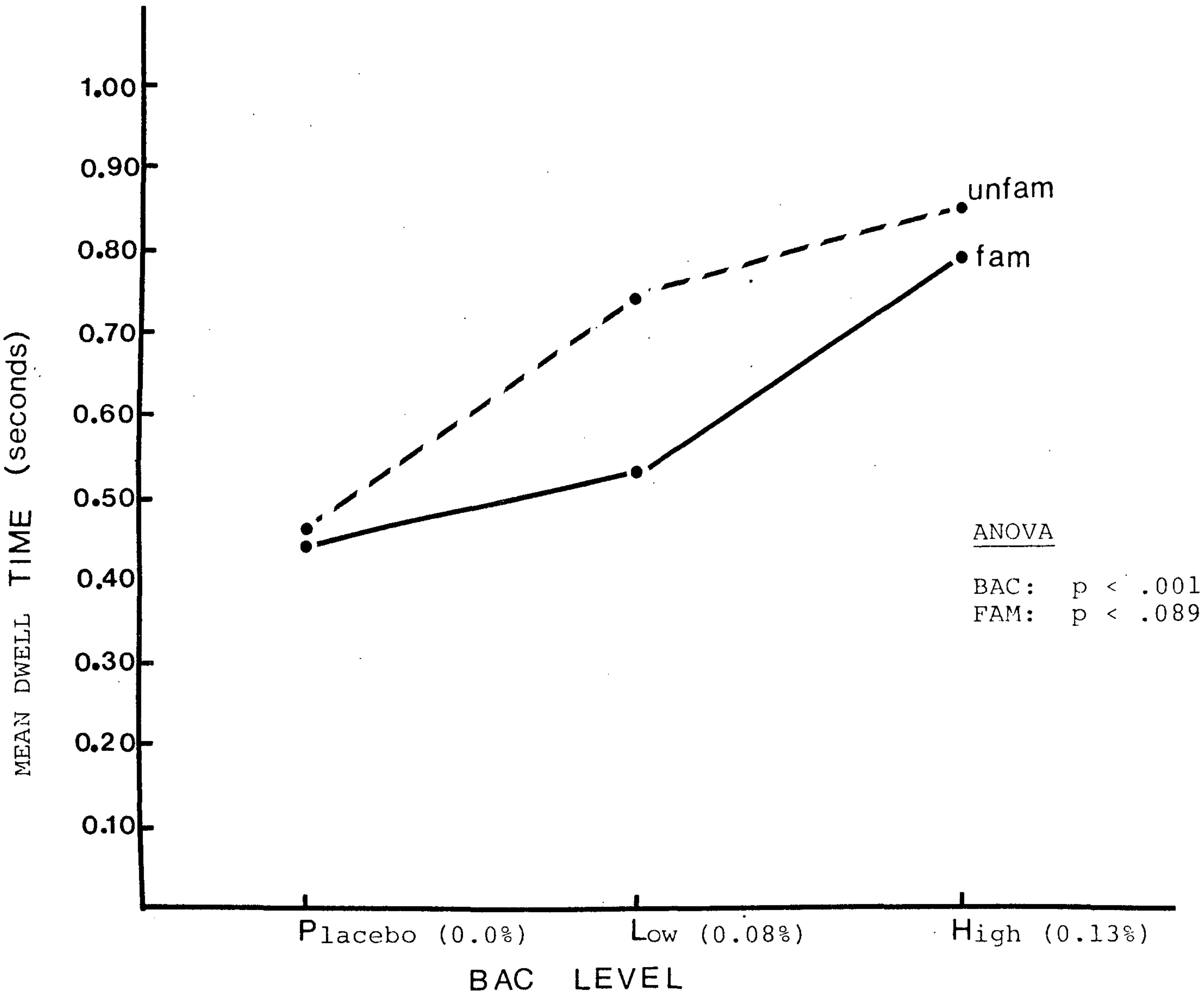



FIGURE 5-11: Route Sign Mean Dwell Times versus BAC Level

The effect of the alcohol treatment on mean times for route sign dwells in shown in Figure 5-12 at each information demand level. Three pairs of curves are shown. Each pair presents mean dwell time for the FAM and UNFAM groups versus BAC at a given level of information demand (lower pair: recognition of blank sign; middle pair: recognition of non-destination city; upper pair: recognition of destination city). The differences between the three sets of curves suggest that an interaction occurred between BAC, familiarity and information demand:

a) For dwells on the blank sign, the FAM and UNFAM groups had nearly equal mean dwell times at all BAC levels (bottom pair of curves in Figure 5-12). Thus, each group required about the same amount of dwell time to determine that a sign was blank, regardless of BAC level. Dwell time increased for both groups with increasing BAC.

b) For dwells on non-destination city names, the UNFAM group required about 0.20 sec. to 0.25 sec. longer to examine the city names than did the FAM group (middle pair of curves in Figure 5-12). Dwell time also increased for both groups as a function of increasing BAC, but the increase was somewhat greater for the UNFAM group.

c) For dwells on destination city names, except for the placebo case, a marked difference in dwell times occurred between the FAM and UNFAM groups, comparing placebo to active BAC treatments (top pair of curves in Figure 5-12). Whereas dwell time increased about 0.15 sec. for the FAM group, a much larger increase of 0.5 sec. was found for the UNFAM group.

Various analyses were performed to examine the statistical significance of the results described above. The analysis was complicated by three problems: (1) the small N involved in the destination city dwell data (the total number of dwells for all subjects for each familiarity/BAC category varied from 19 to 27, as shown in Figure 5-12)*, (2) the large differences in the N between the blank, non-destination city and destination city dwells (the total Ns varied from a maximum of 27 for destination city dwells to over 1000 for dwells on the blank sign), and (3) the large variability and lack of normality typically found in eye fixation data, which is accentuated for small Ns. The large difference in Ns and consequent inhomogeneity of variance between information demand levels precluded a three-way ANOVA (familiarity x BAC x information demand). The use of three separate two-way ANOVAs, one at each information demand level, would have justified for the blank and non-destination cases but not for the destination city dwells.

Based on these considerations, Friedman two-way non-parametric analyses (subjects x BAC) were applied separately to the FAM and UNFAM groups at each information demand level. These results are given in Table 5-3. A significant alcohol effect on mean dwell time is shown <u>for all levels of information demand for the UNFAM group</u>. However,

*Two destination city presentations were given per run and typically only one dwell was given to the sign at each presentation.

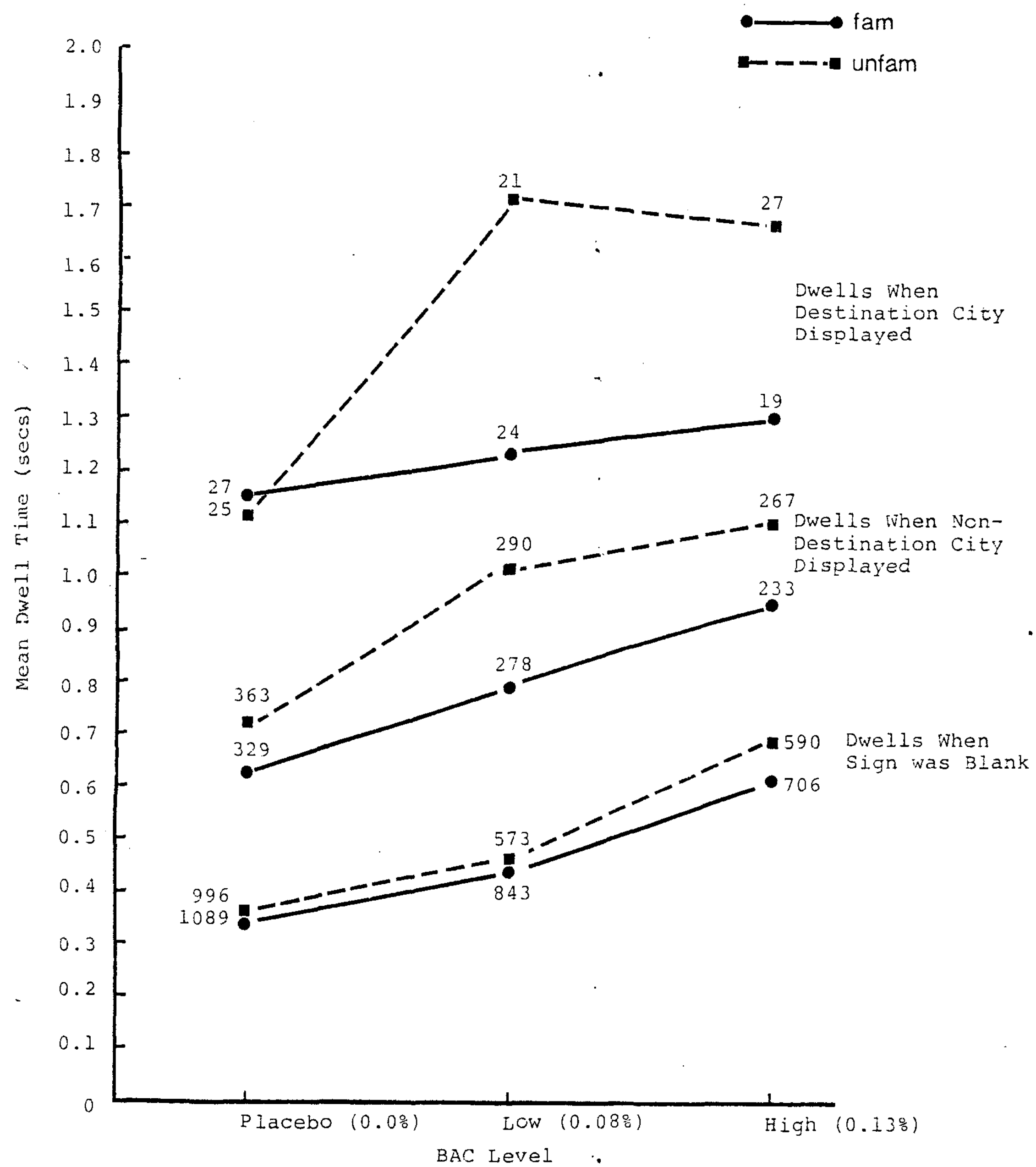



FIGURE 5-12: Route Sign Dwell Times at Three Levels of Information Processing Demand (Numerals next to each point indicate the total N on which the corresponding mean is based.)

Table 5-3. Friedman Non-Parametric Analysis of Route Sign Dwells

| Information Demand Level | Alcohol Effect: Friedman Test Probability Value |
|---|---|
| Blank | |
| FAM | .037 |
| UNFAM | .0015 |
| Non-Destination | |
| FAM | .146 |
| UNFAM | .0004 |
| Destination | |
| FAM | .70 |
| UNFAM | .029 |

for the FAM group significance is only reached for dwells on the blank sign, i.e., alcohol did not have a significant effect on non-destination and destination city dwell time. Thus, the magnitude of impairment due to alcohol is jointly dependent on the level of route familiarity and the information demand level. Apparently, the FAM group had sufficiently overlearned the recognition task so as to partially compensate for the effect of BAC on information processing rate.*

5.6.4 Frequency and Response Time for Correct Responses to Destination City Presentations (Turn Signal Responses)

Mean frequencies of correct destination city response (as indicated by correct turn signal responses) are shown in Figure 5-13. Note that the maximum possible correct response frequency is 2.0, corresponding to the two destination city presentations per run. A trend towards a decreased frequency of correct responses is shown under alcohol.

Reaction times for the turn-signal response to destination cities did not show any consistent trend. As shown in Figure 5-14, reaction times were on the order of 2.2 seconds under all conditions.

No statistical evaluation was performed for these data due to the small N involved. However, the trends shown in Figure 13 indicate poorer recognition performance at elevated BACs.

5.7 Steering Control and Speedometer Monitoring

5.7.1 Steering Control

Algebraic mean error and root-mean-square (RMS) error for steering control (heading angle) are shown in Figure 5-15. As discussed previously, the steering task was to keep the car pointing "straight down the road" in the face of random disturbances. This required orientation of the simulator cab longitudinal axis at right angles to the screen, corresponding to a 0 degree heading angle error.

Mean steering error (top curves in Figure 5-15) increased from about 0.5 degree heading angle (placebo) to about 2.0 degrees heading angle (high BAC) for both the FAM and UNFAM groups. In addition the FAM group showed a trend toward a smaller mean steering error at all BAC levels, compared to the UNFAM group.

RMS steering error (bottom curves in Figure 5-15) increased from about 2.0 degrees (placebo) to 2.8 degrees (high BAC). In this case no consistent familiarity group difference is apparent.

In spite of the large differences in mean steering error, an ANOVA indicated that neither the familiarity nor alcohol effect was statistically significant; however, an ANOVA on RMS steering error

*Results of two-way ANOVAs (BAC x familiarity) at each information demand level, using a log transformation to reduce heterogeneity of variance, were consistent with the Friedman tests.

Figure 5-13
MEAN FREQUENCY OF CORRECT DESTINATION
CITY RESPONSES

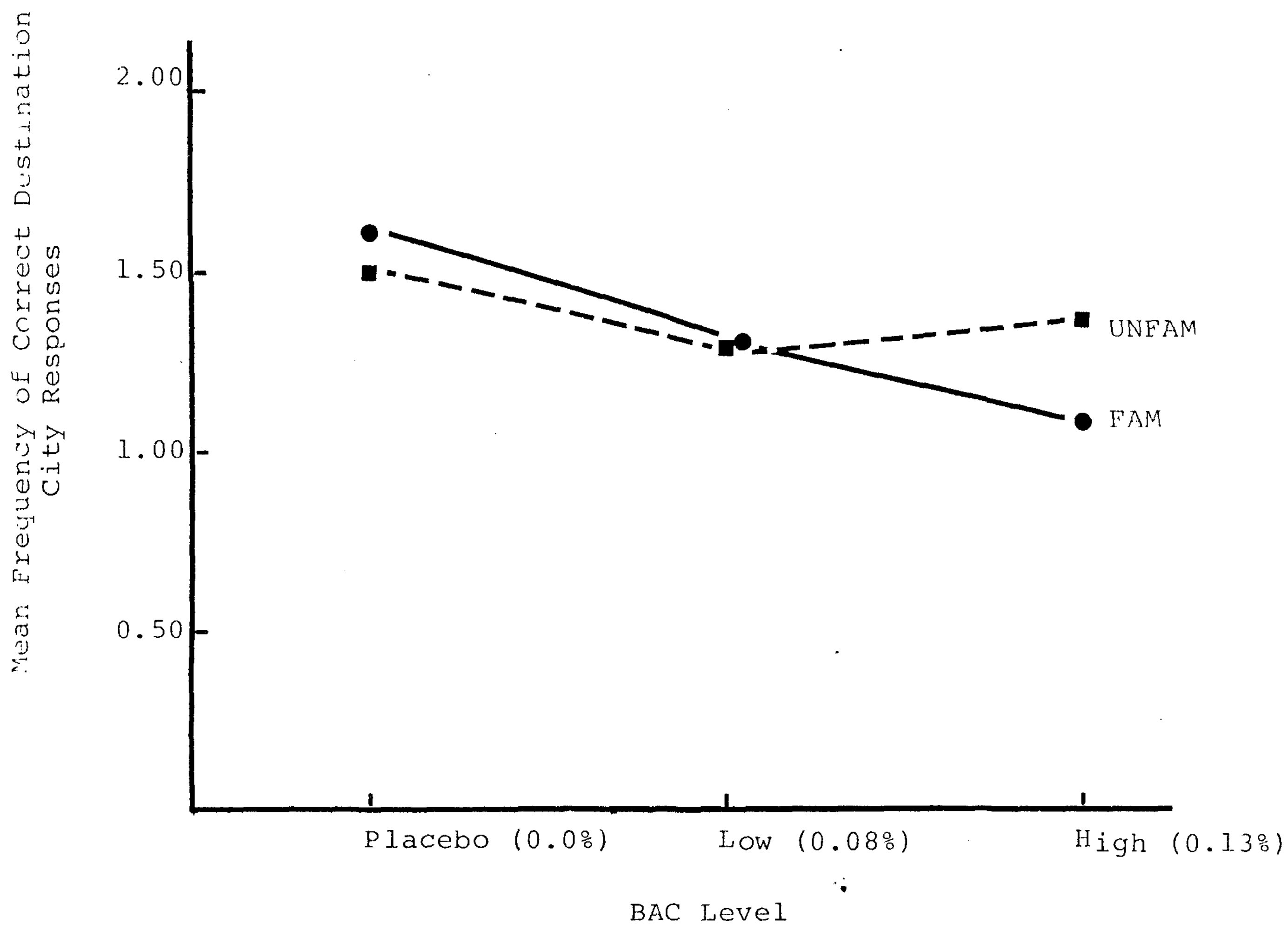


Figure 5-14
MEAN REACTION TIMES TO DESTINATION CITY CORRECT RESPONSES

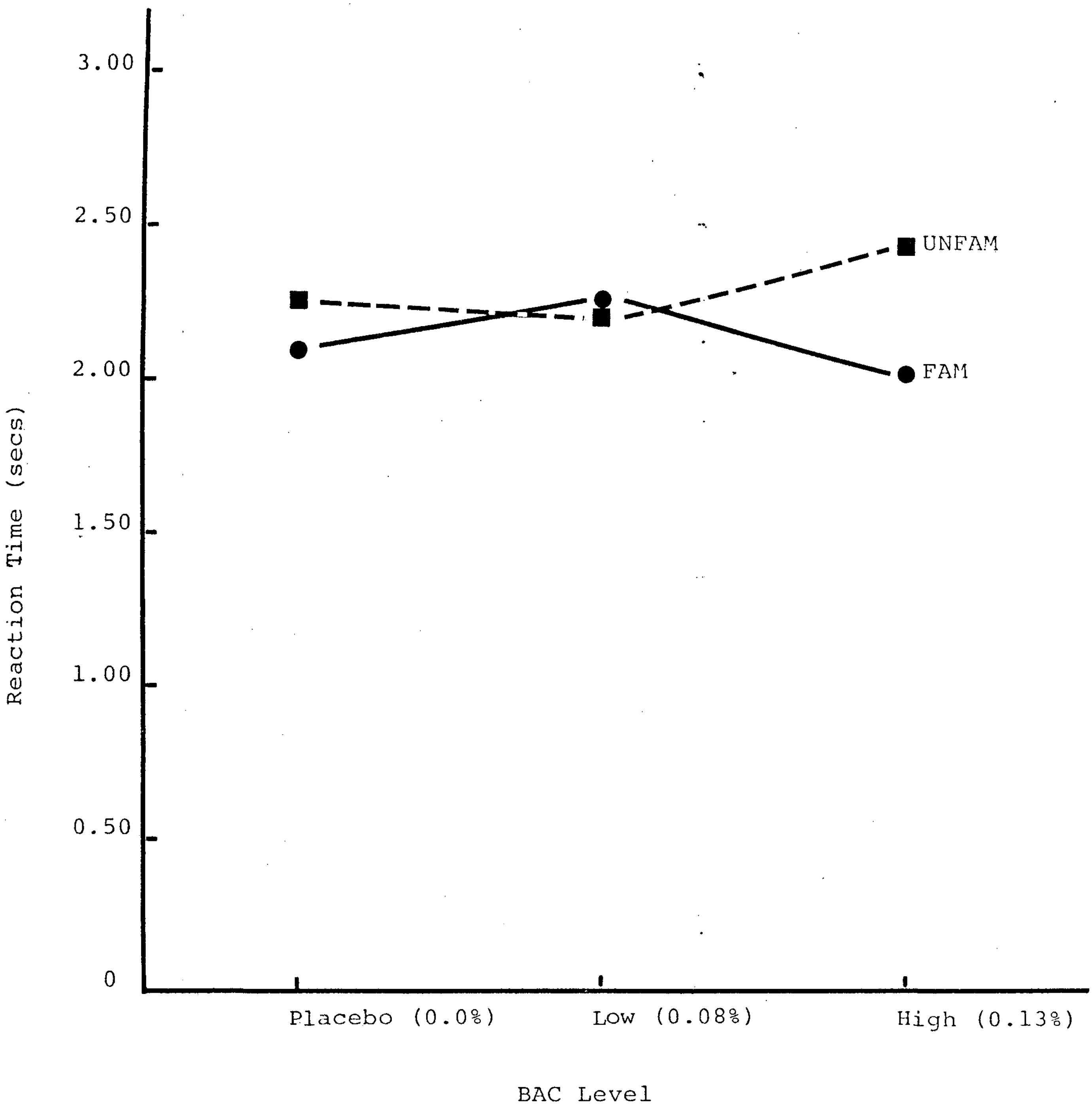
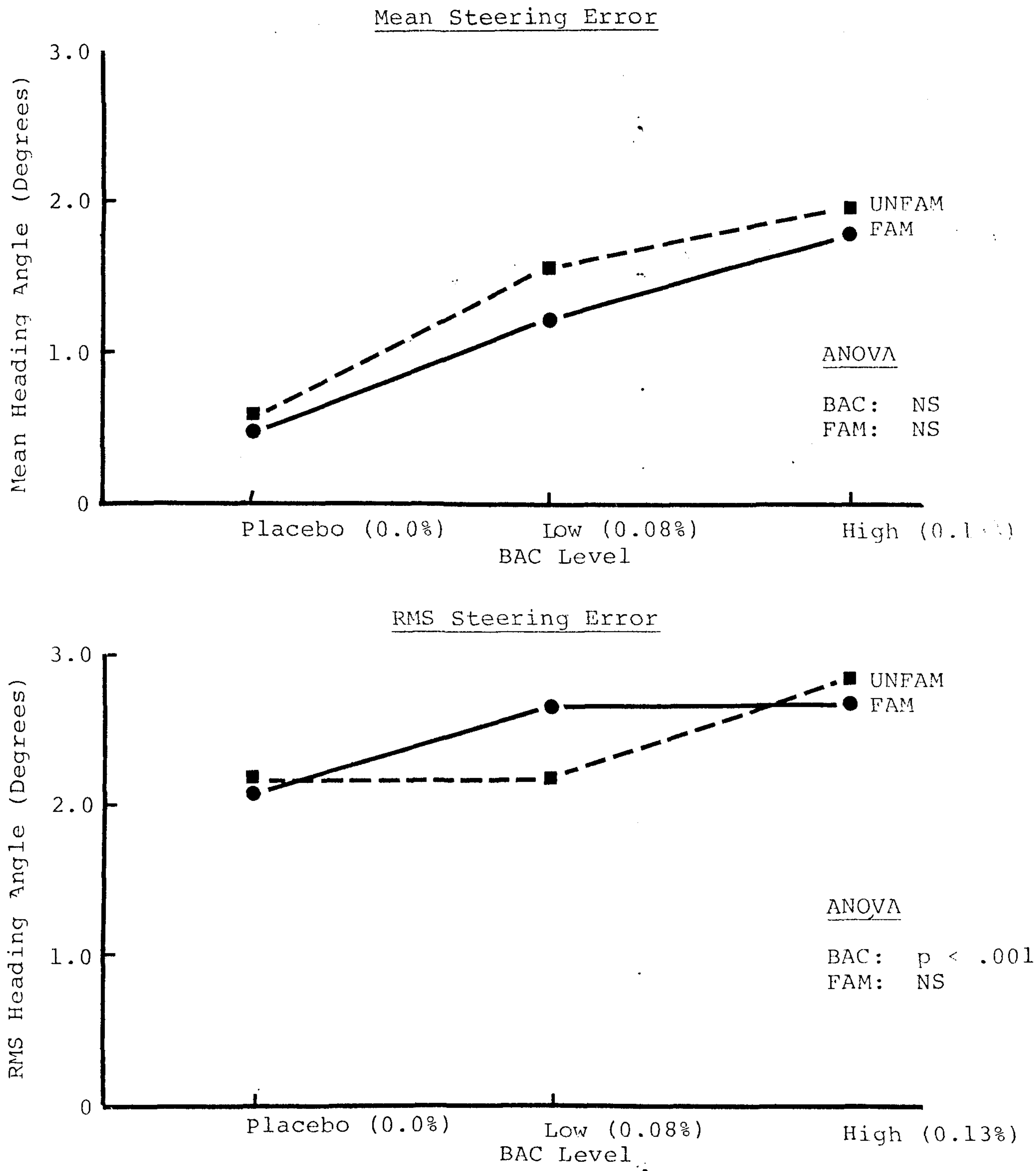


FIGURE 5-15: Heading Angle (Steering Control) - Algebraic Mean Error and RMS Error



indicated the alcohol effect was significant, ($p < .001$).

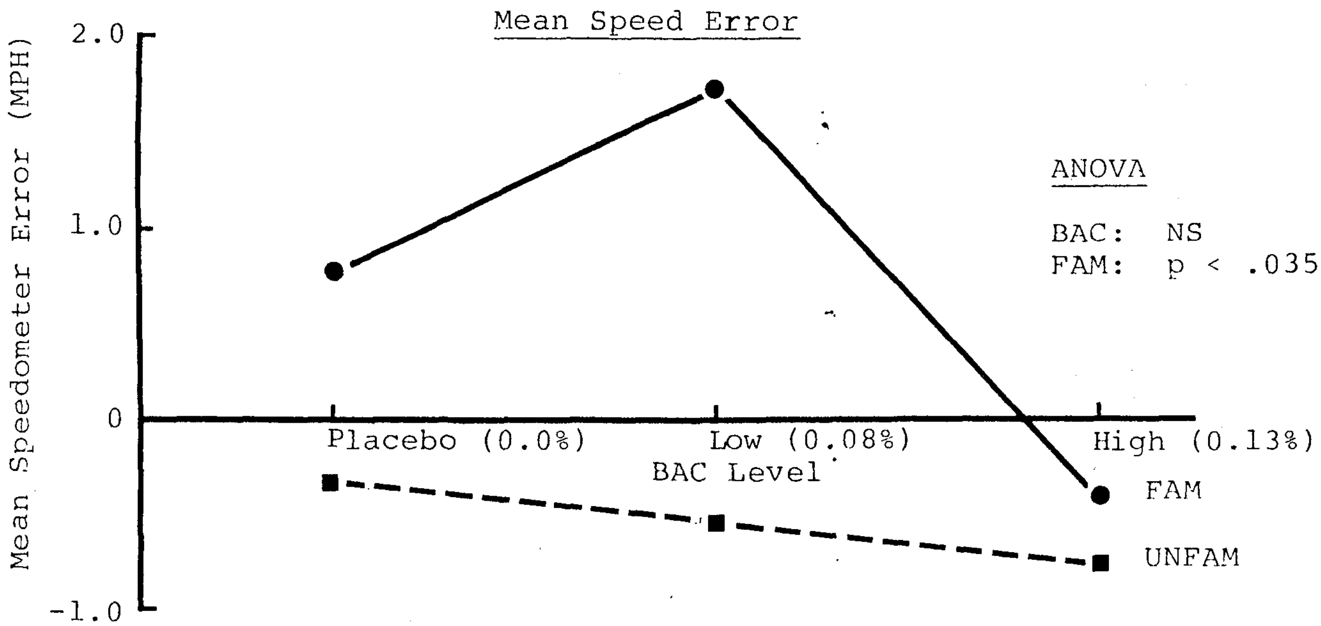
5.7.2 Speedometer Monitoring

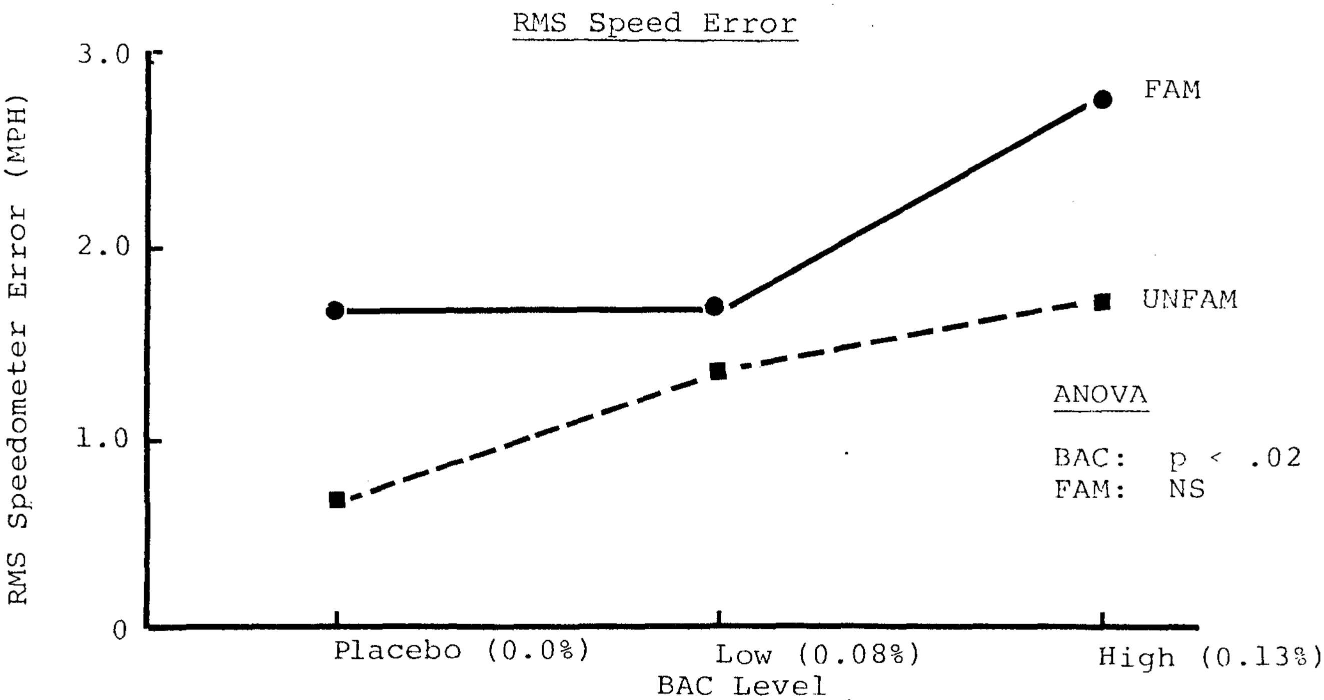
The speedometer task required maintenance of a 40 mph speedometer indication by keeping a constant force on the accelerator pedal. Algebraic mean error and RMS error are given in Figure 5-16. Mean speed error (top curves, Figure 5-16) did not exceed 2 mph for any condition. Except for the high BAC condition, the FAM group showed a positive mean speed error (mean speed > 40 mph), whereas the UNFAM group showed a negative speed error (mean speed < 40 mph). An ANOVA showed a significant familiarity effect ($p < .035$) but no alcohol effect.

RMS speedometer error increased with increasing BAC (bottom curves, Figure 5-16); the FAM group consistently exhibited a greater RMS speedometer error (i.e., greater speed variability) than did the UNFAM group. An ANOVA showed a significant alcohol effect ($p < .02$) but not a familiarity effect.

The RMS error scores provide a measure of variability for both steering control and speedometer monitoring performance and are considered more important measures than are the mean error scores, as increased variability in vehicle control is more likely to be related to accident potential than are changes in mean performance. Based on the variability measures, both steering control and speedometer monitoring performance was impaired at elevated BACs, but were not significantly affected by familiarity level.

FIGURE 5-16: Speedometer Monitoring - Algebraic Mean Error and RMS Error



## 6.0 DISCUSSION

### 6.1 Overview and Significance of Results

All subtasks examined showed either statistically significant impairment or trends towards impairment at elevated BACs, with the exception of critical event detection. In addition, a change in allocation of attention, from the roadway to the speedometer, was found under alcohol. The inference from the previous study by Moskowitz, Ziedman and Sharma (1976 a,b), that longer eye dwell durations under alcohol when viewing a traffic scene are due to a slowed information rate, was supported by the finding that dwell durations increased as information demand increased. This was shown for two types of variations in demand, level of route familiarity and route sign information content.

Level of route familiarity was shown to have a significant effect on performance of a predominantly perceptual task, reading a route sign, but did not effect performance on perceptual-motor tasks (steering control and speed maintenance). In addition, subjects familiar with the route showed a larger spatial distribution of dwells and performed better on detection of critical events than did the route unfamiliar group. Thus, route familiarity, and, by inference, information processing demand, was found to be an influential factor in perceptual performance.

The question of possible selective effects of elevated BACs on the various driving tasks is complex. Selectivity of alcohol impairment was found in that (a) critical event detection was unchanged over alcohol treatment and (b) the impairing effect of alcohol on information processing rate was greater under conditions of greater information processing demand. However, one should not conclude that similar selectivity of alcohol effects (or, shifts of attention from roadway to the speedometer) would occur in all driving situations. Rather, the importance of the present results is in showing that the manner in which alcohol-induced impairment is exhibited in driving situations will depend on the information processing demands of the situation as well as the state of the driver with regard to factors such as his familiarity with the route and perceived importance of the various subtasks in driving. For instance, speedometer monitoring is probably not considered a high priority task by most drivers in normal driving and the increased attention given to the speedometer under alcohol in this study could be a consequence of the instructions on speed maintenance performance. An intensive experimental effort, involving systematic variation of relative processing demands of the various component tasks in driving (motor as well as perceptual), in combination with manipulation of the driver's priorities for performance on each component task, would be required to fully analyze this issue.

In spite of the complexity of this problem, an understanding of the relationship between alcohol impairment and processing demand increases the ability to analyze alcohol-related driving impairment, and in accidents. Further, the usefulness of eye-point-of-regard data in analyzing the driver's allocation of attention and perceptual performance has been further validated, especially through confirmation of the hypothesis that dwell duration reflects the driver's visual information processing rate. Additional discussion of the above issues and related topics is given in the following sections.

## 6.2 Dwell, Pursuit and Saccadic Characteristics

The dose response curves for roadway dwell duration versus BAC showed a levelling-off in the present study (e.g., see Figure 5-1), as they did in the previous experiment (Moskowitz, Ziedman, and Sharma 1976 a,b). This result is somewhat surprising as (a) a physiological limit in dwell duration was not reached, and (b) measures sensitive to alcohol effects do not typically show a levelling in the BAC range studied. This phenomenon is probably related to the continuous movement of the visual scene, combined with a need to view each fixated area longer under alcohol. When a dwell on a given target is extended in time, the target will move away from the fixation point and, if visual examination is to be maintained, the target must be followed either with a series of saccades and dwells, or with a pursuit movement. The hypothesized effect would explain the levelling off of the dose-response curve for mean dwell duration versus BAC, as some longer dwells would have been transformed into pursuits. On the other hand, mean dwell time on the route sign, a static display, showed a more linear dose-response relationship, thus confirming that the levelling of dwell time for roadway dwells is related to the moving scene.

The increase in saccadic duration (Figure 5-7) with increased BAC is consistent with studies on oculomotor performance showing slowing of saccadic velocity under alcohol (e.g., Wilkinson, 1974). Based on the findings that EPR characteristics show an interaction with task variables such as information processing demand, it is concluded that EPR measurements exhibit the effects of alcohol two mechanisms: (1) effects on the oculomotor control system influencing saccadic velocity, fixation control, etc., and (2) effects on information processing capability for perceptual tasks, influencing fixation or dwell duration, allocation of attention, etc.

## 6.3 Alcohol, Visual Information Processing Capability, and Allocation of Attention

The hypothesis presented in the Background section that the primary debilitating effect of alcohol on human performance arises through a decreased information processing rate was based on laboratory studies with simplified tasks, with some supporting evidence from previous simulation studies. The results of the present study provide evidence that a decreased rate of information processing under alcohol occurs in the context of a complex, driving-like task as well as in simpler task situations. This finding supports the conclusions from the previous NHTSA study (Moskowitz, Ziedman, and Sharma 1976a,b) and agrees with Beideman and Stern (1976) who also concluded from a driving simulator study that alcohol affects drivers' information processing capability and division of attention. In addition, the present study showed a shift in allocation of attention as a function of both BAC level and familiarity.

It is important to emphasize that possible shifts in attention allocation due to a reduced information processing rate could be exhibited in various ways. The so-called "tunnel vision" phenomenon referring to concentrated attention "down the road", that has been claimed to be produced by alcohol has not been observed in this or in the precursor study and may only occur in certain conditions, e.g., nighttime driving with a restricted visual environment. The two studies demonstrate that it is possible to maintain an extensive visual search pattern (distribution of dwells) under alcohol. Although alcohol did not significantly alter the drivers' visual search patterns, other aspects of performance were impaired.

It is likely that the pattern of imapirment found under alcohol in the present study was partially related to the low demands of the steering and guidance tasks. Increased demand for vehicle guidance and control would require greater attention to the roadway and its delineations. Thus, with additional demand for vehicle control and guidance it would be more difficult to maintain an extensive search pattern. If an additional stress, such as alcohol, were added, even greater perceptual impairment would be expected.

## 6.4 Alcohol, Visual Information Processing and Accidents

Any given driving accident generally involves a variety of factors which, in combination, result in an accident situation. The fact that the dominant behavioral effect of alcohol is a deficit in information processing rate does not necessarily imply that this deficit is, by itself, the only factor in alcohol-related accidents. However, an information processing deficit has a substantial effect on the driver's ability to handle stressful situations requiring rapid decisions and actions. For instance, in the present study, unfamiliarity represents a kind of stress, and, as shown, greatly increases the time required to read a simple sign under alcohol. A driver starting to drive off the road due to sleepiness is much less likely to recognize the situation in time to recover safely under alcohol than if sober. Thus, the importance of the present results, and their use in analyzing alcohol-related accidents, lies in the interaction between the information processing deficit produced by alcohol and the many other factors contributing to accidents. Available accident studies, in which behavioral analyses were made of causal factors, generally do not provide sufficient detail to allow conclusions regarding the issues raised in the above discussion. Although accident analyses are fraught with difficulties, use of experimental findings on the effects of alcohol as a guide for selection of appropriate driver behavioral and situational measures, would enhance the useability of such investigations.

## 6.5 Alcohol Effects and Training

The finding that task familiarity partially compensated for the degrading effects of alcohol raises the intriguing possibility that extended task training would be a useful tool to assist drivers in overcoming various performance degrading states. Although driving in an abnormally degraded state is hardly desirable, such behavior is difficult to change in the driving population and task specific training to overcome such deficits may be a useful adjunct to driver training and/or re-training.

The present results found under alcohol can reasonably be expected to hold for other deficits (e.g., other drugs, fatigue) which affect rate of information processing. More research would be needed to identify the degree to which extended training is useful, the specific skills to which it is applicable, and amount of training required for beneficial results.*

### 6.6 Visual "Gazing" Phenomenon

An increase in the proportion of long dwells or fixations under alcohol has been reported by three studies of driving performance (the present study; Moskowitz, Ziedman and Sharma, 1976a,b; Beideman and Stern, 1976). Such long dwells are strongly suggestive of the "highway hypnosis" phenomenon in which drivers report "staring blankly" or "driving in an unaware state" for periods of time. Two issues are of importance in considering such a phenomenon: (1) concentrated attention to one aspect of the visual scene, in itself, prevents adequate time-sharing of attention, and (2) information processing must be slowed or otherwise altered during these periods. That is, it is of interest to identify the state or states of the driver during such "gazing" periods in order to suggest possible countermeasures (gazing due to sleepiness or alcohol may be less amenable to counteraction than gazing due to boredom). These issues cannot be resolved with available data; an experiment is needed in which "gazing" periods can be identified in real time and appropriate stimuli presented during normal visual scanning periods and during "gazing" periods. Understanding of this phenomenon is potentially important for both "normal" and alcohol-impaired driving as it may provide an explanation of a wide range of accidents ('didn't see', drove off the road, etc.).

### 6.7 Generalization to Other Drinker Populations

A heavy drinker group was chosen for this study because this population is substantially overrepresented in driving accidents. Substantial impairment under alcohol was shown for this group at 0.08% BAC, which is below the typical legal limit in the United States. Even greater impairment could be expected for moderate and light drinkers at equivalent BACs.

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*Moskowitz and Mori (unpublished study) found that extended training did not improve performance on several skills tasks, indicating that training effects are likely to be task dependent.

## 7.0 COUNTERMEASURES

The present study was not designed to test the effectiveness of specific countermeasures, but rather to identify possibilities for countermeasures to alcohol-related accidents based on knowledge of the behavioral effects of alcohol. Two general areas of countermeasure applications are indicated:

1. changes in design of roadways design and traffic control devices to compensate for perceptual impairment due to alcohol, and

2. driver training and public information and education relating to increasing self-knowledge of alcohol effects on perceptual processes and/or to produce resistance to deficits through extensive training in particular skills.

The present study results, as well as those of prior studies on alcohol effects, suggest that the focus of countermeasures intended to minimize the degrading effects of alcohol on driver information processing rate should be (1) to reduce the rate at which information must be processed by the driver and (2) to assist the driver in maintaining a reasonable division of attention among the various driving tasks (or, to minimize the tendency to focus on one task).

Standards for highway guidance systems typically are based on data from young, healthy subjects. Various authors have argued that such standards are inappropriate for the general driving population. Particular attention has been given to visual performance and age. Hills (1975) concluded that movement perception and decision time degraded with age; Pulling, et al. (1978) found glare resistance declined with age; and Sivak, Olson and Pastalon (1979) found legibility distances for older subjects to be 65 to 77% of those for younger ones. Sarlanis and Lewis (1970), in a review of age, health, drugs and visual deficiencies, suggest that highway design criteria should take into account the range of visual characteristics found in the on-the-road population.

Estimates from roadside surveys indicate that at certain periods 10% or more of drivers are legally drunk and as many as 30% have above zero BACs. Thus, drinking drivers represent a significant proportion of the driving population. Further, the principal deficits induced by alcohol (slowed information processing) may be similar to deficits in other groups (older drivers, other drugs). Thus, a general argument can be made for evaluating highway design criteria in terms of deficits induced by other factors as well as alcohol.

The results of the present study and others on the effects of alcohol suggest several topics in which information-processing deficits could reduce accidents. Redundancy in the design of warning and guidance signs could reduce the driver's information processing load. Improving "attention-getting" aspects of signs or other guidance displays may help overcome an inappropriate focus of attention. The use of special "wrong-way" signs on California freeway exit ramps was effective in reducing wrong-way entrances on the part of DWI and elderly drivers (Tamburi, 1968). A study by Hicks (1976) showed that increased sign luminance could partially compensate for alcohol effects on sign recognition. An important category of alcohol-related accidents that occurs in rural environments, "the single car driving off the road" might be reduced by appropriate roadway delineations to reduce the amount of information processing necessary to monitor vehicle position and trajectory. The results of the present study indicate that it would be profitable to identify classes of alcohol-related accidents which may be amenable to such environmentally applied countermeasures.

The results of the present study also suggest that an understanding of the nature of alcohol-induced deficits should be emphasized in driver training and re-training programs. Awareness of the nature of alcohol impairment may assist a driver in driving more effectively even if impaired. For instance, can a driver maintain conscious direction of visual search if she or he is aware that search efficiency is likely to be reduced under alcohol? (Driving more slowly is a simple means of reducing information processing demands.) Specific skills such as visual search strategy, mirror use, etc., might be made more resistant to alcohol degradation with increased training.

The various possibilities for countermeasures derived from this study all require additional investigation before specific recommendations can be made. It is important to note, however, that the kinds of countermeasures discussed above will likely have an accident reducing potential beyond that for just alcohol-related accidents, as other drugs and stressors have effects related to those of alcohol.

In this sense, the alcohol case serves as a model for development of countermeasures based on an understanding of driver's behavioral processes and how those processes are affected by various conditions. The most effective countermeasure, of course, is to not drive, if impaired. However, as impaired drivers are likely to remain a large proportion of drivers on the road, results of studies such as the present one are useful to develop ways of increasing safety without encouraging driving under impaired conditions.

## 8.0 SUMMARY OF RESULTS/CONCLUSIONS

In presenting the following conclusions, reference is made to the study goals given in Section 2.4.

1. Were there differences in allocation of attention among: steering control, speed maintenance, route sign recognition, and hazard recognition tasks? As measured by relative dwell frequencies, shifts in allocation of attention were found to be related to BAC level. Under alcohol, subjects looked more at the speedometer and less at the roadway whereas attention to the route sign remained unchanged. Note, however, that a pattern of attention allocation is certainly related to the demands of a given driving situation and the present results should not be generalized to all situations.

2. Did alcohol impair performance equally on all driving tasks or was performance selectively affected? Although performance of all tasks, except critical event recognition, was impaired under alcohol, the magnitude of impairment was especially sensitive to the visual information processing demand. Thus, the effect of alcohol may be related as much to task demand as to the type of task itself.

3. Did an alcohol-induced decrease in information processing rate exhibit itself in the task situation? The dwell duration results for reading the route sign clearly showed the effects of a decreased information processing rate. This result substantiates previous conclusions that increased dwell durations found under alcohol reflect a decreased information processing rate, and further emphasize the value of using eye movement data in studies of driver behavior.

4. Were the effects of alcohol different as a function of route familiarity? Lack of route familiarity resulted in a much larger deficit under alcohol for time required to read the route sign, compared to the case in which subjects were familiar with the route. Level of familiarity did not change the influence of BAC for any of the steering control or speedometer maintenance measures.

5. Do the results suggest possible countermeasures to alcohol-induced impairment? Areas indicated for investigation as countermeasures include: 1) treatments to roadway and signs designed to minimize selected types of alcohol-related accidents, and 2) consideration of driver training techniques and public information and education for counteracting alcohol effects.

Finally, it should be emphasized that the results discussed above pertain to a heavy drinking population; the impairing effects demonstrated would be greater for moderate or light drinkers at equivalent BACs.

## 9.0 RECOMMENDATIONS

The results of this study point to several topics deserving additional effort. These are:

1. An examination of the driver's allocation of attention, under conditions of fatigue, nighttime driving, and monotony, in combination with alcohol, should be performed to extend the results of previous studies. Such a study could be conducted in an appropriate closed-loop driving simulator, with proper attention to motivating factors. The results from the recomended study would, together with prior studies, provide data on driver information processing and allocation of attention under alcohol for a wide range of conditions.

2. The effects of alcohol on visual information processing capabilities of light and moderate drinkers should be examined to support generalization of results from the present study.

3. An examination of situations most susceptible to alcohol-related accidents should be made to examine countermeasures based on improved visual treatments of the roadway, signing, or traffic control devices. Roadway delineations to alleviate the single car driving off the road accidents in rural areas is suggestd as a likely candidate.

4. Eye movement techniques lend themselves ideally to an investigation of the "gazing" phenomenon, and its possible relationship to "highway hypnosis" and should be pursued with further research. This could prove to be a fruitful area for development of not only alcohol countermeasures, but for techniques that would be useful for alleviating other effects related to driving under conditions of fatigue and/or low information processing demands.

5. The potential for developing resistance to alcohol-induced deficits with extended training in perceptual tasks should be further pursued. Specifically, the type of tasks amenable to such training should be identified and practical training programs devised.

As pointed out previously, the results of this study as embodied in the above recommendations have applicability beyond the alcohol-related accident. Results from the recommended studies will apply to any situation in which the driver's information processing capability is impaired.

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Appendix A

Training Instructions

INSTRUCTIONS TO SUBJECTS (TO BE READ WHEN THEY ARRIVE FOR THEIR FIRST APPOINTMENT).

- You will be sitting in a cut-down car body located in the rear section of our offices. While seated in the car, you will be watching a movie of a road scene. You will be asked to perform several tasks. These are:

1. Steering to keep the car straight on the road.
2. You will be given the name of a destination city; and you will have to watch for the name of that city to appear on a road sign screen. The destination sign will look like this:

   | CORONA |
   |---|
   | NEXT LEFT |

   When you see your destination appear, you must operate the turn signal to indicate whether the turn is right or left. Your destination sign may appear several times, or not at all. Other destination signs will appear; but do not respond to these. You will be told the name of your city at the beginning of each session.

3. Watch for two kinds of events that would be important if you were actually driving. The events are:
   a. pedestrians walking on the side of the road (either right or left), and
   b. cars coming from or pulling our of a side road or driveway.

   If you see either one of these events (pedestrian or car on the side road) press on the horn.

- IMPORTANT - Keep both hands on the steering wheel during the test, except when you are operating the turn signal or the horn.
- You will have a chance to practice all these tasks, and any questions you have will be answered then.
- On some of the runs you will be wearing a motorcycle helmet and a device that records your eye movements. Nothing will touch your eyes, and it is not dangerous.
- We will be automatically recording how well you can perform. Try to do all of the tasks as well as possible.
- No alcohol will be given during the first week of testing.

  During the next three weeks, you may or may not be given alcohol. Please reserve the whole day for the experiment during those three weeks. Sometimes you will be done early, but sometimes you may have to stay.
- Do you have any questions?
- We cannot answer any other questions about the purpose of the experiment at this time; after we have finished the entire study we will be glad to answer any other questions.

DUAL SIMULATOR SESSIONS (WED.)

TO BE READ TO Ps IN TREATMENT ROOM

VS-4 Participant Instructions

Day 1:

1. Today we won't be using the helmet or glasses. Both of you will ride a total of 3 times in the car together, switching between the driver and passenger seats. "______" will be driving twice today, and "_____" will be driving once.
2. The purpose of these runs is for you to learn as much as possible about the roadway you will be driving.
   a) The person in the driver's seat should do all the tasks you did last time:
      1. steer down the road.
      2. keep the speedometer at 40 mph.
      3. watch for pedestrians and cars on side roads.
      4. watch for the destination city (you both have the same destination) and respond with the turn signal.
   b) The passenger should:
      1. watch the movie for the events.
      2. watch for the destination city.
   c) Pretend you are on a ride together and that you are looking for the turn-off to your destination. You will be wearing headphones, so you won't be able to talk to each other.
3. Your destination is "______".
4. Today's film will be six segments long; everything else about the film, including the dot sequences, will be the same as last time.
5. Any questions?

DUAL SIMULATOR SESSIONS (THURS.)

TO BE READ TO Ps IN TREATMENT ROOM

VS-4 Participant Instructions

Day 2:

1. Today you will again ride in pairs, switching seats.
2. All the tasks and the film are the same as yesterday.
   a) The person in the driver's seat should do all the tasks you did last time:
      1. steer down the road.
      2. keep the speedometer at 40 mph.
      3. watch for pedestrians and cars on side roads.
      4. watch for the destination city (you both have the same destination) and respond with the turn signal.
   b) The passenger should:
      1. watch the movie for the events.
      2. watch for the destination city.
3. Your destination is "______".
4. Any questions?

## INDIVIDUAL SESSIONS

To Be Read to Ps in Treatment Room

1. The run today will be with the sensors.
2. Today's movie will be the same as the last two times. Your destination city is "__________".
3. All the driving tasks will be the same as before.
4. Because the dot tests are very important for us in order to get good data, we would like you to read the instructions for these tests now before you go into the simulator room. They will be reviewed again in the simulator before you run. Thanks.

REMINDERS ON DRIVING IN THE SIMULATOR

Driving Tasks:

a) Steer the car straight down the road.

b) Keep the speed at 40 mph.

c) When your destination city comes up, signal for a right or left turn, as directed on the sign.
   - Don't try to turn right or left, just work the turn signal.
   - Your destination city may come up more than once. Keep looking for it.
   - Only signal a turn for your destination, not for any other city.
   - Let the turn signal spring back after you signal.

d) Watch the movie for two kinds of events:
   - pedestrians on the shoulder, on either side of the road
   - cars on side roads that might be pulling out onto your road.

   As soon as you see this kind of event, press on the horn. Don't wait until you actually could be in a dangerous situation, but signal as soon as you are sure you recognize the event. Use your own judgment, if you aren't exactly sure what to respond to and when to respond.

e) Remember to keep both hands on the wheel except when you operate the horn or turn signals.

Dot Tests:

1. Remember that the movie is divided into 6 sections of driving. Before anything happens in the movie, the word "start" flashes on the center of the screen. This warns you that the film is about to start and that you should center your head and hold it still. The first dot test will then start.

2. When the dot test is happening, you should:

   a) Keep your head in the straight-ahead position.

b) Look steadily at each dot while it is on the screen. Use both eyes; do not move your head.

c) If you have to blink, try to do it just after a dot disappears, while you are changing from one dot to another.

It's very important not to look away from the dot once you have started looking at it. Blinking is okay, but try not to do it if you can avoid it.

d) All of this procedure is only for looking at the dots. After the last dot on the road sign, the driving movie will start, and then you can look normally. However, don't use large head movements, like looking all the way to the side.

e) The dot test that I just described is repeated at the end of the film. Do exactly the same thing as you did for the first dot sequence.

3. Remember that between each section there is another dot test. For this test there are only two dots:

a) The driving scene will disappear.
b) You will have about 2 seconds of blank blue background. During this time, center your head as you did for the other dot sequences.
c) The center (#5) dot comes on for 5 sec. Look steadily at it with your head straight ahead.
d) Then the road sign dot comes on for 5 sec. Look steadily at it, only moving your eyes.

This happens between each driving segment.

4. Finally,

a) During all of the dot tests, the car will automatically become centered - don't worry about steering.
b) Also, don't worry about the speedometer during any of the dot tests. It's okay to keep your foot on the gas, but your speed doesn't matter.

c) In other words, during the dot tests only pay attention to the dots.

d) During the traffic part of the film, you can move your head normally - during the dot tests you must keep your head still and centered as I described.

5. If you have any questions, ask them now or when you go into the simulator room.

Appendix B

Testing Instructions

Version #1 F

ALCOHOL RUNS

VS-4 Participant Instructions (To Be Read to Ps in Treatment Room)

READ DURING FIRST DRINK

1. Today we will be doing runs with the eye movement sensors. All of the dot tests in the movie will be the same as the times before.
2. The movie is six traffic sections long. You will be driving down the same road you drove last time, but the movie events may be different. Your destination is "________" as before.
3. Everything else, including all your driving tasks, will be the same as before.
4. As we told you before, it is extremely important that you understand what to do during the dot tests - if you don't look properly at the dots, we can loose some of your data. To help you remember, we would like you to read some instructions during your first drink, and then read them again during your third drink. If you have any questions, ask the experimenters before you are tested. Thanks.

# ALCOHOL RUNS

VS-4 Participant Instructions (To be read to Ps in Treatment Room)

## READ DURING FIRST DRINK

1. Today we will be doing runs with the eye movement sensors. All of the dot tests in the movie will be the same as the times before.
2. The movie is six traffic sections long. You will be driving down a different road from that you drove before. You new destination is "__________".
3. Everything else, including all your driving tasks, will be the same as before.
4. As we told you before, it is extremely important that you understand what to do during the dot tests - if you don't look properly at the dots, we can loose some of your data. To help you remember, we would like you to read some instructions during your first drink, and then read them again during your third drink. If you have any questions, ask the experimenters before you are tested. Thanks.

Sample test given during drinking period. Participant was asked to point to his destination city

WYMORE

ACADIA

GILMAN

LEADER

BARTOW

LENNOX

BEULAH

FILLER

WALDEN

TACOMA

SHOALS

AUSTIN

VINTON

TAPPEN

GILMAN

KEARNY

ANTIGO

NORTON

NELSON

V3

Appendix C

Screening and Alcohol Scale (QFV)

SUMMARY OF INSTRUCTIONS TO TELEPHONE INTERVIEWERS

1. Check for preliminary qualifications:
   - Age
   - 20-25 vision with out corrective lenses
   - Valid California driver's license
   - Available by phone

2. Explain the experiment; discuss scheduling and pay.

3. Stress the committment necessary on the part of the participant for the entire experiment. Mention the expense of training, the importance of keeping appointments, and being on time.

4. If the caller is still interested, explain that people are classified according to their drinking habits. Give truncated version of QFV.

5. If caller <u>does not</u> qualify on the basis of the QFV, explain that we need people in other drinking categories. <u>Never</u> suggest by word or manner that the caller is disqualified because he doesn't drink enough or because he drinks too much or because of any personal shortcoming.

6. If caller qualifies, schedule appointment for interview.

## SCREENING PROCEDURE - TELEPHONE INTERVIEW

INTERVIEWERS: Please read the following script several times. The script is intended as a guide; you may use your own words. Be sure to convey the same attitude toward prospective subjects as illustrated here.

- Do you wear glasses?
  (If YES, then we can't use you.)

- Do you have 20-25 vision? We will give you an eye test during your personal interview. We can only use people with good vision.
  (If NO, then we can't use you.)

- Do you have a valid California driver's license?
  (If NO, then we can't use you.)

- Do you have a phone? Or can you be easily reached by phone?
  (If NO, then we can't use you.)

- The experiment involves sitting in a cut down car body, watching a film of a road while steering. For some tests you will be given alcohol to drink. You will have to wear a motorcycle helmet with special glasses that measure eye movements. It is not dangerous, and nothing will touch your eyes.

- The experiment spans a five-week period, and involves a serious committment on your part. You will be required to be here for a few hours a day, each day for the first week of testing; and then only one day a week for three successive weeks. There will be no alcohol given during the first week. During the following three weeks alcohol may be given and you should plan to be here all day. You will be involved in the experiment for 30 to 35 hours. We will pay $2.75 an hour, plus a $40 bonus upon completion of the study.

(Stress the cost and time involved in the study, and the importance of a serious committment by the participant to complete the study).

- People are sorted according to their drinking habits, so we use a questionnaire to help us determine which group you fall into.

  (Give QFV. Never say anything like "How much alcohol can you handle?" or "Are you a heavy drinker?" People will usually lie if they need the money).

- IF, after analyzing the QFV, the prospective participant is unacceptable, say - I am sorry, but you don't fit into the categories that we need. (Never leave caller with the feeling that he doesn't drink enough or has personality problems or is otherwise personally unacceptable).

- IF, caller is acceptable, make appointment for personal interview, give directions to SCRI, etc.

- You will be paid $3 for coming in to be interviewed. Please bring your driver's license with you.

PERSONAL INTERVIEW WITH PROSPECTIVE PARTICIPANTS

- Give eye test
- Check driver's license
- Give QFV; analyze results
- Participant has a brief interview with Ken, Marcy, or Stan.
- Review scheduling instructions; remind subject of the importance of keeping appointments and being on time.
- Remind participant to reserve the entire day during Weeks III - V.
- Read consent form aloud; have subject sign it.
- Give participant a small card with his appointment time; include SCRI telephone number and names of R.A.s. (Do not give home phone numbers)
- Pay person $3.00 for the interview, whether or not he is accepted as a subject.
- Do not mention training sessions. It is important for participants to be motivated for all runs.
- IMPORTANT: PARTICIPANT MUST NOT DRINK THE EVENING BEFORE ANY RUN. TELL THEM WE WILL CHECK BAC WHEN THEY FIRST COME IN AND THEY WILL NOT BE RUN OR PAID FOR THAT DAY IF THEY HAVE BEEN DRINKING.

## Instructions for Administering and Calculating the Alcohol QFV

The QFV (Quantity-Frequency-Variable) gives a rough estimate as to the drinking habits of the subject. The subject is classified as either Abstainer, Infrequent, Light, Moderate or Heavy drinker. It is a useful tool in selecting participants for alcohol studies, and in excluding certain classes of drinkers (i.e., Heavy) from drug studies. The questionnaire is usually administered as part of the office interview and is not considered appropriate for telephone interviews.

A. Administering QFV

1. For the first section of the QFV (frequency), the form is handed to the subject to check the appropriate box for each type of beverage (wine, beer and liquor) and for types of alcoholic drink combined regardless of type. The answer to this last question must have a frequency at least as high or higher than the most frequently consumed beverages.

2. For the other sections of the QFV (quantity), the subject is handed a card with the possible answers on it so that he may view the answers while responding.

   a. For each beverage that the subject responded to with a frequency greater than "less than once a month", he should be questioned about the amount of each beverage he drinks. The questioning would go as follows:

      "when you drink wine, how often would you say you had as many as 5 or 6 glasses?"

   b. If the subject responds with a quantity that is "nearly everytime" or "more than half the time", go to the next beverage.

   c. If the subject responds with "less than half the time", "once in a while' or "never", check his answer and go to the next quantity level (i.e., 3-4, and if still less than half, check 1-2).

   d. Repeat procedure for all beverages which subject drinks at least once a month.

B. Scoring QFV

1. Find the modal quantity (amount drunk "nearly everytime" or "more than half the time") in the first column of Part 1 of the QFV Scoring Sheet.

2. Find the maximum quantity drunk in the second column opposite the modal quantity.

3. The number in the third column is the Quantity-Variability class, and is used for Part 2.

4. Find the highest frequency drunk in the first column of Part 2.

5. Match that across in the second column with the appropriate Quantity-Variability class.

6. The subject's QFV group is listed in the third column.

7. Note the Q-V class and QFV group at the bottom of the page.

## QFV Scoring Sheet

### Part 1

| Modal Quantity | Maximum Quantity | Quant.-Var. Class |
|---|---|---|
| 5-6 | 5-6 | 1 |
| 3-4 | 5-6 less than 1/2 | 2 |
| 3-4 | 5-6 once in a while | 3 |
| no mode specified | 5-6 less than 1/2 | 4 |
| 3-4 | 3-4 | 5 |
| 1-2 | 5-6 less than 1/2 | 6 |
| No mode specified | 5-6 once in a while | 7 |
| 1-2 | 5-6 once in a while | 8 |
| 1-2 | 3-4 less than 1/2 | 9 |
| 1-2 | 3-4 once in a while | 10 |
| 1-2 | 1-2 | 11 |

### Part 2

| Highest Frequency (of any alcohol) | Quantity Variability Class | QFV Group |
|---|---|---|
| 3 or more times a day | 1-11 | |
| 2 times a day | 1-9 | |
| once a day/nearly every day | 1-8 | HEAVY |
| 3-4 times a week | 1-5 | |
| once or twice a week | 1-4 | |
| 2-3 times a month | 1 | |
| 2 times a day | 10-11 | |
| Once a day/nearly every day | 9-10 | |
| 3-4 times a week | 6-9 | MODERATE |
| once or twice a week | 5-9 | |
| 2-3 times a month | 2-8 | |
| about once a month | 1-6 | |
| once a day/nearly every day | 11 | |
| once or twice a week/3-4 times a week | 10-11 | LIGHT |
| 2-3 times a month | 9-11 | |
| about once a month | 7-11 | |
| Less than once a month but at least once a year | | INFREQUENT |

Subject Name_______________

Current Alcohol Use (past two months)

PUT ONE CHECK MARK IN EACH COLUMN:

| | Wine | Beer | Whiskey Liquor | Any kind of drink |
|---|---|---|---|---|
| 3 or more times a day . . . . . | | | | |
| 2 times a day . . . . . . . . . | | | | |
| Once a day . . . . . . . . . . | | | | |
| Nearly every day . . . . . . . | | | | |
| 3-4 times a week . . . . . . . | | | | |
| Once or twice a week . . . . . | | | | |
| 2-3 times a month . . . . . . . | | | | |
| About once a month . . . . . . | | | | |
| Less than once a month but at least once a year . . | | | | |
| Less than once a year . . . . . | | | | |
| Never had it . . . . . . . . . | | | | |

How often do you have as many as 5 or 6 glasses (or cans)?

| | Wine | Beer | Whiskey Liquor |
|---|---|---|---|
| *Nearly every time . . . . . . . | | | |
| *More than half the time . . . . | | | |
| Less than half the time . . . . | | | |
| Once in awhile . . . . . . . . | | | |
| Never . . . . . . . . . . . . . | | | |

How often do you have as many as 3 or 4 glasses (or cans)?

| | Wine | Beer | Whiskey Liquor |
|---|---|---|---|
| *Nearly every time . . . . . . . | | | |
| *More than half the time . . . . | | | |
| Less than half the time . . . . | | | |
| Once in awhile . . . . . . . . | | | |
| Never . . . . . . . . . . . . . | | | |

How often do you have as many as 1 or 2 glasses (or cans)?

| | Wine | Beer | Whiskey Liquor |
|---|---|---|---|
| *Nearly every time . . . . . . . | | | |
| *More than half the time . . . . | | | |
| Less than half the time . . . . | | | |
| Once in awhile . . . . . . . . | | | |
| Never . . . . . . . . . . . . . | | | |



*[illegible] to [illegible] beverage

Appendix D

Informed Consent

# 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 0.06 oz alcohol per pound bodyweight. For example, the maximum dose for a 150 lb person would be 9 oz of 80 proof alcohol.

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, the L.A. County Paramedics will be called or transportation will be provided to the UCLA emergency hospital. The telephone numbers for both organizations are posted.

It will be necessary for you to observe the instructions given to you pertaining to the experiment. A schedule will be given to you indicating the days and hours when you will participate. You should not make appointments which you will require your presence during those times. The experimenter may discharge you earlier or later than these times depending on the results of alcohol breath tests.

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 E. Table of Means, Standard Deviation and Statistical Test Results

TABLE E -1

Dwell Duration for all Dwells (Figure 5-1)
Entries are mean (standard deviation)

| | | UNFAMILIAR | FAMILIAR | MARGINAL |
|---|---|---|---|---|
| BAC% | 0.0 | 0.50 (0.11) | 0.50 (0.12) | 0.50 |
| | 0.08 | 0.68 (0.17) | 0.68 (0.23) | 0.68 |
| | 0.13 | 0.63 (0.13) | 0.65 (0.39) | 0.64 |
| MARGINAL | | 0.60 | 0.60 | 0.60 |
| COUNT | | 14 | 12 | 26 |

ANOVA RESULTS

| EFFECT | P VALUE |
|---|---|
| FAMILIARITY | $<0.990$ |
| ALCOHOL | $<0.000$ |
| ALCOHOL X FAMILIARITY | $<0.962$ |

TABLE E-2

Dwell Frequency Ratio for Dwells > 1.0 sec to Dwells < 1.0 sec (no figure)
Entries are mean (standard deviation)

| | | UNFAMILIAR | FAMILIAR | MARGINAL |
|---|---|---|---|---|
| BAC% | 0.0 | 0.11 (0.06) | 0.11 (0.06) | 0.11 |
| | 0.08 | 0.20 (0.08) | 0.20 (0.12) | 0.20 |
| | 0.13 | 0.18 (0.07) | 0.18 (0.20) | 0.18 |
| MARGINAL | | 0.16 | 0.16 | 0.16 |
| COUNT | | 14 | 13 | 27 |

ANOVA RESULTS

| EFFECT | P VALUE |
|---|---|
| FAMILIARITY | <0.960 |
| ALCOHOL | <0.000 |
| ALCOHOL X FAMILIARITY | <0.991 |

TABLE E-3

Mean Duration for Dwells $<$ 1.0 sec Duration (Table 5-2)
Entries are mean (standard deviation)

| | | UNFAMILIAR | FAMILIAR | MARGINAL |
|---|---|---|---|---|
| BAC% | 0.0 | 0.36 (0.03) | 0.34 (0.03) | 0.35 |
| | 0.08 | 0.40 (0.04) | 0.38 (0.04) | 0.39 |
| | 0.13 | 0.40 (0.05) | 0.36 (0.07) | 0.38 |
| MARGINAL | | 0.38 | 0.36 | 0.37 |
| COUNT | | | | |

ANOVA RESULTS

| EFFECT | P VALUE |
|---|---|
| FAMILIARITY | $<$ 0.105 |
| ALCOHOL | $<$ 0.000 |
| ALCOHOL X FAMILIARITY | $<$ 0.604 |

TABLE E-4

Mean Duration for Dwells > 1.0 sec Duration (Table 5-2)
Entries are mean (standard deviation)

| | | UNFAMILIAR | FAMILIAR | MARGINAL |
|---|---|---|---|---|
| BAC% | 0.0 | 1.87 (0.26) | 1.80 (0.25) | 0.84 |
| | 0.08 | 2.04 (0.35) | 1.99 (0.43) | 0.02 |
| | 0.13 | 1.92 (0.28) | 1.96 (0.53) | 0.94 |
| MARGINAL | | 1.94 | 1.92 | 1.93 |
| COUNT | | 14 | 13 | 27 |

ANOVA RESULTS

| EFFECT | P VALUE |
|---|---|
| FAMILIARITY | $<0.810$ |
| ALCOHOL | $<0.049$ |
| ALCOHOL X FAMILIARITY | $<0.692$ |

TABLE E-5

Dwell Frequency for All Dwells (Figure 5-2)
Entries are mean (standard Deviation)

| | | UNFAMILIAR | FAMILIAR | MARGINAL |
|---|---|---|---|---|
| | 0.0 | 1037.29 (228.62) | 970.08 (245.03) | 1006.27 |
| BAC% | 0.08 | 703.57 (203.89) | 613.42 (193.25) | 661.96 |
| | 0.13 | 601.29 (184.13) | 594.42 (189.82) | 598.12 |
| MARGINAL | | 708.71 | 725.97 | 755.45 |
| COUNT | | 14 | 12 | 26 |

ANOVA RESULTS

| EFFECT | P VALUE |
|---|---|
| FAMILIARITY | $< 0.447$ |
| ALCOHOL | $< 0.000$ |
| ALCOHOL X FAMILIARITY | $< 0.491$ |

TABLE E-6
Mean Pursuit Duration (Figure 5-3)
Entries are mean (standard deviation)

| | | UNFAMILIAR | FAMILIAR | MARGINAL |
|---|---|---|---|---|
| BAC% | 0.0 | 1.48 (0.32) | 1.45 (0.34) | 1.46 |
| | 0.08 | 1.89 (0.59) | 1.76 (0.46) | 1.83 |
| | 0.13 | 1.88 (0.57) | 1.81 (0.43) | 1.85 |
| MARGINAL | | 1.75 | 1.67 | 1.71 |
| COUNT | | 14 | 13 | 27 |

ANOVA RESULTS

| EFFECT | P VALUE |
|---|---|
| FAMILIARITY | $<0.584$ |
| ALCOHOL | $<0.000$ |
| ALCOHOL X FAMILIARITY | $<0.873$ |

TABLE E-7

Pursuit Frequency (Figure 5-4)
Entries are mean (standard deviation)

| | | UNFAMILIAR | FAMILIAR | MARGINAL |
|---|---|---|---|---|
| | 0.0 | 56.50 (19.05) | 70.92 (29.30) | 63.44 |
| BAC% | 0.08 | 81.00 (30.19) | 112.38 (45.96) | 96.11 |
| | 0.13 | 114.36 (44.55) | 133.15 (54.78) | 123.41 |
| MARGINAL | | 83.95 | 105.49 | 94.32 |
| COUNT | | 14 | 13 | 27 |

ANOVA RESULTS

| EFFECT | P VALUE |
|---|---|
| FAMILIARITY | $< 0.082$ |
| ALCOHOL | $< 0.000$ |
| ALCOHOL X FAMILIARITY | $< 0.545$ |

Table E-8

Mean Saccadic Duration (Figure 5-5)
Entries are mean (standard deviation)

| | | UNFAMILIAR | FAMILIAR | MARGINAL |
|---|---|---|---|---|
| | 0.0 | 0.10 (0.01) | 0.11 (0.02) | 0.10 |
| BAC% | 0.08 | 0.10 (0.01) | 0.12 (0.03) | 0.11 |
| | 0.13 | 0.13 (0.07) | 0.15 (0.05) | 0.14 |
| MARGINAL | | 0.11 | 0.13 | 0.12 |
| COUNT | | 13 | 14 | 27 |

ANOVA RESULTS

| EFFECT | P VALUE |
|---|---|
| FAMILIARITY | $< 0.096$ |
| ALCOHOL | $< 0.001$ |
| ALCOHOL X FAMILIARITY | $< 0.893$ |

TABLE E-9

Mean Saccadic Transition Distance (Figure 5-7)
Entries are mean (satndard deviation)

| | | UNFAMILIAR | FAMILIAR | MARGINAL |
|---|---|---|---|---|
| BAC% | 0.0 | 8.78 (0.86) | 10.85 (1.29) | 9.78 |
| | 0.08 | 8.56 (1.36) | 10.88 (1.95) | 9.68 |
| | 0.13 | 9.16 (2.35) | 11.66 (5.31) | 10.36 |
| MARGINAL | | 8.83 | 11.13 | 9.94 |
| COUNT | | 14 | 13 | 27 |

ANOVA RESULTS

| EFFECT | P VALUE |
|---|---|
| FAMILIARITY | $< 0.003$ |
| ALCOHOL | $< 0.501$ |
| ALCOHOL X FAMILIARITY | $< 0.944$ |

TABLE E-10

Proportions to Total Dwell Frequency Allocated to Speedometer (Figure 5-8)
Entries are mean (standard deviation)

| | | UNFAMILIAR | FAMILIAR | MARGINAL |
|---|---|---|---|---|
| BAC% | 0.0 | 0.05 (0.03) | 0.02 (0.02) | 0.04 |
| | 0.08 | 0.08 (0.05) | 0.05 (0.04) | 0.06 |
| | 0.13 | 0.09 (0.06) | 0.05 (0.05) | 0.07 |
| MARGINAL | | 0.07 | 0.04 | 0.06 |
| COUNT | | 13 | 14 | 27 |

ANOVA RESULTS

| EFFECT | P VALUE |
|---|---|
| FAMILIARITY | < 0.010 |
| ALCOHOL | < 0.016 |
| ALCOHOL X FAMILIARITY | < 0.788 |

TABLE E-11

Proportion of Total Dwell Frequency Allocated to Route Sign
(Figure 5-8)
Entries are mean (standard deviation)

| | | UNFAMILIAR | FAMILIAR | MARGINAL |
|---|---|---|---|---|
| BAC% | 0.0 | 0.08 (0.04) | 0.07 (0.03) | 0.08 |
| | 0.08 | 0.08 (0.03) | 0.07 (0.04) | 0.08 |
| | 0.13 | 0.09 (0.04) | 0.09 (0.06) | 0.09 |
| MARGINAL | | 0.09 | 0.08 | 0.08 |
| COUNT | | 13 | 14 | 27 |

ANOVA RESULTS

| EFFECT | P VALUE |
|---|---|
| FAMILIARITY | $< 0.642$ |
| ALCOHOL | $< 0.213$ |
| ALCOHOL X FAMILIARITY | $< 0.632$ |

TABLE E-12

Proportion of Total Dwell Frequency Allocated to Roadway (Figure 5-8)
Entries are mean (standard deviation)

| | | UNFAMILIAR | FAMILIAR | MARGINAL |
|---|---|---|---|---|
| BAC% | 0.0 | 0.86 (0.06) | 0.90 (0.05) | 0.88 |
| | 0.08 | 0.84 (0.07) | 0.87 (0.05) | 0.86 |
| | 0.13 | 0.82 (0.07) | 0.86 (0.09) | 0.84 |
| MARGINAL | | 0.84 | 0.88 | 0.86 |
| COUNT | | 13 | 14 | 27 |

ANOVA RESULTS

| EFFECT | P VALUE |
|---|---|
| FAMILIARITY | < 0.061 |
| ALCOHOL | < 0.016 |
| ALCOHOL X FAMILIARITY | < 0.939 |

Table E-13

Mean Frequency of Critical Events Recognized (Figure 5-9)
Entries are mean (standard deviation)

| | | UNFAMILIAR | FAMILIAR | MARGINAL |
|---|---|---|---|---|
| BAC% | 0.0 | 2.46 (1.39) | 1.71 (1.07) | 2.07 |
| | 0.08 | 2.00 (1.47) | 1.64 (1.39) | 1.81 |
| | 0.13 | 2.08 (1.32) | 1.71 (1.33) | 1.89 |
| MARGINAL | | 2.18 | 1.69 | 1.93 |
| COUNT | | 13 | 14 | 27 |

ANOVA RESULTS

| EFFECT | P VALUE |
|---|---|
| FAMILIARITY | $< 0.079$ |
| ALCOHOL | $< 0.770$ |
| ALCOHOL X FAMILIARITY | $< 0.841$ |

TABLE E-14

Mean Dwell Duration of all Route ign Looks versus Information Level (Figure 5-10)
Entries are mean (standard deviation)

| | | UNFAMILIAR | FAMILIAR | MARGINAL |
|---|---|---|---|---|
| BAC% | 0.0 | 1.14 (0.41) | 1.46 (0.76) | 1.31 |
| | 0.08 | 0.77 (0.22) | 0.94 (0.30) | 0.86 |
| | 0.13 | 0.47 (0.19) | 0.45 (0.14) | 0.46 |
| MARGINAL | | 0.80 | 0.95 | 0.88 |
| COUNT | | 12 | 13 | 25 |

ANOVA RESULTS

| EFFECT | P VALUE |
|---|---|
| FAMILIARITY | $< 0.200$ |
| ALCOHOL | $< 0.000$ |
| ALCOHOL X FAMILIARITY | $< 0.228$ |

TABLE E-15

Mean Dwell Duration of all Route Sign Looks versus BAC Level (Figure 5-11)
Entries are mean (standard Deviation)

| | | UNFAMILIAR | FAMILIAR | MARGINAL |
|---|---|---|---|---|
| | 0.0 | 0.44 (0.12) | 0.46 (0.12) | 0.45 |
| BAC% | 0.08 | 0.53 (0.12 | 0.74 (0.26) | 0.64 |
| | 0.13 | 0.78 (0.36) | 0.85 (0.24) | 0.82 |
| MARGINAL | | 0.58 | 0.68 | 0.64 |
| COUNT | | 13 | 14 | 27 |

ANOVA RESULTS

| EFFECT | P VALUE |
|---|---|
| FAMILIARITY | $< 0.08$ |
| ALCOHOL | $< 0.00$ |
| ALCOHOL X FAMILIARITY | $< 0.23$ |

TABLE E-16

Friedman Test: Mean Dwell Duration for the Blank Sign Case, FAMILIAR (Figure 5-12)

| BAC% | MEAN | STANDARD DEVIATION | MINIMUM | MAXIMUM |
|---|---|---|---|---|
| 0.0 | 0.35 | 0.14 | 0.21 | 0.74 |
| 0.08 | 0.43 | 0.16 | 0.23 | 0.73 |
| 0.13 | 0.62 | 0.33 | 0.24 | 1.28 |

FRIEDMAN TEST RESULTS

| BAC% | RANK SUM |
|---|---|
| 0.0 | 19.0 |
| 0.08 | 27.0 |
| 0.13 | 32.0 |

FRIEDMAN TEST STATISTIC = 6.61539

LEVEL OF SIGNIFICANCE = 0.0366

TABLE E-17

Friedman Test: Mean Dwell Duration for the Blank Sign Case, UNFAMILIAR (Figure 5-12)

| BAC% | MEAN | STANDARD DEVIATION | MINIMUM | MAXIMUM |
|---|---|---|---|---|
| 0.0 | 0.35 | 0.16 | 0.21 | 0.75 |
| 0.08 | 0.47 | 0.22 | 0.25 | 1.16 |
| 0.13 | 0.68 | 0.28 | 0.30 | 1.22 |

FRIEDMAN TEST RESULTS

| BAC% | RANK SUM |
|---|---|
| 0.0 | 19.0 |
| 0.08 | 27.0 |
| 0.13 | 38.0 |

FRIEDMAN TEST STATISTIC = 13.00000

LEVEL OF SIGNIFICANCE = 0.0015

TABLE E-18

Friedman Test: Mean Dwell Duration Non-Destination City FAMILIAR (Figure 5-12)

| BAC% | MEAN | STANDARD DEVIATION | MINIMUM | MAXIMUM |
|---|---|---|---|---|
| 0.0 | 0.65 | 0.13 | 0.40 | 0.90 |
| 0.08 | 0.80 | 0.28 | 0.43 | 1.43 |
| 0.13 | 0.95 | 0.33 | 0.52 | 1.69 |

FRIEDMAN TEST RESULTS

| BAC% | RANK SUM |
|---|---|
| 0.0 | 21.0 |
| 0.08 | 26.0 |
| 0.13 | 31.0 |

FRIEDMAN TEST STATISTIC = 3.84616

LEVEL OF SIGNIFICANCE = 0.1462

TABLE E-19

FRIEDMAN TEST: Mean Dwell Duration Non-Destination City, UNFAMILIAR (Figure 5-12)

| BAC% | MEAN | STANDARD DEVIATION | MINIMUM | MAXIMUM |
|---|---|---|---|---|
| 0.0 | 0.72 | 0.25 | 0.45 | 1.29 |
| 0.08 | 1.02 | 0.41 | 0.29 | 1.69 |
| 0.13 | 1.10 | 0.42 | 0.57 | 1.94 |

FRIEDMAN TEST RESULTS

| BAC% | RANK SUM |
|---|---|
| 0.0 | 16.0 |
| 0.08 | 33.0 |
| 0.13 | 35.0 |

FRIEDMAN TEST STATISTIC = 15.57143

LEVEL OF SIGNIFICANCE = 0.55612

TABLE E-20

Friedman Test: Mean Dwell Duration Destination City, FAMILIAR
(Figure 5-12)

| BAC% | MEAN | STANDARD DEVIATION | MINIMUM | MAXIMUM |
|---|---|---|---|---|
| 0.0 | 1.15 | 0.35 | 0.69 | 1.73 |
| 0.08 | 1.21 | 0.72 | 0.00 | 2.45 |
| | 0.96 | 0.83 | 0.00 | 2.42 |

FRIEDMAN TEST RESULTS

| BAC% | RANK SUM |
|---|---|
| 0.0 | 24.0 |
| 0.08 | 22.0 |
| 0.13 | 20.0 |

FRIEDMAN TEST STATISTIC = 0.72728

LEVEL OF SIGNIFICANCE = 0.6951

TABLE E-21

Friedman Test: Mean Dwell Duration Destination City, UNFAMILIAR (Figure 5-12)

| BAC% | MEAN | STANDARD DEVIATION | MINIMUM | MAXIMUM |
|---|---|---|---|---|
| 0.0 | 1.10 | 0.44 | 0.57 | 2.17 |
| 0.08 | 1.56 | 0.80 | 0.70 | 3.46 |
| 0.13 | 1.67 | 0.94 | 0.74 | 4.05 |

FRIEDMAN TEST RESULTS

| BAC% | RANK SUM |
|---|---|
| 0.0 | 15.0 |
| 0.08 | 24.0 |
| 0.13 | 27.0 |

FRIEDMAN TEST STATISTIC = 7.09091

LEVEL OF SIGNIFICANCE = 0.0289

TABLE E-22

Analysis of Variance with Log Transformation: Mean Dwell Duration for the Blank Sign Case (Figure 5-12)
Entries are mean (standard deviation)

| | | UNFAMILIAR | FAMILIAR | MARGINAL |
|---|---|---|---|---|
| BAC% | 0.0 | 0.13 (0.04) | 0.13 (0.05) | 0.13 |
| | 0.08 | 0.15 (0.05) | 0.16 (0.06) | 0.16 |
| | 0.13 | 0.20 (0.08) | 0.22 (0.07) | 0.21 |
| MARGINAL | | 0.16 | 0.17 | 0.17 |
| COUNT | | 13 | 14 | 27 |

ANOVA RESULTS

| EFFECT | P VALUE |
|---|---|
| FAMILIARITY | 0.635 |
| ALCOHOL | 0.000 |
| ALCOHOL X FAMILIARITY | 0.839 |

TABLE E-23

Analysis of Variance with Log Transformation: Mean Dwell Duration Non-Destination City
(Figure 5-12)
Entries are mean (standard deviation)

| | | UNFAMILIAR | FAMILIAR | MARGINAL |
|---|---|---|---|---|
| BAC% | 0.0 | 0.21 (0.04) | 0.23 (0.06) | 0.22 |
| | 0.08 | 0.25 (0.07) | 0.30 (0.09) | 0.27 |
| | 0.13 | 0.28 (0.07) | 0.32 (0.08) | 0.30 |
| MARGINAL | | 0.25 | 0.28 | 0.27 |
| COUNT | | 13 | 14 | 27 |

ANOVA RESULTS

| EFFECT | P VALUE |
|---|---|
| FAMILIARITY | $< 0.135$ |
| ALCOHOL | $< 0.000$ |
| ALCOHOL X FAMILIARITY | $< 0.629$ |

TABLE E-24

Analysis of Variance with Log Transformation: Mean Dwell Duration Destination City (Figure 5-12)
Entries are mean (standard deviation)

| | | UNFAMILIAR | FAMILIAR | MARGINAL |
|---|---|---|---|---|
| BAC% | 0.0 | 0.33 (0.07) | 0.31 (0.08) | 0.32 |
| | 0.08 | 0.32 (0.15) | 0.39 (0.12) | 0.36 |
| | 0.13 | 0.25 (0.19) | 0.41 (0.14) | 0.33 |
| MARGINAL | | 0.30 | 0.37 | 0.34 |
| COUNT | | 11 | 11 | 22 |

ANOVA RESULTS

| EFFECT | P VALUE |
|---|---|
| FAMILIARITY | $< 0.069$ |
| ALCOHOL | $< 0.631$ |
| ALCOHOL X FAMILIARITY | $< 0.108$ |

TABLE E-25

Look Back Frequencies (not discussed)
Entries are mean (standard deviation)

| | | UNFAMILIAR | FAMILIAR | MARGINAL |
|---|---|---|---|---|
| BAC% | 0.0 | 0.92 (0.95) | 1.50 (1.16) | 1.22 |
| | 0.08 | 0.85 (1.28) | 0.93 (0.73) | 0.89 |
| | 0.13 | 0.46 (0.66) | 0.71 (0.61) | 0.59 |
| MARGINAL | | 0.74 | 1.05 | 0.90 |
| COUNT | | 13 | 14 | 27 |

ANOVA RESULTS

| EFFECT | P VALUE |
|---|---|
| FAMILIARITY | $< 0.213$ |
| ALCOHOL | $< 0.035$ |
| ALCOHOL X FAMILIARITY | $< 0.562$ |

## TABLE E-26

Mean Steering Error (Figure 5-15)

| | | UNFAMILIAR | FAMILIAR | MARGINAL |
|---|---|---|---|---|
| BAC% | 0.0 | 0.44 (2.94) | 0.56 (3.50) | 0.50 |
| | 0.08 | 1.14 (3.34) | 1.46 (2.38) | 1.31 |
| | 0.13 | 1.81 (3.28) | 1.95 (2.92) | 1.89 |
| MARGINAL | | 1.13 | 1.33 | 1.23 |
| COUNT | | 13 | 14 | 27 |

ANOVA RESULTS

| EFFECT | P VALUE |
|---|---|
| FAMILIARITY | $< 0.811$ |
| ALCOHOL | $< 0.194$ |
| ALCOHOL X FAMILIARITY | $< 0.989$ |

TABLE E-27

RMS Steering Error (Figure 5-15)
Entries are mean (standard deviation)

| | | UNFAMILIAR | FAMILIAR | MARGINAL |
|---|---|---|---|---|
| BAC% | 0.0 | 2.10 (0.76) | 2.12 (0.48) | 2.11 |
| | 0.08 | 2.70 (0.78) | 2.17 (0.50) | 2.42 |
| | 0.13 | 2.75 (1.18) | 2.86 (0.82) | 2.81 |
| MARGINAL | | 2.52 | 2.38 | 2.45 |
| COUNT | | 13 | 14 | 27 |

ANOVA RESULTS

| EFFECT | P VALUE |
|---|---|
| FAMILIARITY | $< 0.551$ |
| ALCOHOL | $< 0.001$ |
| ALCOHOL X FAMILIARITY | $< 0.162$ |

TABLE E-28

Mean Speed Error (Figure 5-16)

| | | UNFAMILIAR | FAMILIAR | MARGINAL |
|---|---|---|---|---|
| BAC% | 0.0 | 0.73 (3.61) | -0.34 (1.21) | 0.18 |
| | 0.08 | 1.70 (4.30) | -0.56 (1.98) | 0.53 |
| | 0.13 | -0.36 (2.10) | -0.75 (1.47) | -0.56 |
| MARGINAL | | 0.36 | -0.55 | 0.05 |
| COUNT | | 13 | 14 | 27 |

ANOVA RESULTS

| EFFECT | P VALUE |
|---|---|
| FAMILIARITY | $< 0.035$ |
| ALCOHOL | $< 0.312$ |
| ALCOHOL X FAMILIARITY | $< 0.451$ |

TABLE E-29

RMS Speed Error (Figure 5-16)

| | | UNFAMILIAR | FAMILIAR | MARGINAL |
|---|---|---|---|---|
| BAC% | 0.0 | 1.61 (1.24) | 1.09 (0.94) | 1.34 |
| | 0.08 | 1.68 (1.33) | 1.23 (1.08) | 1.45 |
| | 0.13 | 2.39 (2.17) | 1.70 (1.02) | 2.13 |
| MARGINAL | | 1.96 | 1.34 | 1.64 |
| COUNT | | 13 | 14 | 27 |

ANOVA RESULTS

| EFFECT | P VALUE |
|---|---|
| FAMILIARITY | $< 0.126$ |
| ALCOHOL | $< 0.020$ |
| ALCOHOL X FAMILIARITY | $< 0.735$ |