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A Simulator Study of the Combined Effects of Alcohol and Marihuana on Driving Behavior—Phase II

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16. Abstract

The study described in this report investigated the effects of alcohol and marihuana, alone and in combination, on driver performance and behavior in a fully interactive driving simulator. The simulator provided the driver a complex visual scene similar to a rural nighttime drive, and allowed the driver full control of steering and speed maneuvers. Performance and behavior data were collected during a 10-12 mile drive requiring about 15 minutes to complete. A variety of events were encountered during the drive, including curves, obstacles in the roadway, and winding roads. Accidents, tickets, and speed were recorded as traffic safety measures during the overall drive. Driver behavior, speed control, and steering performance were collected during each event to provide insight into the impairment mechanisms of alcohol and/or marihuana on the driver.

A full placebo experimental design was employed which included all combinations of 3 marihuana (0, 100, and 200 μg Δ^9 THC/kg body weight) and 2 alcohol (0 and 0.10 percent BAC) levels. Based on a large number of driver performance and behavior variables, alcohol was found to have a pervasive and significant impairing effect. Simulator accidents increased reliably under alcohol, which was accounted for by increased steering and speed control variability. Marihuana effects were minimal, the primary one being speed reduction. This speed reduction, while statistically reliable, was minimal in terms of actual driving behavior and is probably of no practical significance. A significant drug interaction effect was observed in simulator accidents; however, the data do not allow us to identify the impairment mechanism leading to this result.

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METRIC CONVERSION FACTORS

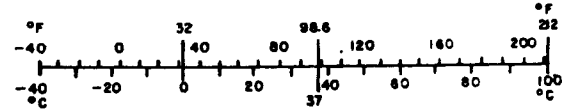
Approximate Conversions to Metric Measures

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



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EXECUTIVE SUMMARY

One concern of the National Highway Traffic Safety Administration is determining the effects of alcohol and/or marihuana on traffic safety. The role of alcohol in traffic accidents has been well established. Current estimates attribute alcohol involvement to 55 percent of the reported accidents. Marihuana involvement, however, is still an unknown. Marihuana has recently become almost commonplace in our society, particularly with those under 35. Laws pertaining to marihuana possession and use have been made more lenient, thus its potential for impairing driver behavior has increased. The objectives of this research program are 1) to determine the traffic safety implications of alcohol and marihuana both alone and in combination; and 2) to determine the impairment mechanisms of these drugs.

This report covers the final phase of a two-phase study to determine the effects of alcohol and marihuana, both alone and in combination, on driver behavior and performance. Phase I (Allen, Stein, and Hogue, 1982) involved tests with moderate marihuana doses. The results for marihuana impairment proved inconclusive. Because of this, the results reported herein are for an experiment similar in nature, but with marihuana levels twice those used in Phase I.

Approach

Subjects were tested in a fully-interactive driving simulator providing a complex visual scene similar to a rural nighttime drive, and allowed the driver full control of steering and speed maneuvers. Performance and behavior data were collected during a 10-12 mile drive requiring about 15 minutes to complete. A variety of events were encountered during the drive, including curves, obstacles in the roadway, and winding roads. Accidents, tickets, and speed were recorded as measures of traffic safety during the overall drive. Driver behavior, speed control and steering performance were collected during each event to provide insight into the impairment mechanisms of alcohol and/or marihuana on the driver.

A full placebo experimental design was employed which included all combinations of 3 marihuana (0, 100, and 200 μg Δ^9 THC/kg body weight) and 2 alcohol (0 and 0.10 percent BAC) levels. As alcohol effects on traffic safety are well established, only one non-zero alcohol level was included. The 0.10 percent BAC level is a typical legal limit, and correlates with significant driver impairment. The three marihuana levels were chosen to allow measurement of a potential dose response relationship, and to determine if doubling the maximum dose in Phase I would lead to consistent and measurable impairment. Subjects were selected on the basis of good health, and the ability to reach the 0.10 percent BAC level.

Results

Based on a large number of driver performance and behavior variables, the results were quite consistent with the Phase I research. Alcohol was found to have a pervasive and significant impairing effect, while marihuana effects were found only occassionally. One significant difference between this experiment and the Phase I experiment was in the combination effects. In this experiment a significant drug interaction effect was observed in simulator accidents.

Again, the primary alcohol impairment appears to be increased variability in both steering and speed control. The data did not allow us to identify the impairment mechanism of the combined treatment.

Conclusions

- Alcohol at a BAC of 0.10 percent impairs the drivers ability significantly and consistently. These impairments account for the majority of the observed impairment.

- Alcohol impairment is evidenced by an increase in accidents resulting from an increase in driver speed and steering control variability and an increase in reaction time.

- Marihuana doses of 100 and 200 μg Δ^9 THC/kg body weight do not lead to any consistent driver impairment. They do, however lead to a general decrease in vehicle speed. Because of the relatively small absolute speed difference, these results may not be of practical significance, however.

- The combined effects of alcohol and marihuana at the highest dose combination increased accidents, a primary traffic safety issue.

- No adverse subject reactions were observed at any of the doseage combinations.

Recommendations

- Because of the findings concerning the 0.10 percent BAC plus 200 μg/kg Δ^9 THC dose we recommend that further study be conducted to validate and explain the increased accident rate. The measures tested in this experiment were unable to explain the accident increase, thus other driver/vehicle measures should also be examined.

- Any further research should include Δ^9 THC blood plasma concentrations as an independent variable. Enough blood should be drawn to allow for back-up plasma in the event of analysis difficulties.

- The major driver impairments observed were an increase in variability and reaction time. Countermeasures should address these impairments through road and vehicle designs that allow for these impairments. More importantly, drivers should be made aware of the impairing effects of alcohol, and the combination of alcohol and marihuana in an effort to reduce the number of drivers choosing the drive in an impaired state.

SECTION I

INTRODUCTION

This research was performed as part of the overall NHTSA Alcohol and Drug Impaired Driver Research Program. The research had the twofold objective of (1) identifying how alcohol, marihuana, and their combination lead to impaired driver accidents; and (2) developing potential accident countermeasures based on this identification. Alcohol has repeatedly been identified as a leading cause of driving accidents (Committee on Public Works, 1968). With increasing social acceptance of marihuana (HEW, 1976), concurrent with the reduction of penalties for possession and use, there is legitimate concern for its possible effect (both alone and combined with alcohol) on traffic safety.

Extensive research has been conducted on the effects of alcohol on both human behavior and driving capability; and Hurst (1974) was able to establish dose response relationships between blood alcohol concentration and accident rate. The research that has been conducted with marihuana has been far less wide spread. We are just beginning to understand its basic effects, and are far from establishing possible dose response relationships. While both drugs are used in combination quite often (Waller, 1975), even less is known about the possible combined effects.

This volume presents a study of the separate and combined effects of two levels of alcohol and three levels of marihuana on driving performance. An interactive driving simulator was used to study driver control and safety behavior. Analyses were performed to identify the effects of alcohol and marihuana on basic traffic safety variables, as well as the associated driver behavior correlating with these variables.

Section II of this volume presents a summary of the work done under Phase I of this contract, as well as a review of the current literature relevant to this study. Section III presents the experimental methods used to conduct the experiment. The results of the experiment are presented and discussed in Section IV; and in Section V we draw conclusions and make recommendations based on the experimental results.

SECTION II

BACKGROUND

This section presents the background and rationale for conducting the experiment described in this report. Presented first is a summary of the laboratory experiment conducted under Phase I in 1976 (Allen, Stein, and Hogue, 1982), which recommended this study. Following this discussion is a brief review of the relevant literature which has been published since the completion of the 1976 experiment.

A. PHASE I SUMMARY

The initial work on this project was conducted from 1975 to 1978. Included in this work was a thorough review of the literature on driver control behavior, alcohol impairments, marihuana impairments, and the combined effects of alcohol and marihuana. This literature review led to the following conclusions:

- Alcohol effects on driver behavior and traffic safety are fairly well established and a clear dose response relationship has been established for accident involvement. A primary alcohol impairment mechanism appears to be interference with divided attention capability.

- Marihuana effects on driver behavior and traffic safety are not clear, and increased variability between drivers in their response to marihuana may be somewhat responsible for the confusion. The locus of primary marihuana effects seems to be in sensory-perceptual capabilities.

- There is some evidence for synergistic effects of alcohol and marihuana, but there are also occasional measurements of antagonistic effects. There is also no clear epidemiological evidence of combined effects on traffic safety.

From this analysis of prior research a driving simulator experiment was designed to test the combined effects of alcohol and marihuana on the driver's control behavior.

The simulator used in the Phase I tests had full interactive capability allowing the driver to control steering and speed on a video-projected two-lane roadway. Subject behavior and performance were measured during a 10 mile drive which required about 15 minutes to complete. A variety of events were encountered during the driving scenario, including wind gusts, winding roads, obstacles, and isolated curves. Simulated accidents and speeding tickets were recorded as measures of traffic safety during the overall drive. During each event, measures of driver behavior and performance in steering and speed control were obtained in order to determine those driver factors which are impaired by alcohol and/or marihuana and to determine their contribution to reduced traffic safety.

A full placebo experimental design was employed in Phase I which included all six combinations of two alcohol levels, 0 and 0.10 percent BAC (Blood Alcohol Concentration), and three marihuana levels, 0, 50, and 100 μg Δ^9 THC/kg body weight. Alcohol effects on traffic safety have been well established, so only one non-zero BAC level was included which was set at a typical legal limit. Three marihuana dosage levels were included to allow measurement of a potential dose response relationship. Subjects were selected on the basis of good health and being able to reach a BAC of 0.10 without getting sick.

Based on a large number of measures of driver behavior and performance, alcohol was found to have a consistent and significant impairment effect, while marihuana had only an occasional effect. Also, there was little evidence of interaction between alcohol and marihuana. Simulated accidents and speeding tickets reliably increased under alcohol, but no marihuana or combined alcohol and marihuana influence was noted. The alcohol impairment effects on steering and speed control behavior and performance were consistent with the increased accident and ticket rate.

The primary alcohol impairment mechanism seems to be increased variability in steering and speed control behavior. Variability between subjects was found to be similar for alcohol and marihuana considered alone. Combined alcohol and marihuana treatments lead to significantly increased variability between subjects, however, which may partially

account for the lack of reliable interaction effects between these two drugs.

These Phase I results led to the following conclusions and recommendations.

1. Conclusions

- Alcohol at a BAC of 0.10 percent impairs driver control behavior significantly and consistently, as evidenced in a wide range of measurements. These effects are correlated with degraded traffic safety as measured in terms of simulated accidents and speeding violations. Driver steering and speed control deteriorated with increasing BAC. Response speed and accuracy also deteriorated on a sign detection and recognition task.

- Marihuana doses of 50 and 100 μg Δ^9 THC/kg body weight did not lead to consistent impairment of driver control or detection and recognition processes.

- The effects of alcohol and marihuana in combination are not significantly different than the effects of alcohol or marihuana considered alone.

- The effects of combined alcohol and marihuana are not as consistent between subjects as are the effects of alcohol or marihuana considered separately.

2. Recommendations

- The combined alcohol and marihuana conditions employed did not lead to any adverse or unexpected reactions from subjects, and higher marihuana dosages should be considered in a subsequent simulator experiment.

- The major driver/vehicle control performance effects observed in this experiment were reduced driver response speed and accuracy, as discussed above. Countermeasures should address these impairments. Road and vehicle designs should minimize requirements for driver response speed and accuracy. The trend toward smaller, more agile cars should help in this regard. Also,

through driver education and public information, motorists should be made aware of the inevitable reduction in their vehicle control capabilities with alcohol impairment in order to discourage drinking and driving.

A complete discussion of this prior research is found in The Effects of Alcohol and Marihuana on Driver Control Behavior in a Driving Simulator (Allen, Stein, and Hogue, 1982).

B. RECENT LITERATURE

Because of the long time span between the Phase I and Phase II experiments, several relevant research projects were reported in the literature as discussed below.

Belgrave, et al. (1979), found that oral administration of 320 μg Δ^9 THC caused performance decrements in reaction speed, cognitive processes, standing steadiness, and psychomotor coordination. Peak Δ^9 THC effects were observed at 100 minutes and 160 minutes post ingestion. The long delay times between Δ^9 THC administration and peak effects are due to the oral administration of the drug. They also found that 0.54 g/kg alcohol (BAC > 0.08) caused performance decrements in reaction speed, standing steadiness, and psychomotor coordination. Peak effects were observed at 100 minutes post ingestion, and all effects had worn off by 280 minutes post ingestion. No combined effects were observed.

Joscelyn, et al. (1980), discuss the recent interest in the possible highway problems associated with psychotropic drugs such as marihuana. The problems with the current body of research are emphasized, and are directly associated with a lack of a well-funded and coordinated research effort as has been done with alcohol. They also point to the lack of an objective measure for marihuana impairment that correlates with driving performance, such as the use of BAC as a correlate for alcohol impairment. The report summary, in part, states:

> "Research and development of methods to support efforts both to study and to deal with the drug and driving problem are also required, including:

> Valid and reliable behavioral methods to measure the effects of drugs on skills related to driving, and to detect drug impaired drivers."

The report continues with a review of some pertinent marihuana/driving literature, and concludes:

> "In summary, evidence from laboratory tests indicates that marihuana at certain dosages, alone and combined with alcohol and other drugs, impairs skills and behavior related to driving. Less numerous studies involving actual car handling generally support the implication that marihuana use by drivers can increase the likelihood of traffic crashes, especially in higher doses."

In the preliminary results of a National Institute of Drug Abuse (NIDA) sponsored research project studying the effects of various doses of marihuana on behavior related to driving behavior, Hawks (1980) reports:

> "...The analysis of this data is not yet complete, but what is obvious so far is that even though some consistency exists across given individuals smoking a given dose of marihuana, in terms of expected blood levels, the associated behavioral impairments of these doses do not show the same consistency."

Two recent research efforts directly studied the combined effects of alcohol and marihuana on various driving tasks. Sutton (1980) found no effects of either alcohol at BAC = 0.06 or of marihuana when smoked in a cigarette containing 2 percent Δ^9 THC, on measures of driving performance or on a patrol officer's evaluation of driving performance. He also found no effects on driving performance when the drugs were combined. He did, however, find a combined effect of the drugs on the patrol officer's evaluation variable. He postulated that his lack of results may be due to either insensitive measures or experienced impaired driving on the part of his subjects.

Attwood, et al. (1981), studied the combined effects of alcohol and marihuana on closed-course driving performance. The introduction presents a concise review of the recent literature relevant to both their study and to ours. This review is presented, with permission of the

primary author, as Appendix C. The authors provide justification for further research in this area when they state:

> "Except for performance on some tasks that are reported to be representative of driving, there is no consistent evidence that normal social levels of marihuana seriously affect driving performance. There is some indication, however, that the effects of marihuana and alcohol are additive when taken together though the evidence is by no means clear."

In prior work, Attwood (1975) concluded that the techniques used to detect differences between drug conditions must assume that driving is a complex and overlearned task that can best be explained by using multivariate descriptors.

The conclusions and recommendations of the Phase I experiment (Allen, Stein, and Hogue, 1982), when combined with the findings reported in the more recent literature discussed above, make a strong case for further research in this area. They also provide a basis for testing higher Δ^9 THC concentrations, and for performing blood assays to determine the actual Δ^9 THC levels in an attempt to correlate any resultant impairment.

SECTION III

METHODS

A. BASIC EXPERIMENTAL APPROACH

The basic approach of this experiment involved investigating the effects of various levels of alcohol and marihuana, both alone and in combination, on the driver's control behavior. Twelve subjects were tested in a driving simulator using a double-blind, full-placebo, counterbalanced design.

Advertisements were placed for potential subjects, and those volunteers meeting stringent requirements were accepted as subjects. After training in the simulator, each subject returned for six experimental sessions, one at each alcohol/marihuana condition. Blood Alcohol Concentration (BAC) was determined by a gas chromatograph breath sampling device, and blood was drawn for subsequent Δ^9 THC concentration analysis.

Twice during each experimental day each subject drove a simulator scenario which presented a 15 minute sequence of driving tasks. The first drive was prior to any drug administration, and was used as a baseline for individual performance; the second drive was after alcohol ingestion and marihuana inhalation, and was timed to coincide with the peak effect of both drugs.

Data were collected on basic traffic safety measures, driver/vehicle performance, and driver control behavior. These data were analyzed using multivariate statistical analysis techniques.

B. SIMULATION

The simulator and driving tasks were designed to allow measurement of driver behavior, driver/vehicle performance, and traffic safety. The objective was to be able to correlate drug effects with driver behavior, and to determine if the drugs impaired driving performance to the point that traffic safety was affected.

The driving simulator used in the Phase II experiment was an updated version of that used in Phase I and is described more completely in Appendix A. It consists of a cut-down car cab with fully interactive controls. The interactive features include complete steering and speed control of a video-projected two-lane roadway. An associated dynamic imagery slide projector introduces signs at a distance down the road (≈ 500 ft) and brings them a factor of about 8.5 times closer to the driver using a computer-controlled zoom lens. A second slide projector presents a background horizon scene.

The background scene slide and roadway sign slides were photographed using high-resolution 35mm color film. These slides were then projected and optically combined with the roadway delineation. The background positioning and the roadway sign location in respect to the roadway shoulder were controlled by a servo-driven mirror to provide coordination with the roadway image for vehicle heading changes.

In addition to the roadway signs the subject was presented various driving tasks such as curves in the road; fixed obstacles requiring the driver to "thread" his way through (a double lane change task); unexpected obstacles requiring driver avoidance maneuvers; and a steering control task not unlike gusty winds.

The driver's impression was one of driving on a rural roadway, at dusk, under somewhat reduced visibility. Mountains were viewed in the distance, and periodically the driver needed to negotiate a curve, avoid an obstacle, or correct for wind gusts.

A modified PDP-11 digital computer controlled the overall simulator operation, presenting events at the appropriate roadway location and collecting data during the driving session. An analog computer was used to perform the requisite equations of motion for the vehicle and provide the driver with appropriate audio and visual feedback (i.e., speedometer readings, roadway location, and wind and engine noise).

C. DRIVING SCENARIO

A typical simulator drive involved a 10 to 12 mile drive during which various events were encountered. The digital computer, described earlier, presented these events at specified locations on the drive. This meant that event occurrence was proportional to car speed. A typical sequence of events is illustrated in Fig. 1, and the individual tasks are described in more detail below.

1. Steering Control With Divided Attention

Steering control of the vehicle is a psychomotor task involving both visual perception and motor control. Driver steering behavior and lane keeping control have been found to be sensitive to alcohol impairment (Allen, Stein, and Hogue, 1982; and Allen, Jex, et al., 1975), and to marihuana impairment (Allen, Stein, and Hogue, 1982) in prior studies. Two tasks were presented to the drivers, both requiring the driver to compensate for random wind gusts while following a random winding road. The wind gusts require the driver to compensate for disturbances which are perceived only by their effects on the vehicle. The winding road allows the driver to directly perceive and anticipate the appropriate vehicle path. During this task, measurements were obtained for driver control behavior and lane keeping ability (further discussion of these measurements is found in Appendix B).

A divided attention component was added to one of these driver control runs. Using the dynamic sign projection capability described earlier, the driver was presented a series of warning type road signs (FHWA, 1978). He was required to respond to the sign by either pressing a horn button, using the turn signal switch, or depressing a "dimmer" foot switch. The correct response was dictated by the sign: signs requiring the driver to turn or change lanes required a left or right turn signal response; "men working" and other similar warning signs required the horn switch to be pressed; motorist information and guide signs required a dimmer response. As soon as the driver responded, the digital computer turned off the sign and recorded response time, distance, and correctness.

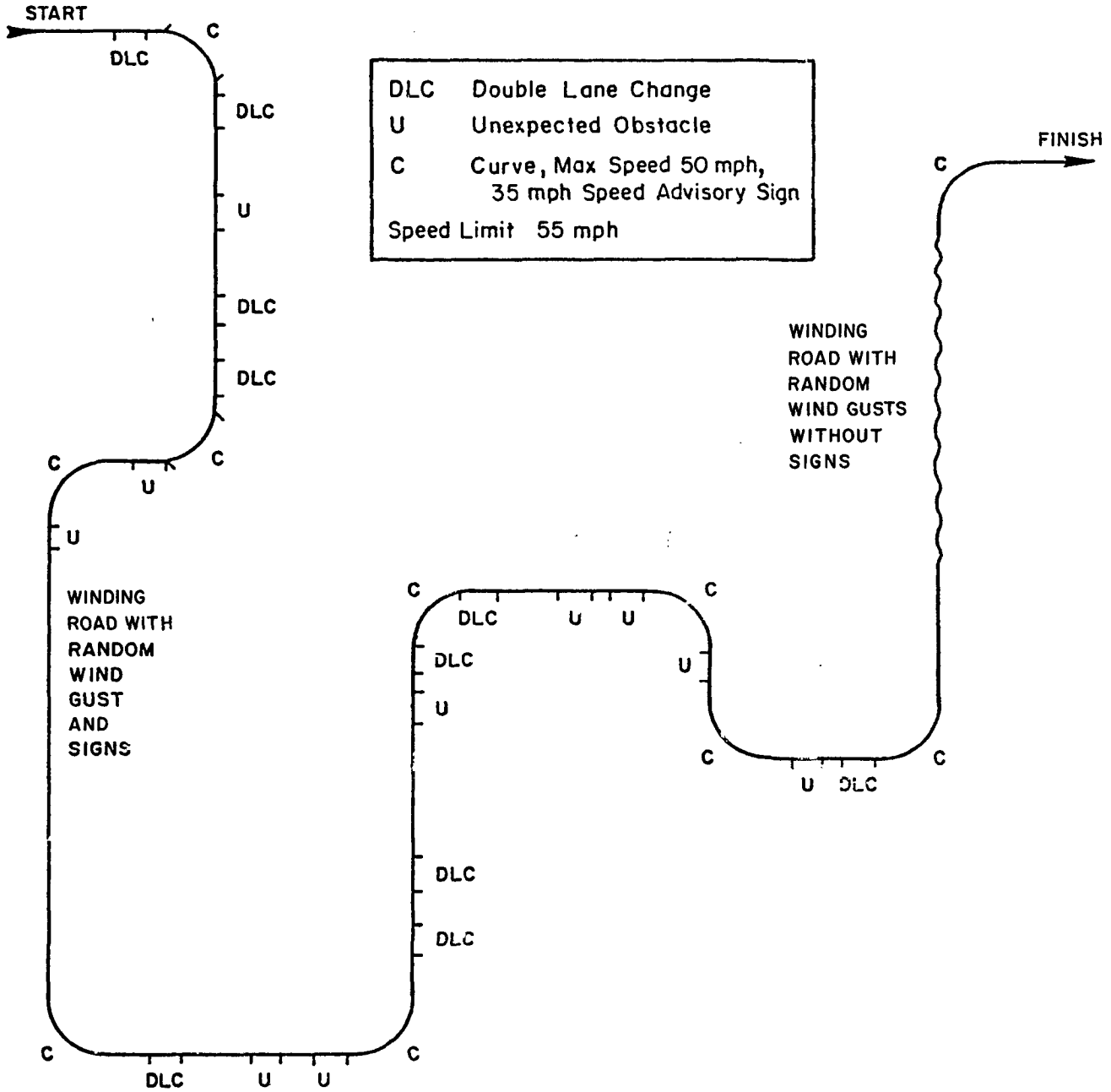

Figure 1. Typical Driving Scenario

2. Isolated Curves

This event requires the driver to control both speed and steering during the negotiation of a 90 deg curve. A decrease in speed was required in order to avoid loss of tire traction during the maneuver and a speed advisory sign of 35 mph was displayed prior to the curve. Previous research has found this task is sensitive to both alcohol (Allen, Stein, and Hogue, 1982; and Allen, Schwartz, et al., 1978) and marihuana impairment (Allen, Stein, and Hogue, 1982), and represents a situation which frequently leads to the single vehicle roadway departure category of accidents (Terhune, et al., 1980).

The digital computer was used to sample the lane position and speed profiles during the maneuver. Data from the several repeated encounters in a run were ensemble averaged at the completion of the run to provide means and variances.

3. Obstacle Avoidance

Transient lane changes were induced by both anticipated and unexpected obstacles displayed in the roadway. The anticipated obstacles consisted of three stationary objects positioned in such a way that the driver was required to make a double lane change maneuver to avoid an accident (Fig. 2a). This maneuver tested the drivers ability to coordinate and time a relatively precognitive transient driver response. The unexpected obstacle was designed to simulate an object entering the roadway unexpectedly, such as a car backing out of a driveway, or a dog running into the street. It was obscured from the driver's view until it moved into the roadway. This maneuver is also shown in Fig. 2b. The computer measured time and distance to peak amplitudes in both steering response and lane deviation profiles. These events and measures test the driver's visual motor steering reaction time and his subsequent maneuver coordination (further discussion of these measures is given in Appendix B).

A summary of the tasks, measurements, and number of events presented in the driving scenario is given in Table 1.

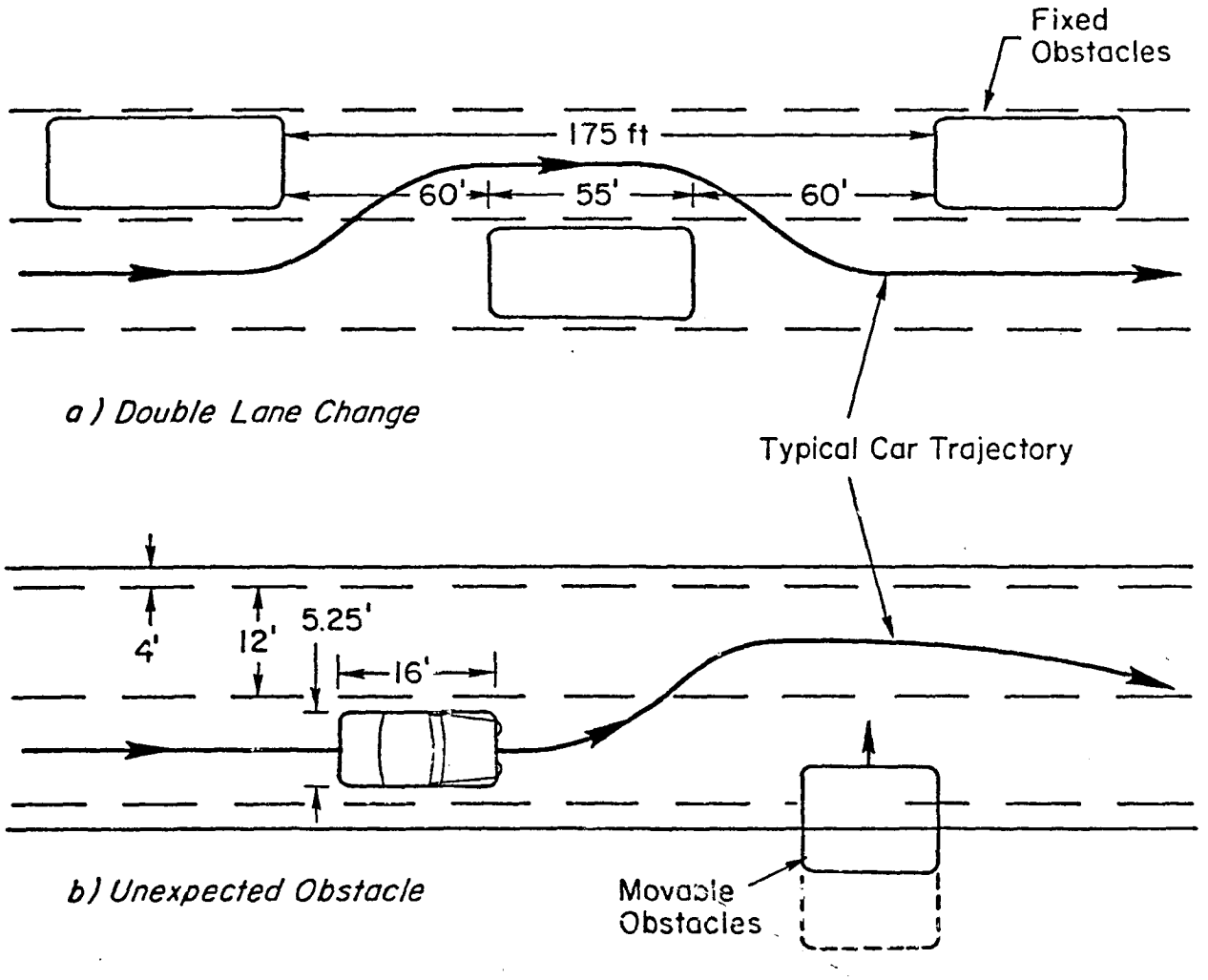

Figure 2. Ground Plane Representation of the Obstacle Avoidance Tasks

TABLE 1. SIMULATED DRIVING SCENARIO

TASK	MEASUREMENTS	NUMBER
Overall Scenario Performance	Number of speeding tickets (55 mph speed limit) Number of crashes (hitting obstacles, exceeding road edges)	
Random Wind Gust and Winding Road Tracking	Driver dynamic response and remnant parameters Lane deviation errors	Two 100 second measurement periods
Highway Sign Detection and Recognition (during above tracking task)	Response time Response errors	12 signs presented using appropriate visual dynamics
Isolated Curve Control	Ensemble speed response Ensemble path deviations	10 curves
Fixed Obstacle (double lane change) and Unexpected Obstacle	Ensemble time and distance events in steering and lane position	10 each

D. EXPERIMENTAL DESIGN

The objectives of this experiment were to:

- Test the interaction between alcohol and marihuana on the driver's control behavior.
- Determine whether a dose response relationship exists between marihuana and driving performance.

A full-placebo design was employed that tested 2 levels of alcohol and 3 levels of marihuana (Fig. 3).

Only two levels of alcohol were chosen because the dose response relationships for alcohol are well established. The 0.10 level was chosen because it is a common legal limit, and is known to cause measurable impairment; additionally, frequent marihuana users are rarely heavy drinkers and higher doses would have placed even more restrictions on our ability to obtain subjects. Three levels of marihuana were chosen to allow measurement of potential dose response relationships. At the request of NIDA (the suppliers of the marihuana), we did not use bulk marihuana as anticipated, but rather used pre-rolled 1 gram cigarettes of known Δ^9 THC concentration. This request was considered acceptable because the actual blood plasma Δ^9 THC levels were being measured. The subject population consisted of 9 individuals weighing 72 kg ± 1 kg and 3 individuals weighing 84 kg ± 1 kg; actual THC concentrations are found in Fig. 4. Because they are so close to the Δ^9 THC levels called for in the design, we have continued to refer to them as 100 μg/kgm and 200 μg/kgm doses.

These marihuana levels were chosen because they represent more typical dosages to the regular marihuana smoker than were tested in Phase I of this project (Allen, Stein, and Hogue, 1982).

Twelve subjects were tested at each of the six treatments, on 6 separate experimental days. The order of treatment exposure was balanced according to a 6 × 6 Latin square design which also controlled for second-order followings (Bradley, 1958).

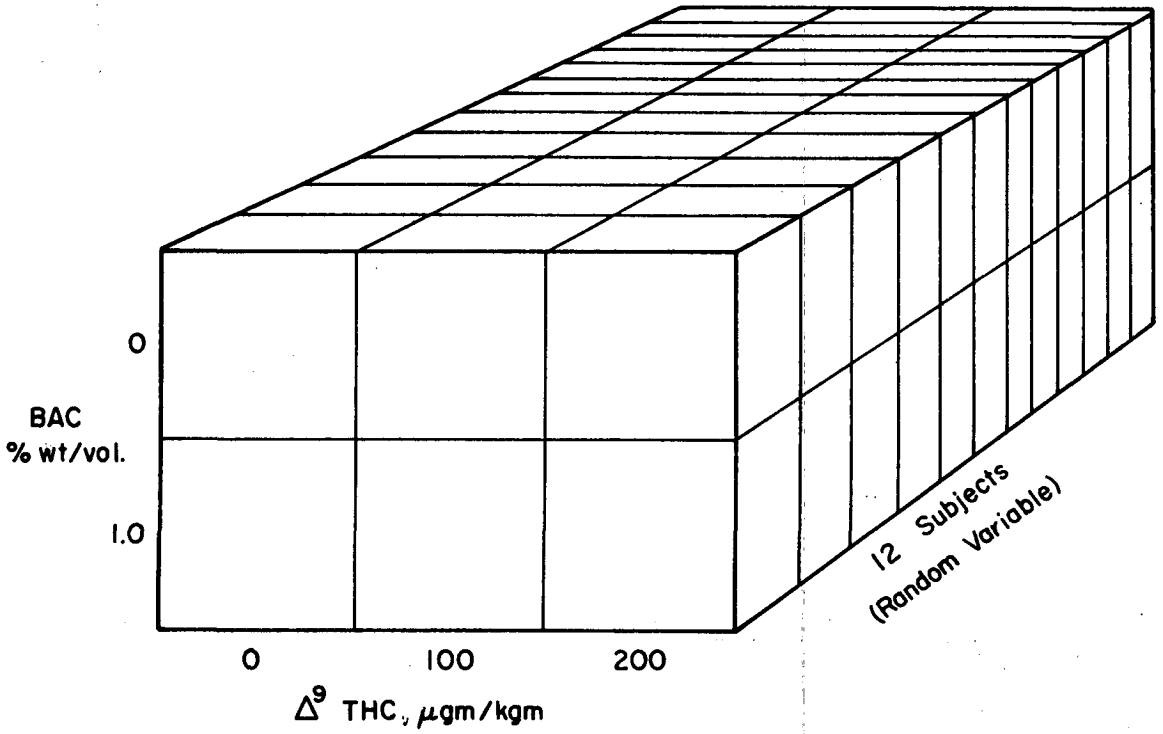

Figure 3. Three-way Experimental Design for Initial Data Analysis

Δ9 THC Concentration (% THC/Weight)	72 (9ss)	84 (3ss)
.088	122.2	104.7
1.54	213.8	183.3

Weight (Kg ± 1Kg)

Figure 4. Δ9 THC Dosage for Δ 1 Gram Prerolled Marihuana Cigarette

E. EXPERIMENTAL PROCEDURES

1. Subjects

Twelve male volunteers were selected from a group of volunteers responding to advertisements placed in local newspapers, college newspapers, and on laundromat bulletin boards (Fig. 5). From this extensive campaign over 400 phone calls were received. Subject selection was broken down into several steps because of the rather stringent selection requirements imposed by various federal and state agencies overseeing marihuana research.

In the first step the callers were read a brief statement about the project which outlined our basic requirements (male, age 21-65, licensed driver, moderate-to-heavy drinker, and current marihuana user) and their involvement in the project; this initial screening also eliminated individuals living too far away to be conveniently driven to and from the test site. This screening eliminated about 50 percent of the callers.

$ WANTED $

SUBJECTS FOR ALCOHOL AND MARIJUANA RESEARCH

WE ARE CURRENTLY DOING GOVT SPONSORED RESEARCH ON THE EFFECTS OF ALCOHOL AND MARIJUANA ON DRIVING. IF YOU ARE A DRINKING DRIVER WHO CAN **REALLY** HOLD YOUR LIQUOR AND ARE CURRENTLY USING MARIJUANA, WHY NOT GET PAID FOR YOUR TALENTS! YOU MUST BE A **HEAVY** DRINKER, MALE, 21-65 YRS., A LICENSED DRIVER IN GOOD HEALTH, AND LIVE IN THE SO. BAY AREA. INTERESTED?

CALL 644-4332 **MON.-FRI. 9AM-5PM**

Figure 5. Typical Subject Recruitment Ad

The remaining applicants were asked various screening questions pertaining to their health, alcohol and drug involvement, and availability. At this stage we eliminated individuals reporting medical problems, poly-drug use, those involved with alcohol or drug rehabilitation programs, and those unable to meet our drinking criteria (i.e., marihuana users tend to be light drinkers). The telephone screening eliminated over 60 percent of the applicants advancing to this stage. Those who passed (22 percent of these who called) were invited to an orientation session.

At the orientation session the applicant was given a complete description of the project and his rights as a subject were explained. He then completed a thorough medical history and took the Minnesota Multiphasic Personality Inventory (MMPI) (Psychological Corp., 1970).

The MMPIs were coded, and individuals with clinically abnormal personalities and those with personality types having a high correlation with violence under alcohol (Evans, 1978) were eliminated from further consideration. The health histories were then reviewed by STI personnel using guidelines prepared by the project physician. Health histories of individuals with potential health problems were discussed with the project physician, who made the decision of rejection or acceptance.

The 42 applicants accepted at this point were then sent to a local medical laboratory for pre-physical tests. These tests included a complete blood screening, a chest x-ray, and a complete urinalysis (a list of all tests performed is found in Table 2). Applicants with blood tests indicating liver damage or other health problems which may be adversely affected by either alcohol or marihuana were eliminated at this stage.

The remaining 20 applicants (5 percent of the original pool) were then sent to the project physician for a physical examination. During the physical exams several medical problems were encountered. Heart arrhythmias were discovered in several applicants; EKGs were administered and some applicants were eliminated because of the interpretation of the test. Other medical problems also surfaced; and at the end of

TABLE 2. LABORATORY TESTS PERFORMED

Chest X-Ray

Complete Urinalysis

Blood Tests

- Two hour post-prandial sugar
- Glucose
- BUN
- Creatinine
- Uric Acid
- Calcium
- Phosphorus
- Protein, Total
- Albumin
- Cholesterol
- Triglycerides
- Bilirubin, Total
- Alkaline Phosphatase
- SGOT
- SGPT
- LDH
- Globulin (by Calculation)
- A/G Ratio
- Anion Gap
- Sodium
- Potassium
- Chloride
- Carbon Dioxide
- CBC with Differential
- ART/RPR Serology
- T-4 by RIA
- T-3 Uptake
- Free Thyroxine Index
- HDL

this stage 10 applicants were accepted, 4 were referred to specialists for specific medical problems (at the applicants' expense) and 6 were rejected.

Of the 4 applicants referred to specialists, only 1 was rejected. The 3 remaining applicants were accepted after being cleared by the specialist and after the project physician and specialist had discussed the case.

After the entire screening process was completed, we were left with 13 subjects; 12 formal subjects and 1 back-up subject. A graphic presentation of the selection procedures is found in Fig. 6.

2. Facility

The experiment was conducted at the STI driver testing simulation facility. This facility, at STI's main office in Hawthorne, CA, includes automotive and truck simulators; computers used for simulation control, data acquisition, and data analysis; and a subject lounge and experimenters' facility. This section will discuss the subject lounge and experimenters' facility, as the simulator and computing facilities were discussed earlier.

The subject lounge and experimenters' facility is contained in a 10 ft × 22 ft mobile office adjacent to our simulator laboratory. An enclosed entrance way connects the two facilities. The office is divided into 2 rooms: a subject lounge area, and an experimenters' area.

The subject lounge is furnished in an apartment-like atmosphere. There are a couch, chairs, tables, and a TV. It is supplied with current magazines, playing cards, games such as chess and dominoes, and daily newspapers. Our intent is to provide a real-world drinking environment while at the same time insuring appropriate experimental controls.

Adjacent to the subject lounge is the experimenters' area. This room contains a refrigerator for storing ice, mixes, and food for lunches; a locked liquor cabinet; a drink mixing table, a desk, and an intoximeter for measuring BAC levels.

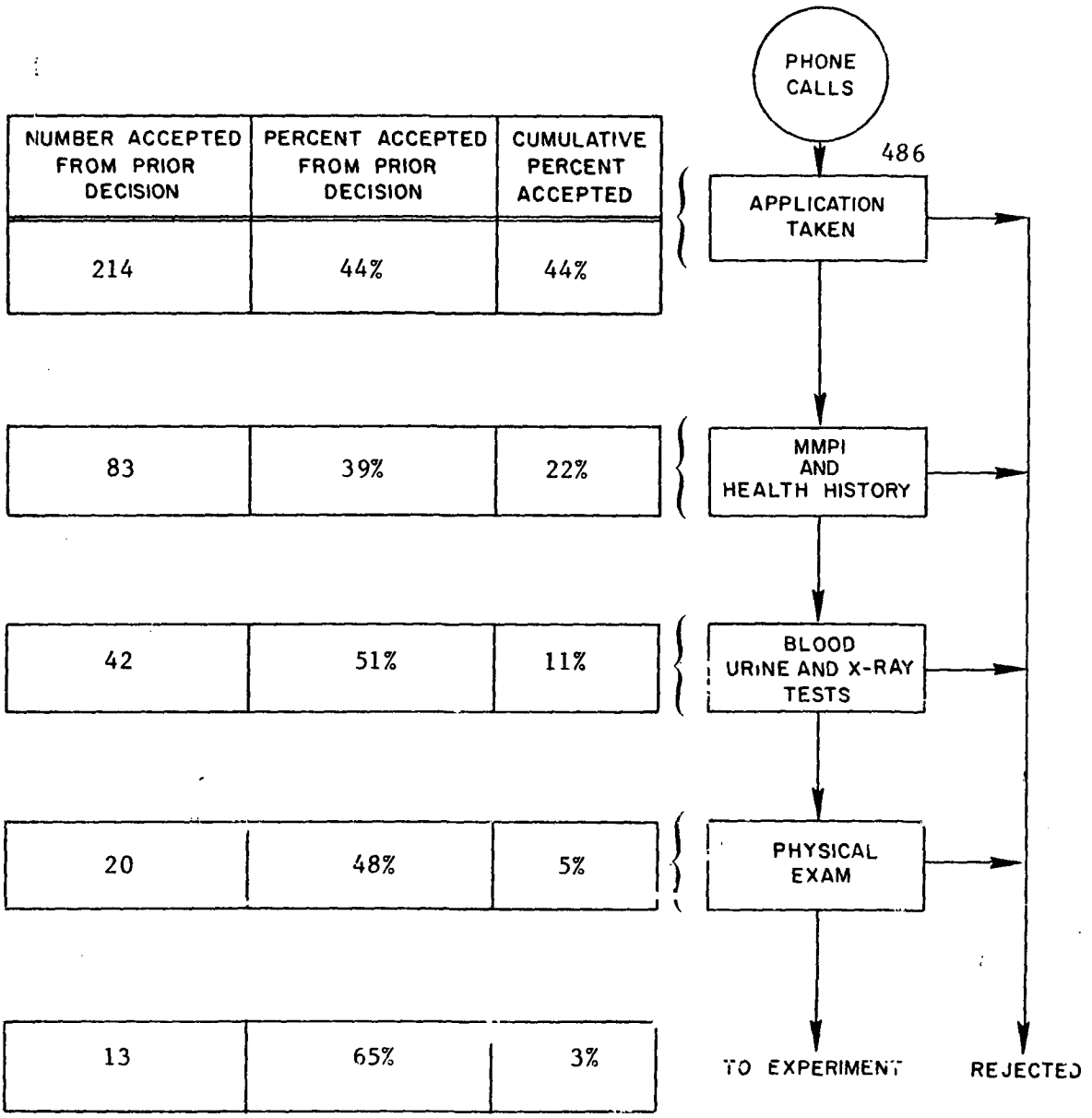

Figure 6. Formal Experiment Subject Selection

Because of the requirement for obtaining blood samples from the subjects, a blood drawing area was constructed using available laboratory space. This area had a table for the subject to lie on during the blood draw and shelves for the nurses' equipment and supplies (tourniquet, needles, tubes, etc.).

3. Training

Prior to the experiments all subjects were trained in the driving simulator. As explained earlier, driving the simulator is not unlike driving a rental car. One knows basically what to expect, but experience with the vehicle's subtleties is required in order to be able to perform emergency maneuvers. This experience was obtained during two training sessions. During each training session the subject completed two experimental scenarios (or "runs"), one for practice and one for money. Additional familiarization was provided during the first training session as follows.

First, subjects were told of the objectives of the experiments, the nature of the experimental task, and the possible hazards or discomforts they might experience. Next, the subject was introduced to the simulator; controls were pointed out and questions answered.

After the orientation, each subject was "walked through" each of the driving maneuvers. Each maneuver was repeated until the driver was able to negotiate it comfortably and at the speed required to maintain "normal" driving behavior (e.g., ample preview is given to allow negotiation of the unexpected obstacle at 55 mph (90 km/hr). If the driver slowed to 35 mph (55 km/hr) then he would be instructed to "try going faster the next time." This coaching would continue until the subject was consistently negotiating the unexpected obstacle at 55 mph (90 km/hr).

Once familiar and comfortable with each task, the subject drove the two test runs. During each run the subject was attempting to maximize his payoff based on a reward-penalty structure, discussed next. Two subjects were trained in each training session and a typical training day is shown in Fig. 7.

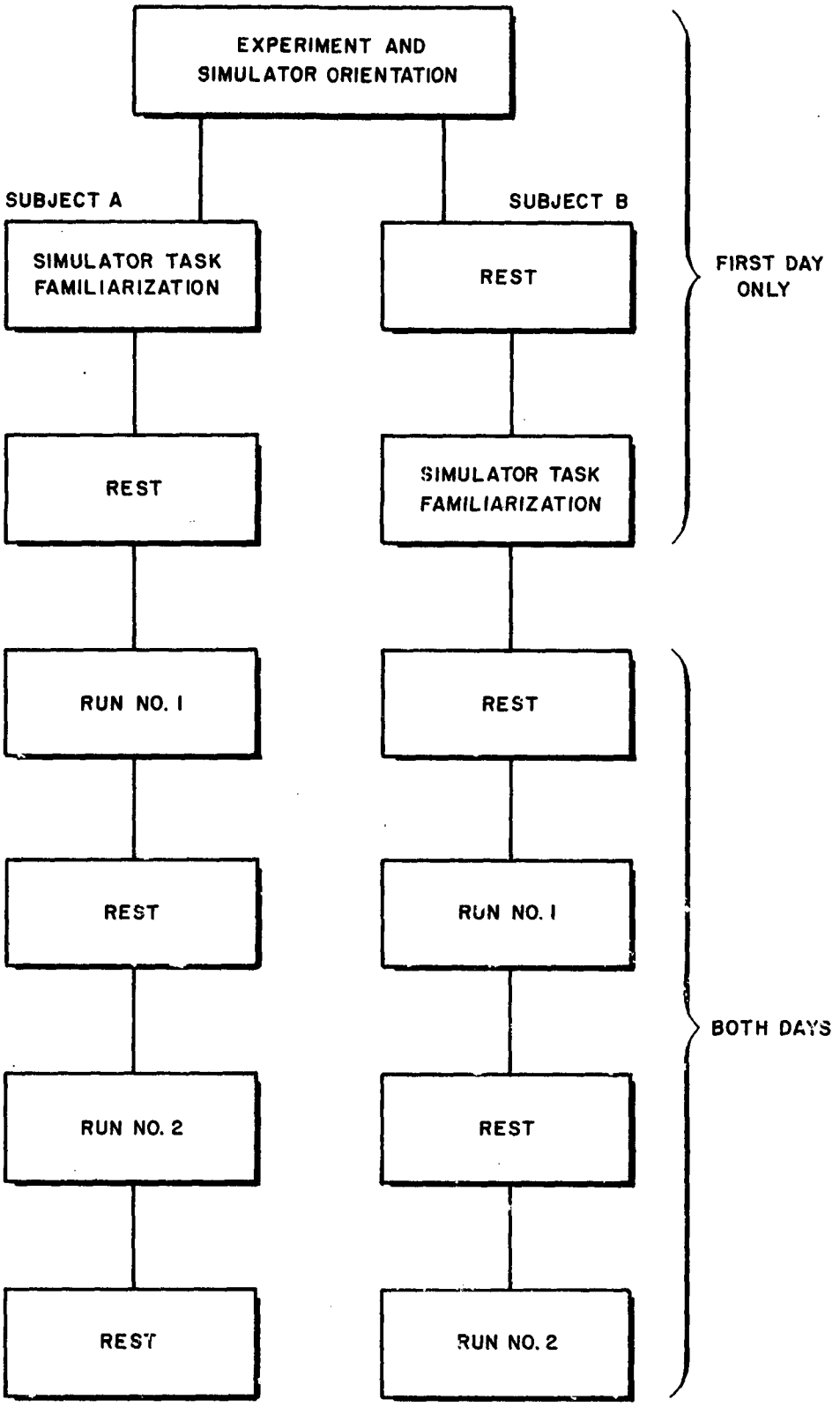

Figure 7. Typical Training Day

4. Reward-Penalty Structure

A reward-penalty structure was included in the test runs to help induce "normal" driving behavior (Stein, Schwartz, and Allen, 1978). Rewards were given for completing the scenario (simulating the real-world motivation of arriving at a destination) and for beating a reference completion time (simulating the real-world motivation of driving with the flow of traffic, at or near the speed limit).

Penalties were assessed for going slower than the reference time (simulating driving considerably slower than traffic and thus alerting police about possible impairment); for an incorrect sign response (simulating a route guidance error); and for getting tickets for speeding (the "cop" was present about 30 percent of the time) and having accidents.

In addition, subjects received an hourly rate for participation in the experiment. To help insure attendance for each of the six experimental sessions subjects were paid an experiment completion bonus, and one-half of their daily bonus money was withheld until completion of the experiment. The components of the reward-penalty structure are found in Table 3.

TABLE 3. REWARD-PENALTY COMPONENTS

ITEM	REWARD	PENALTY
	EXPERIMENT COMPLETION	
Completion Bonus	$100.00	
	PARTICIPATION MONIES	
Hourly Rate	$3.10	
	RUN RELATED MONIES	
Run Completion Bonus	$10.00	
Time Saved Bonus	$1.00/min	
Time Lost Penalty		$1.00/min
Accident Penalty		2.00 ea
Ticket Penalty		1.00 ea
Sign Response Error		.50 ea

5. Experiment

Subjects were nominally run four at a time for efficiency during the formal data trials. Each subject was picked up from his house in the morning and returned in the evening to insure no one was driving while under the influence of either alcohol or marihuana. Subjects were instructed not to drink after 10:00 pm the night before a session and not to smoke marihuana for at least 24 hours prior to a session.

The formal session began with a BAC check to insure subject compliance with the non-drinking rule (in prior studies heavy drinkers have arrived with non-zero BACs in the morning). A baseline heart rate was also obtained. Following this subjects were taken through the drug administration and testing sequence shown in Fig. 8.

First a sober simulator trial was run. Following this, the subjects were given 3 drinks at approximately 40 minute intervals, calibrated by body weight to achieve a maximum BAC of 0.10 percent (on drinking days). Each drink consisted of a measured amount of hard liquor (e.g., vodka,

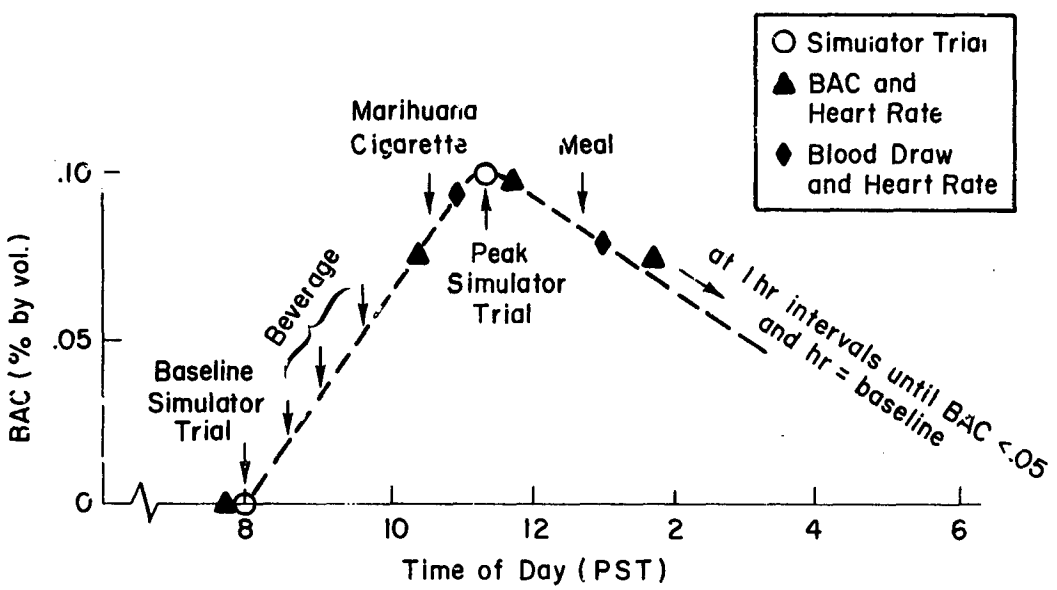

Figure 8. Typical Drug Administration and Testing Profile

bourbon, etc.) combined with a mixer to bring the total alcoholic content of the drink to 20 percent. On placebo days the mixer was combined with the appropriate amount of water (or colored water if the liquor was dark) to dilute the mix. A small amount of liquor was then floated on the top of the drink. This method for creating a credible placebo was found by Keane, et al., (1980) to be the preferred method for a mixed drink placebo. It has an appropriate smell; on the first sip it tastes like the real thing; and the initial liquor float tends to numb the taste buds for the rest of the drink.

Ten minutes after finishing the third drink the subject was administered a 1 g marihuana cigarette. A standard inhaling/exhaling procedure was used and was monitored by an experimenter. A glass tube was used as a "roach holder" to allow the entire cigarette to be consumed.

The subject's heart rate was recorded immediately after the cigarette was finished. Exactly one minute after the cigarette was finished venipuncture was performed and blood was drawn for Δ^9 THC analysis. Blood was collected in vacutainer tubes provided by the Center for Human Toxicology (CHT) at the University of Utah, which performed the blood analysis. The blood sample was refrigerated immediately after being drawn. Within one hour of being drawn, the blood was centrifuged, the plasma transferred to screw top tubes provided by CHT and then the plasma was frozen.

Following the blood draw, the subject's BAC was taken and a subjective rating form was completed by the subject. The subjective rating form was used by the subject to rate how drunk he felt, and the quality of the marihuana.

Once these data were obtained, the subject drove his peak simulator run. After competing the run a BAC was taken and the subject was given lunch.

A second blood sample was obtained exactly 1 hour after the end of smoking. BAC and heart rate were monitored on a continuing basis until the subject's BAC dropped below 0.05 percent and his heart rate returned to within 10 percent of normal. At this time he was driven home.

Double-blind procedures were maintained throughout the experiment. The overall design was known only to the principal investigators. For each experimental day they assigned a color to each subject according to his testing order for that day. They then obtained the marihuana cigarettes for that day and coded them with the appropriate color; they also told the experimenter in charge of drinks who was drinking and who was placebo.

Two experimenters and one nurse conducted the experiments. One experimenter was responsible for drink mixing and obtaining and recording BACs. The nurse was responsible for marihuana administration, blood draws, and heart rate measurement and recording. The second experimenter conducted the simulator trials.

6. Data Analysis

At the conclusion of the experiment the data were transferred from our laboratory minicomputer to a large timesharing computer system which allowed the data to be analyzed with standard statistical analysis programs. The data were arranged according to the experimental design and edited to add BAC, heart rate, and subjective rating data.

Overall scenario performance data were analyzed because they most closely relate to the traffic safety variables causing accidents. These data include tickets, accidents, drive completion time, and reward/penalty payoff.

For each task in Table 1, the data were analyzed to determine changes in driver behavior and in driver/vehicle performance. These data include lane deviations, speed control measures, sign response times, and subjective ratings.

These data were analyzed according to the basic experimental design shown in Fig. 3 using Analysis of Variance (ANOVA) procedures. The objective of the analysis was to look for effects due to alcohol, marihuana, and their combination. All effects were tested against between-subjects interaction terms, and subjects were treated as a random effects variable so that the results can be extrapolated to the heavy drinking, marihuana smoking male driver population in general.

SECTION IV

RESULTS

This section begins with a discussion of the overall scenario performance of the drivers. These results are directly related to the real-world traffic safety problems associated with driving under the influence of the test drugs. Subsequent articles then discuss the performance and behavioral effects found for each of the events within the driving scenario. The section is then concluded with a summary of the findings. The reliability of the following results was tested with analysis of variance procedures (ANOVA). In the text, results are presented as statistically significant or reliable if the Type I error probability is less than or equal to 0.05 ; if it is greater than 0.05 but less than or equal to 0.10 the results are said to be of marginal significance. On the figures the level of significance stated in the ANOVA table is either significant (S), $P < 0.05$; marginally significant (M.S.), $0.05 < P < 0.10$; or not significant (N.S.), $P > 0.10$.

A. INTRODUCTION

The results in this section are reported as a function of alcohol dose, 0 percent BAC and 0.10 percent BAC (actual levels 0 percent and 0.10 percent ± 0.01, Fig. 9); and as a function of Δ^9 THC dose levels, 0-, 100-, and 200- μg Δ^9 THC/kg bodyweight.

As discussed in the methods section, exacting procedures were used to draw blood samples for Δ^9 THC concentration analyses. These analyses were performed by the Center For Human Toxicology at the University of Utah. The resulting blood level concentrations were found to be between 5 and 10 times greater than those observed in any prior research using similar dosages.

Because of these inconsistencies, discussions were held with representatives from the National Institute on Drug Abuse (NIDA). The Center For Human Toxicology, NHTSA, and STI. It was determined that the procedures used to collect, process, and store the blood were done in

ANOVA Summary
(abbreviations defined
on page 28)

A	M	A x M
S	N.S.	N.S.

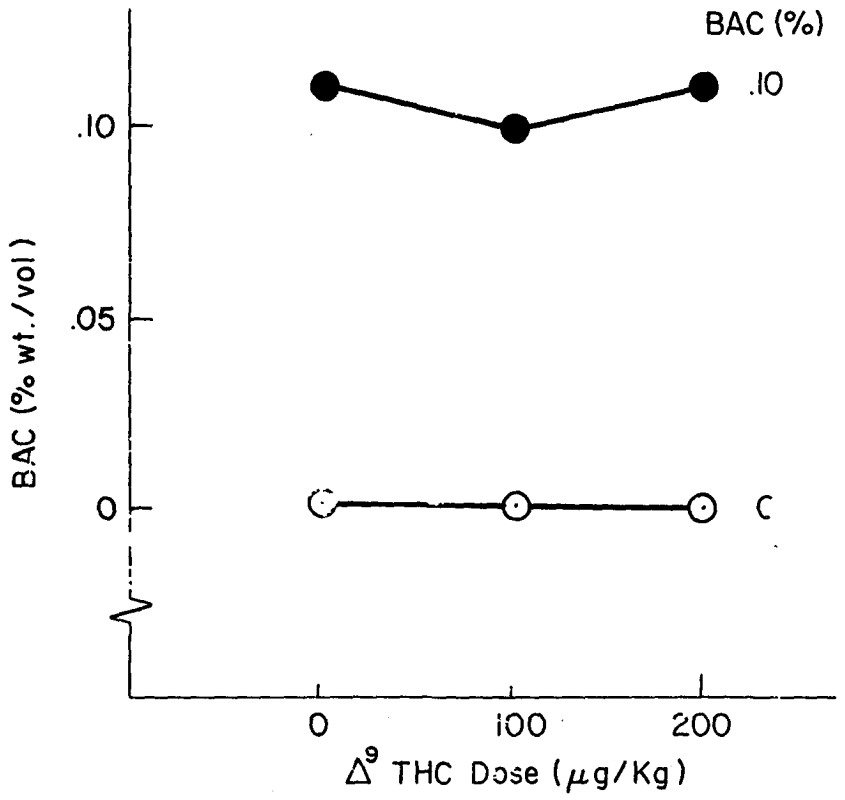

Figure 9. BAC Levels Reached

accordance with Center For Human Toxicology instructions and current accepted practice. It was also determined that the procedures used for analysis of the plasma samples was also performed in accordance with accepted standards.

Currently both NIDA and Center For Human Toxicology personnel feel that the only plausable explanation for the discrepancy between the expected and obtained Δ^9 THC concentrations lie in the Radio/Imuno Assay (RIA) kit supplied to the Center by NIDA. Unfortunately, there was not enough plasma left to reanalyze the data base.

For this reason doseage level, and not blood plasma levels were used in the data analysis.

1. Overall Scenario Performance (Traffic Safety)

Accidents were recorded throughout the driving scenario. In Fig. 10 we show the average accidents per subject as a function of the various alcohol-marihuana conditions. Analysis of variance procedures showed a strong alcohol/marihuana interaction on the number of accidents, as well as showing that alcohol had a marginally significant effect on accidents. The marihuana effect was not statistically significant. The interaction effect of marihuana and alcohol on accidents appears to work in both directions. At the 100 μg/kg dose, marihuana appears to reduce the alcohol effect on accidents, while at the 200 μg/kg dose it appears to increase the alcohol effect.

Treatment effects on speeding tickets are illustrated in Fig. 11. There were no statistically significant effects of treatment on speeding tickets. The result is presented, however, because tickets are an important element in the payoff variable which is discussed later in this section.

Run completion times (Fig. 12) were significantly affected by marihuana while no statistically significant effects were observed for either alcohol or the alcohol-marihuana combination. The results indicate a dose response relationship between increased Δ^9 THC dose and increased run completion time; that is, as the marihuana dose goes up

ANOVA Summary
(abbreviations defined
on page 28)

A	M	A x M
M.S.	N.S.	S

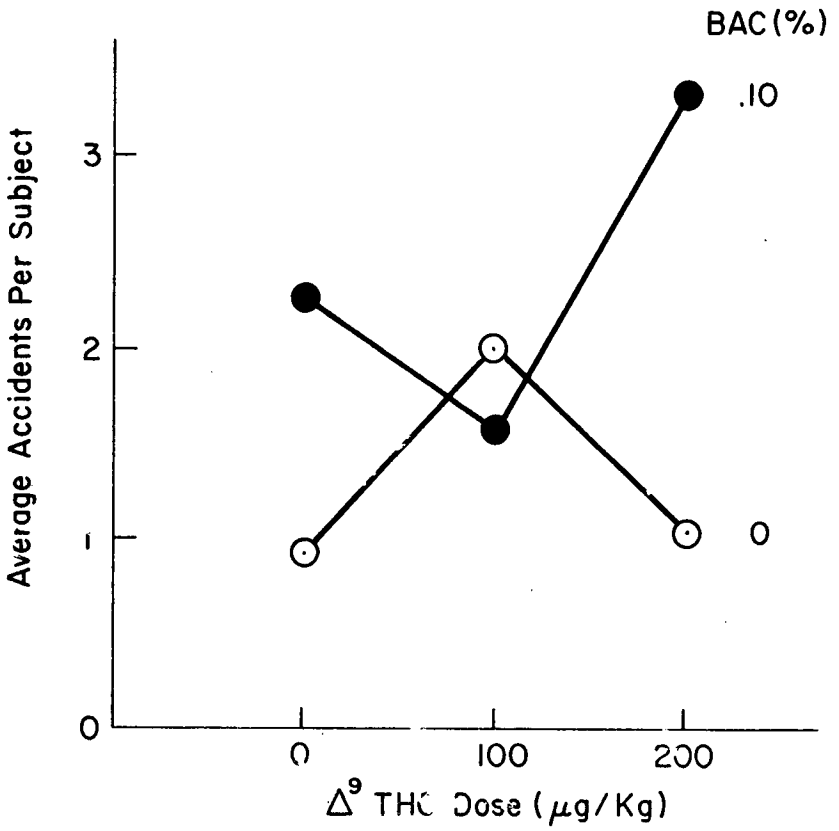

Figure 10. Combined Accidents During Scenario as a Function of Experimental Treatment

ANOVA Summary
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on page 28)

A	M	A x M
N.S.	N.S.	N.S.

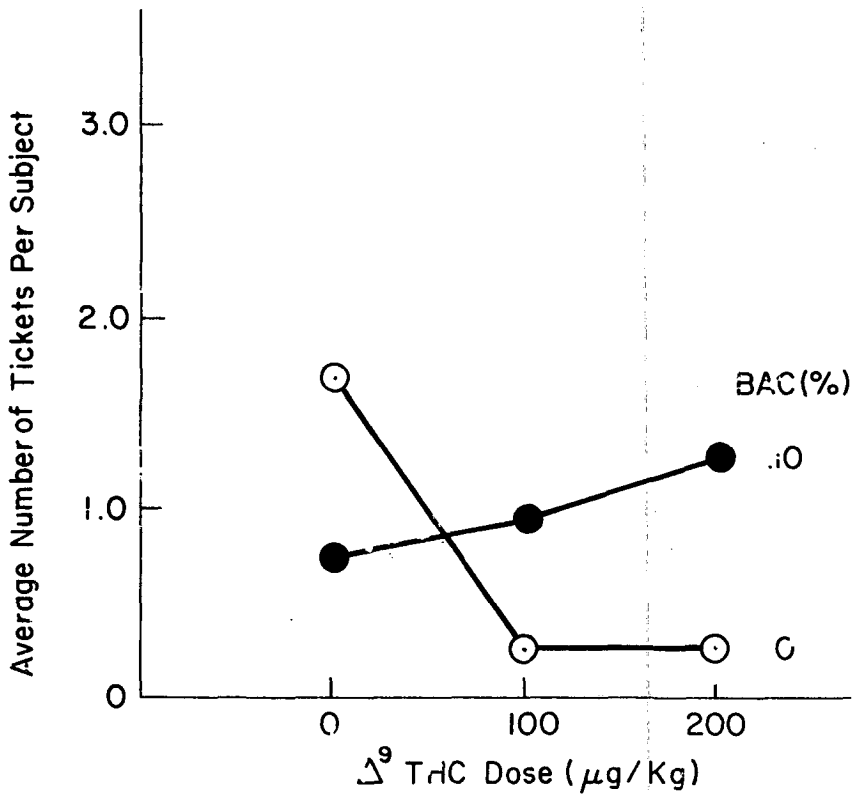

Figure 11. Average Speeding Tickets Per Trial in Driving Scenario

ANOVA Summary
(abbreviations defined
on page 28)

A	M	A x M
N.S.	S	N.S.

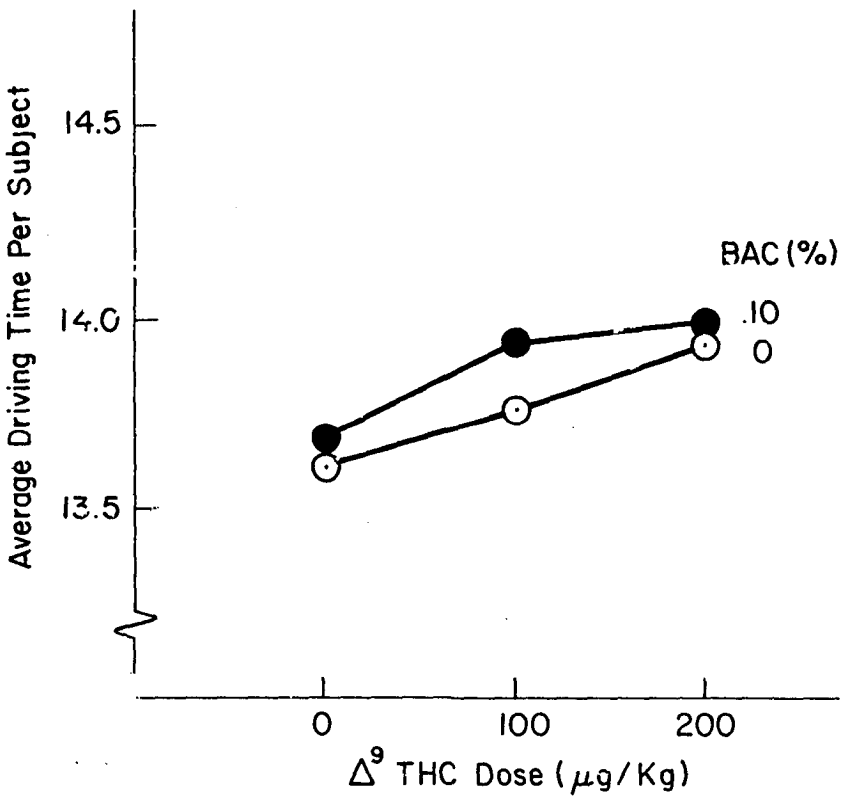

Figure 12. Average Driving Scenario Completion Time Per Trial

the subject drives slower. This finding is not unusual as this effect is a common anecdotal comment of marihuana smokers, as well as a frequent finding in past research.

The final overall performance measure is payoff. This measure combines the three previous measures in a weighted fashion providing a composite measure of traffic safety effects of alcohol, marihuana, and their combination. As shown in Fig. 13 both alcohol and the alcohol-marihuana combinations have a statistically significant effect on this measure, although the alcohol reliability was marginal. Alcohol, in general, decreased driver payoff and thus increased the traffic safety hazard. When combined with marihuana, a significant interaction effect is observed. This interaction is similar to that seen on traffic accidents. The data indicate that the 100 μg/kg dose of marihuana reduces some of the alcohol impairment. However, alcohol impairment is still observed at this treatment condition. At the 200 μg/kg Δ^9 THC plus alcohol condition the observed impairment is considerably worse than either drug alone.

2. Driver Behavior During the Divided Attention Tracking Task

A strong marihuana effect was observed in the drivers mean speed on the divided attention tracking task. As observed in the overall scenario completion time, as the marihuana dose increased the mean speed during the task dropped. Figure 14 also shows lack of statistical significance for both alcohol and the alcohol-marihuana combination. However, slightly higher speeds were observed under the alcohol conditions.

Speed variability (Fig. 15) exhibited a marginal marihuana effect. Drug doseage at the 100 μg/kg level seemed to increase speed variability, while variability decreased at the 200 μg/kg level.

Driver steering behavior was also adversly affected by the alcohol treatment. Figures 16 and 17 both show an increase in lane position variability that was significant. Lane position variability can best be described as "weaving"; since this behavior increases the likelihood of exceeding lane boundries, the chance of being involved in an accident also increases.

ANOVA Summary
(abbreviations defined
on page 28)

A	M	A x M
M.S.	N.S.	S

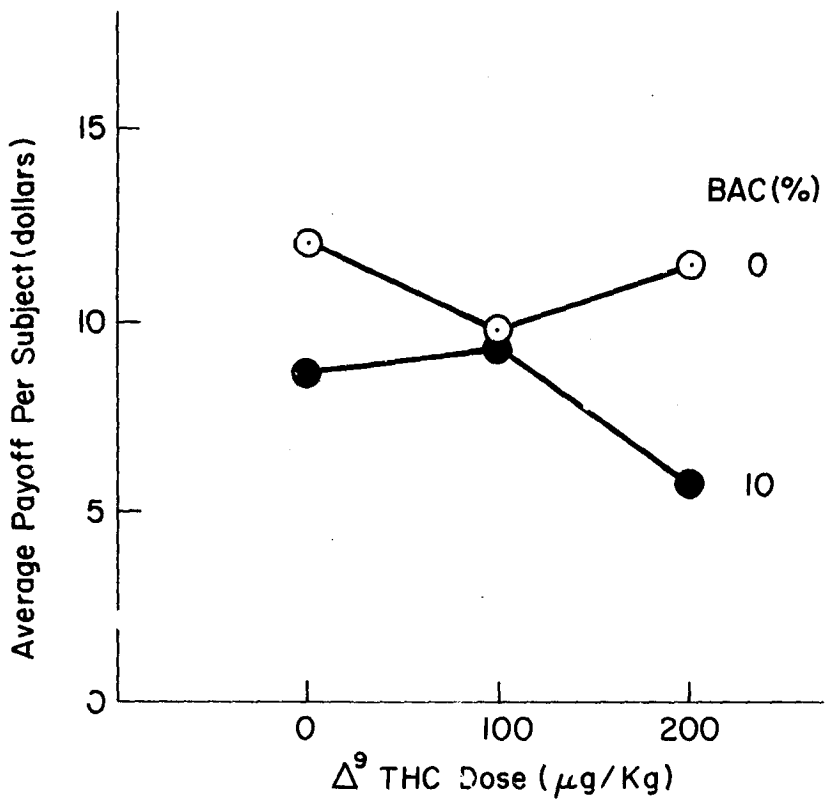

Figure 13. Reward/Penalty Performance as a Function of Drug Dose

ANOVA Summary
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on page 28)

A	M	A x M
N.S.	S	N.S.

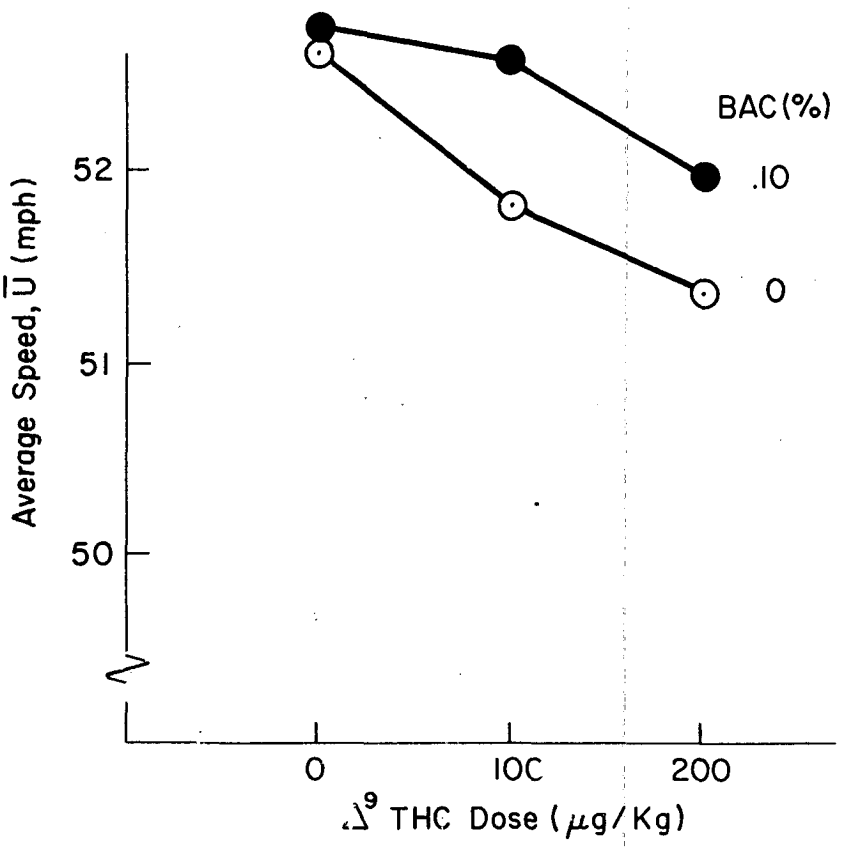

Figure 14. Alcohol and Marihuana Effects on Speed Control During the Tracking Task (Mean Speed)

ANOVA Summary
(abbreviations defined
on page 28)

A	M	A x M
N.S.	M.S.	N.S.

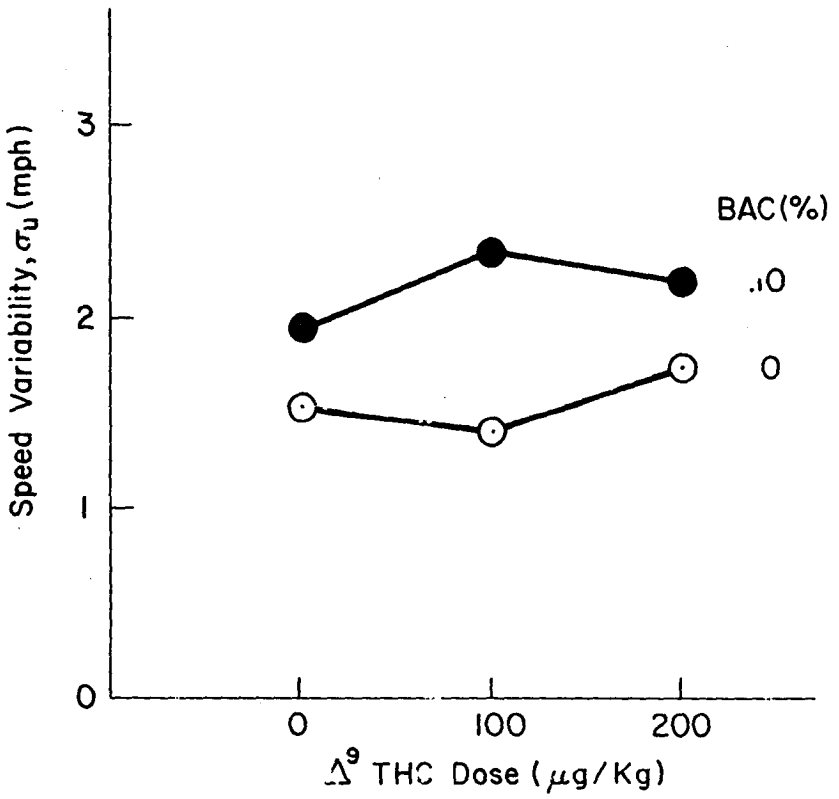

Figure 15. Alcohol and Marihuana Effects on Speed Control During the Tracking Task (Speed Variability)

ANOVA Summary
(abbreviations defined
on page 28)

A	M	A x M
S	N.S.	N.S.

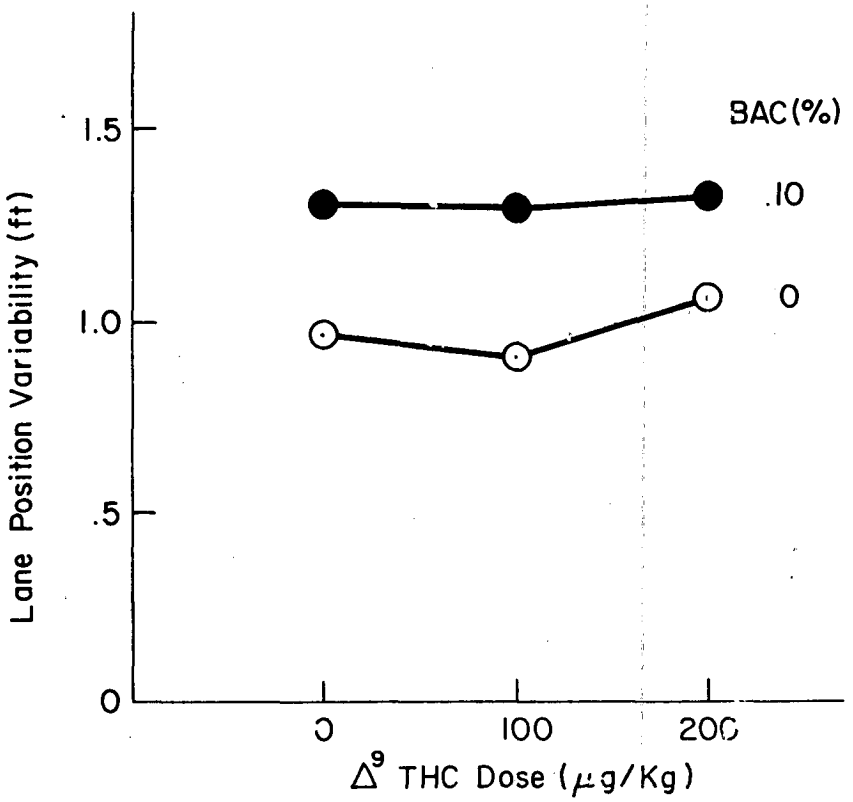

Figure 15. Lane Position Variability During the Tracking Task (Signs Present as a Divided Attention Task)

ANOVA Summary
(abbreviations defined
on page 28)

A	M	A x M
S	N.S.	N.S.

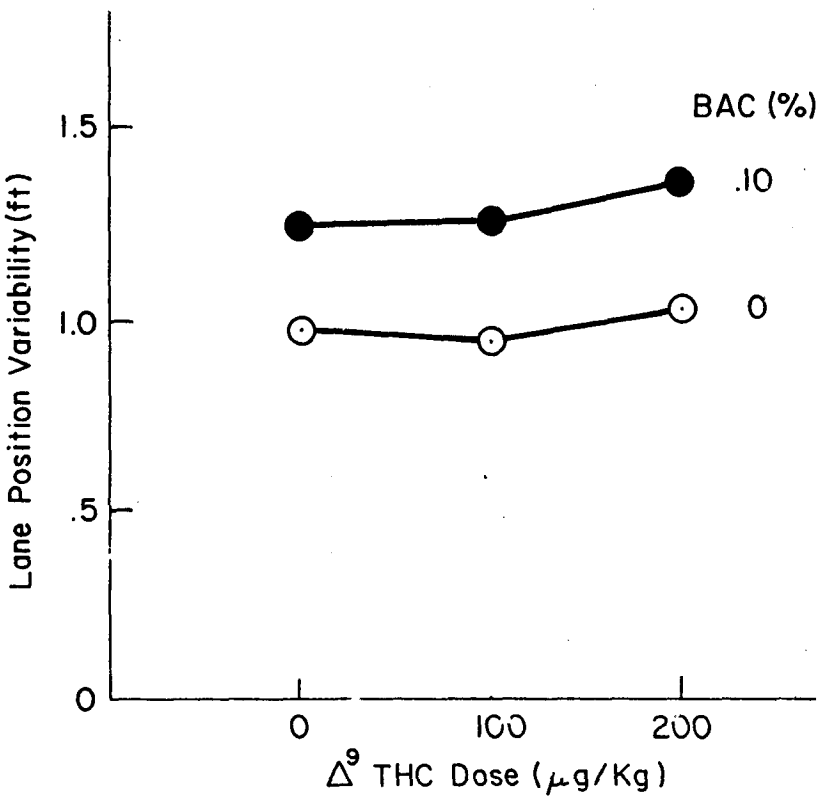

Figure 17. Lane Position Variability During the Tracking Task (No Signs)

The divided attention task in the tracking run required the driver to respond appropriately to various highway signs. Depending on the sign message, the driver was required to depress the horn button, use the right or left blinker, or dim the headlights. Data taken included number of missed signs, number of incorrect responses (e.g., using the right blinker when the left should have been used), mean reaction time, and reaction time variability. Statistical significance was observed only for alcohol effects on mean reaction time and reaction time variability. Figure 18 shows mean reaction time as a function of drug dose. The alcohol runs show an increase in reaction time (slower response) over the sober runs. There also appears to be a mediating effect of marihuana at the 100 μg level, however, this effect was not statistically significant. Reaction time variability is shown in Fig. 19. Again, alcohol increases variability, while marihuana and the combination of alcohol and marihuana have no statistical significance.

3. Isolated Curves

During the curve maneuver data were taken on lane position variability, mean speed, and speed variability. Lane position variability results proved inconclusive. Figure 20 shows the mean speed results. Marihuana has the same speed effect shown throughout the experiment; that is, drivers go slower when under the influence of marihuana. It also appears that an additive effect is seen with alcohol, but this was not statistically significant. Figure 21 shows that alcohol causes a speed variability increase, again consistent with the variability results seen throughout the experiment.

4. Obstacle Avoidance Task

The obstacle avoidance task involved both the double lane change task and the unexpected obstacle task. Figure 22 shows mean speed during the lane change task. Once again, we find only marihuana having a significant effect; and again marihuana causes drivers to go slower. Speed variability is shown in Fig 23. The baseline runs (BAC = 0.00 percent) exhibit a farily consistent variability, while the typical

ANOVA Summary
(abbreviations defined
on page 28)

A	M	A x M
S	N.S.	N.S.

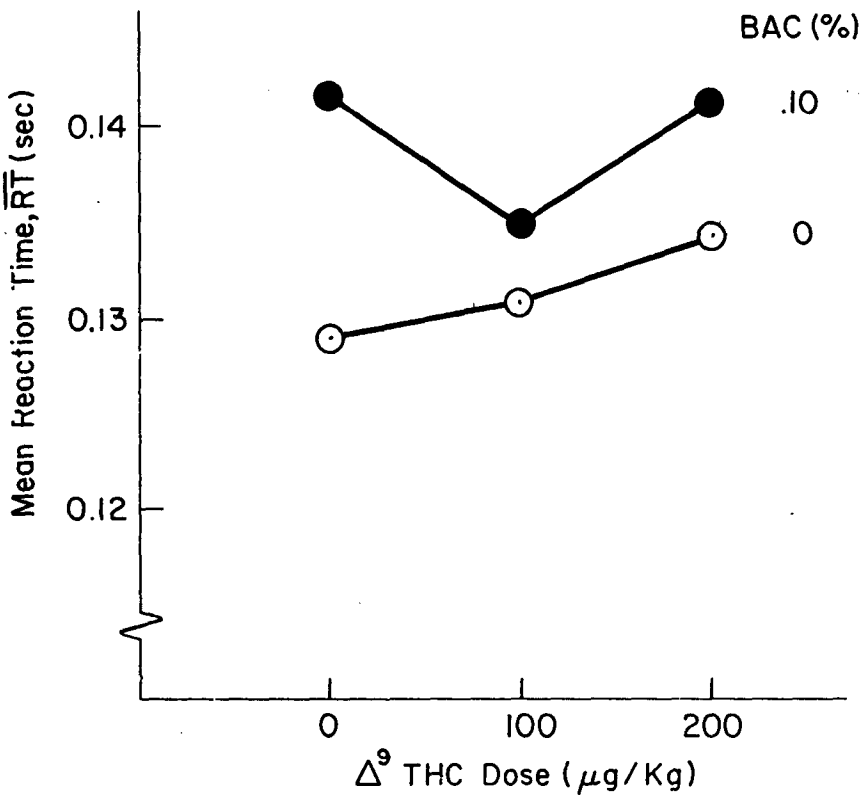

Figure 18. Alcohol and Marihuana Effects on Mean Sign Reaction Time

ANOVA Summary
(abbreviations defined
on page 28)

A	M	A x M
S	N.S.	N.S.

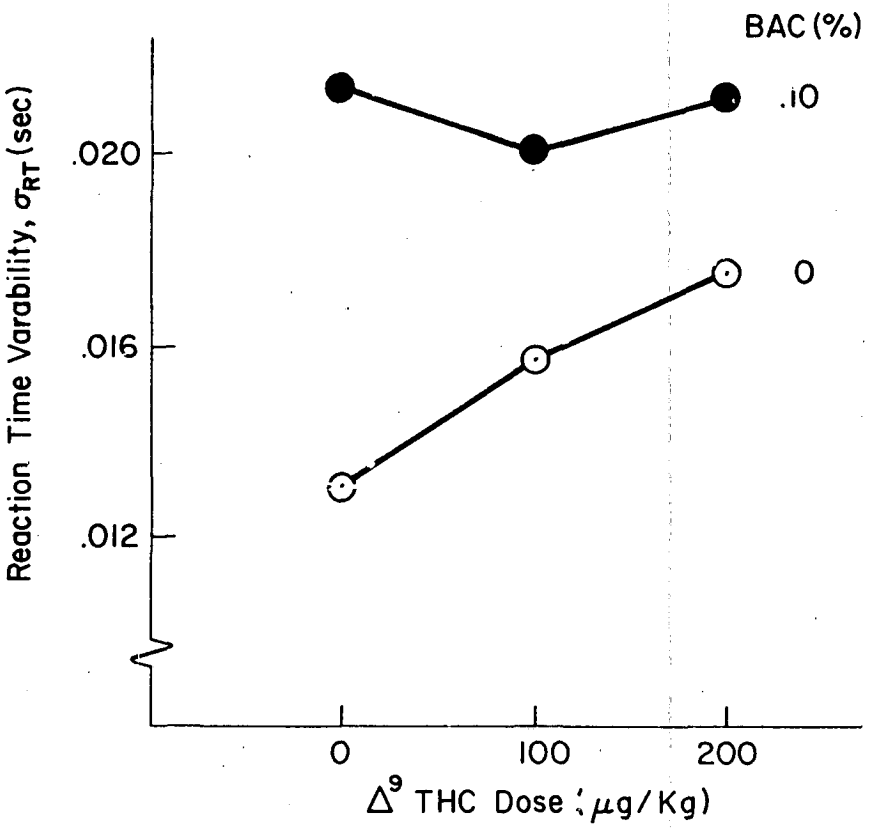

Figure 19. Alcohol and Marihuana Effects on Sign Response Time Variability

ANOVA Summary
(abbreviations defined
on page 28)

A	M	A x M
N.S.	S	N.S.

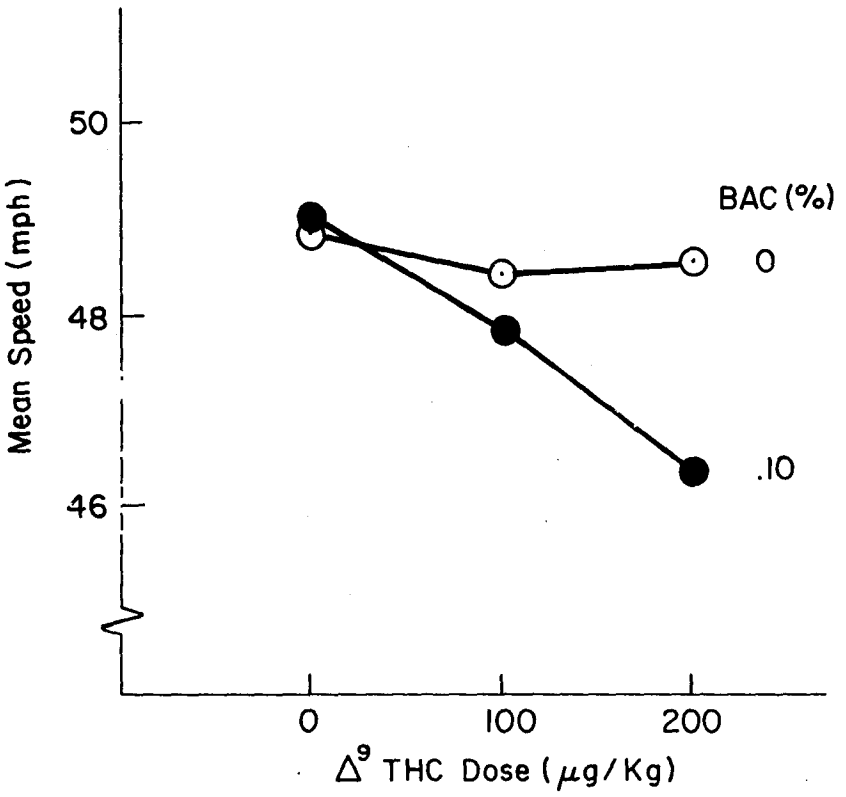

Figure 20. Average Speed During Curve Encounter

ANOVA Summary
(abbreviations defined
on page 28)

A	M	A x M
S	N.S.	N.S.

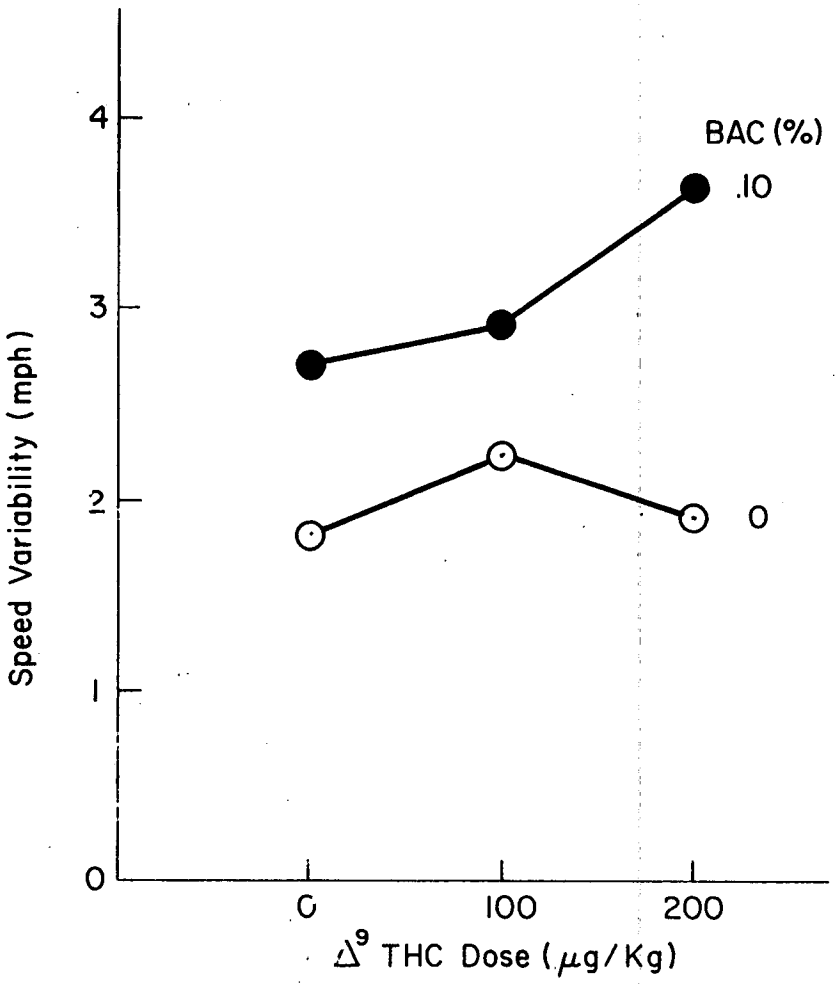

Figure 21. Average Speed Variability During Curve Encounter

ANOVA Summary
(abbreviations defined
on page 28)

A	M	A x M
N.S.	S	N.S.

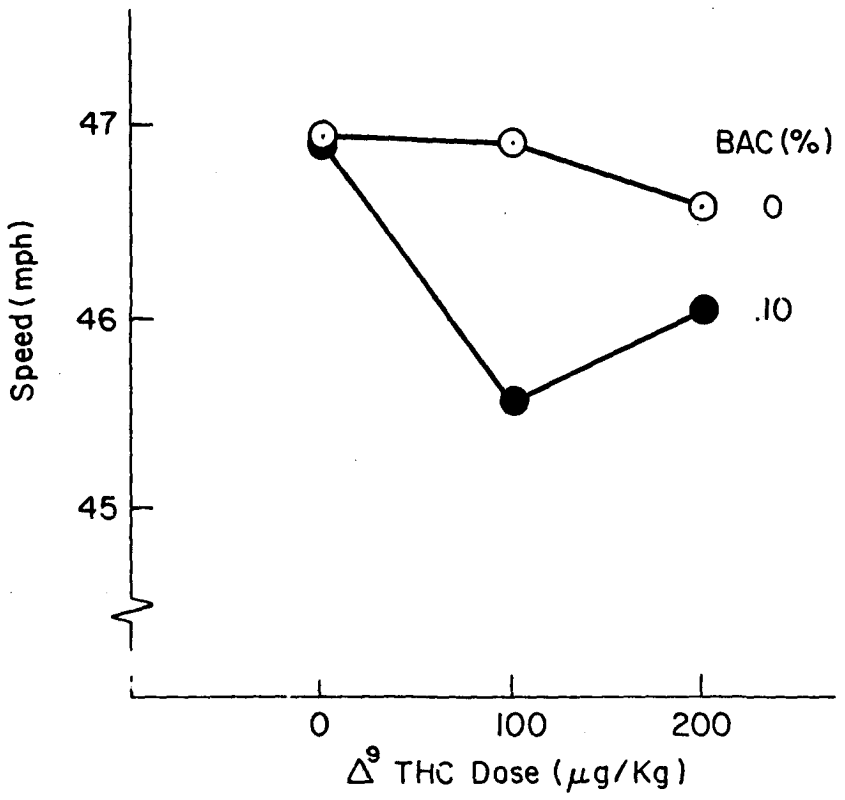

Figure 22. Mean Speed During the Lane Change Maneuver

ANOVA Summary
(abbreviations defined
on page 28)

A	M	A x M
S	N.S.	S

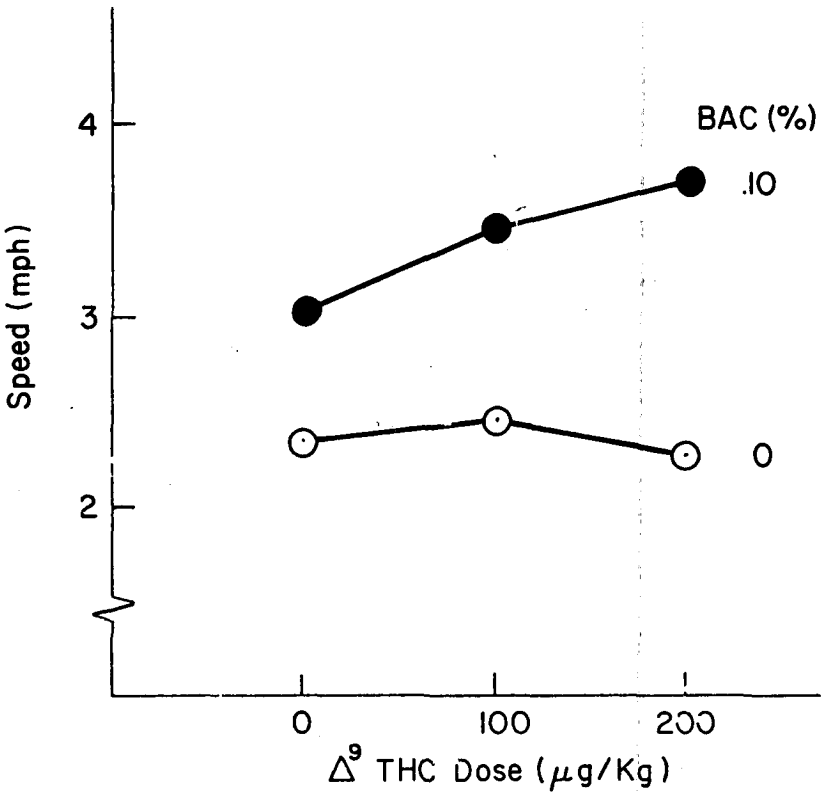

Figure 23. Speed Variability During the Lane Change Maneuver

alcohol effect (increased variability) is observed to be significant. In this maneuver, however, there is also an additive effect of the drugs. That is, alcohol and marihuana in combination cause the variability to increase even more than either substance by itself.

Again, steering behavior is negatively affected by alcohol. Figure 24 shows the drivers' peak displacement to the left of the centerline when trying to avoid an obstacle in his lane. Alcohol appears to reduce the distance the driver veers away from the obstacle. Marihuana also appears to have a similar effect at the 100 μg level, but this effect was not consistent across all marihuana doses, and was not significant.

When combined with the peak lane deviation variability shown in Fig. 25, it becomes obvious that alcohol increases the probability of accident involvement during this maneuver. Alcohol once again has a significant effect on steering variability.

5. Driver Steering Control Behavior

In addition to the traffic safety and system performance measures discussed previously, measures of steering control behavior were also obtained. As discussed in Appendix B steering behavior was measured during the random wind gust tasks, and also for obstacle encounters. Steering behavior during these encounters is the precusor of system performance (e.g., lane deviations and vehicle path around obstacles) which subsequently determines the occurrence of traffic safety events (e.g., lane boundary exceedences, obstacle strikes). As discussed in Appendix B a variety of measures were obtained, and the measures significantly effected by alcohol and/or marihuana were as follows.

In the divided attention tracking task the driver responds to random wind gusts by steering his car as though he were headed toward an effective desired aim point down the road. One of the driver's control behavior parameters is the distance to this aim point, which can also be interpreted as the inverse of the emphasis (or gain) the driver puts on correcting lane deviation errors (Appendix B). As noted in Fig. 26,

ANOVA Summary
(abbreviations defined
on page 28)

A	M	A x M
M.S.	N.S.	N.S.

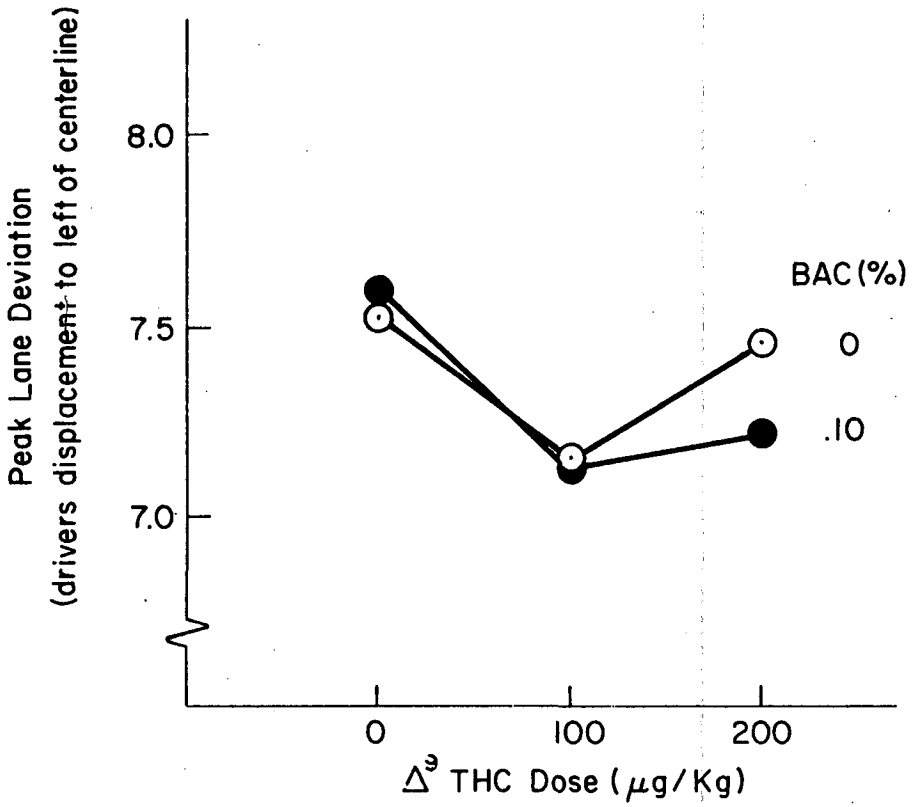

Figure 24. Peak Lane Deviation During the Double Lane Change Maneuver

ANOVA Summary
(abbreviations defined
on page 28)

A	M	A x M
M.S.	N.S.	N.S.

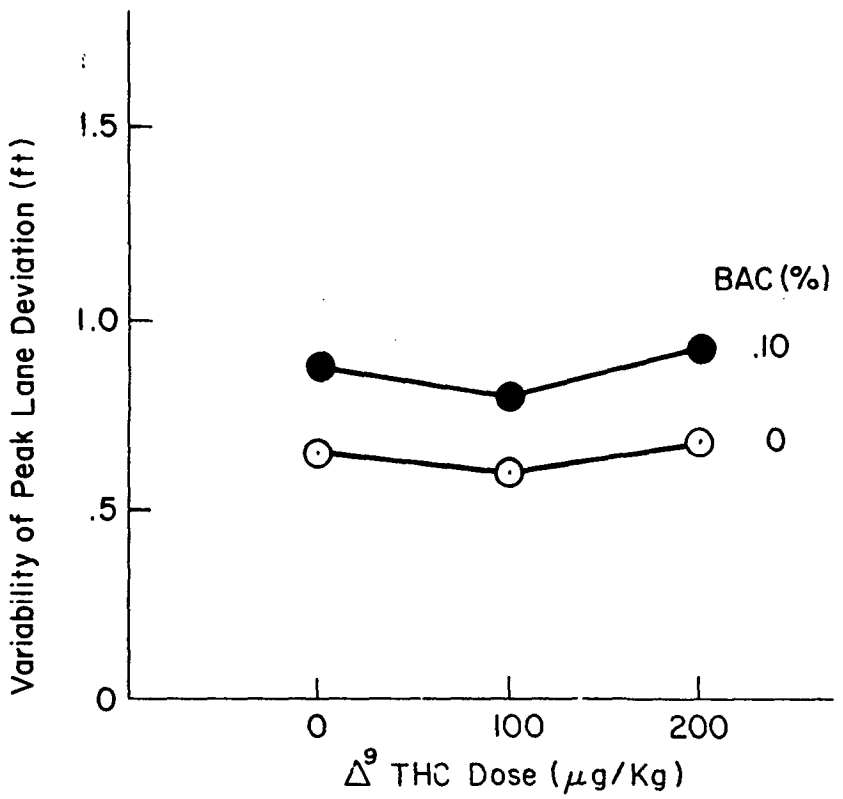

Figure 25. Variability of Peak Lane Deviation During The Double Lane Change Maneuver

ANOVA Summary
(abbreviations defined
on page 28)

A	M	A x M
S	N.S.	N.S.

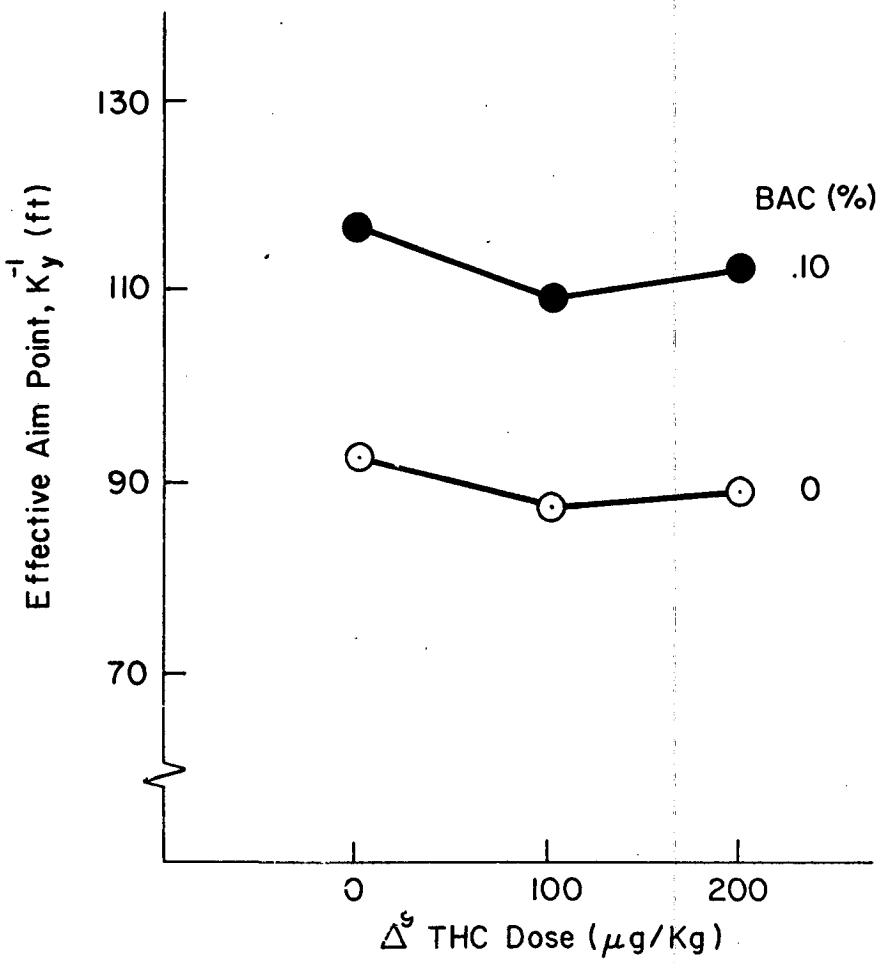

Figure 26. Treatment Effects in Effective Aim Point of the Driver's Steering Control Behavior

alcohol generally caused an increase in the driver's effective aim point, also to be interpreted as a decrease in the gain applied to lane deviation errors. This behavioral change would be expected to result in increased lane deviation variability, which in fact were observed in Fig. 25.

The driver also responds to the observed car heading alignment errors with respect to the desired aim point by applying a steering wheel correction. In Fig. 27 a counteracting effect of alcohol and marihuana is noted on the dirver's measured heading gain (or steering response to heading deviations). Under marihuana conditions only, gain tends to go down with increasing Δ^9 THC dose. Under sober marihuana conditions, 0.10 BAC causes a reduction in heading gain, but adding increasing doses of Δ^9 THC tends to counteract the alcohol gain reduction.

Note that the treatments effect in Fig. 27 amount to gain changes on the order of 11 percent while the percentage changes in Fig. 26 are about twice as large (~ 22 percent). Thus in terms of driver steering response to random inputs, the effective aim point or inverse lane deviation gain would appear to be the more important effect.

The effect of alcohol and marihuana on the driver's steering noise, or percentage of steering activity uncorrelated with the random wind disturbance forcing function, is illustrated in Fig. 28. Here we see that alcohol generally elevated uncorrelated steering actions. During tracking without signs there was also a significant marihuana effect which also tended to elevate uncorrelated steering actions.

During the obstacle avoidance tasks, a characteristic steering profile is required, as described in Appendix B, in order to accomplish the required lane change. A consistent change in timing of specific steering events was noted under alcohol for the fixed obstacle encounters as illustrated in Fig. 29. Under the influence of alcohol there was a small increased anticipation in steering responses. At the average speed the driver's were traveling (nominally 46 mph or 75 km/hr, Fig. 20) the anticipation amounts to on the order a tenth of a second which is probably not of much practical significance.

ANOVA Summary
(abbreviations defined
on page 28)

A	M	A x M
N.S.	N.S.	S

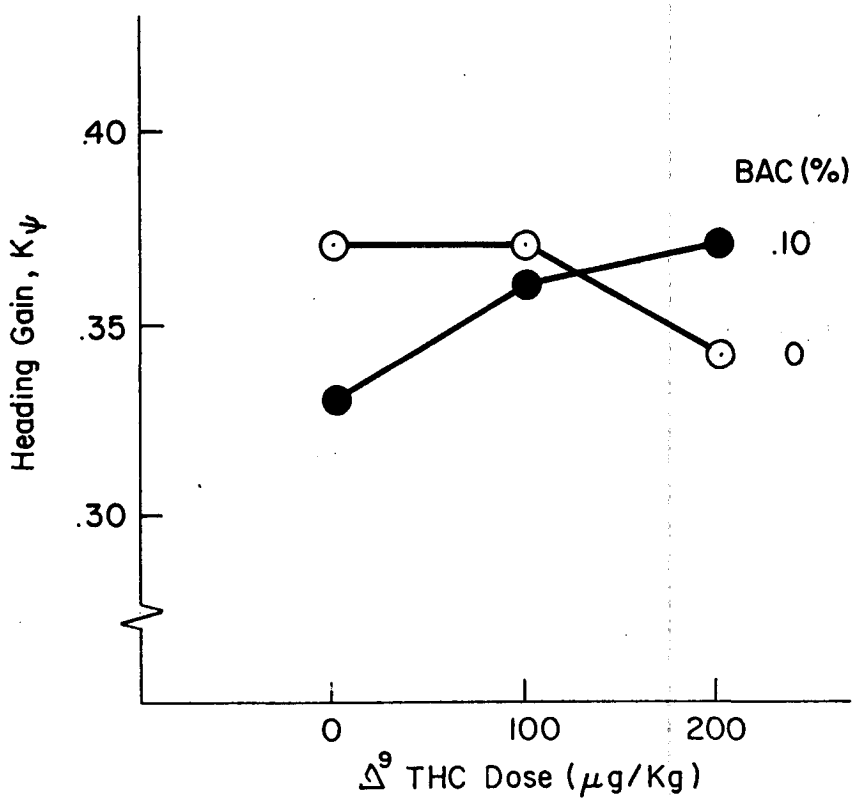

Figure 27. Treatment Effects on Driver Gain Applied to Car Heading Alignment Errors With the Desired Aim Point

ANOVA Summary
(abbreviations defined
on page 28)

Subsidiary Sign Recognition Task	ANOV p Values		
	A	M	A x M
⊙ Without	S	S	N.S.
△ With	S	N.S.	N.S.

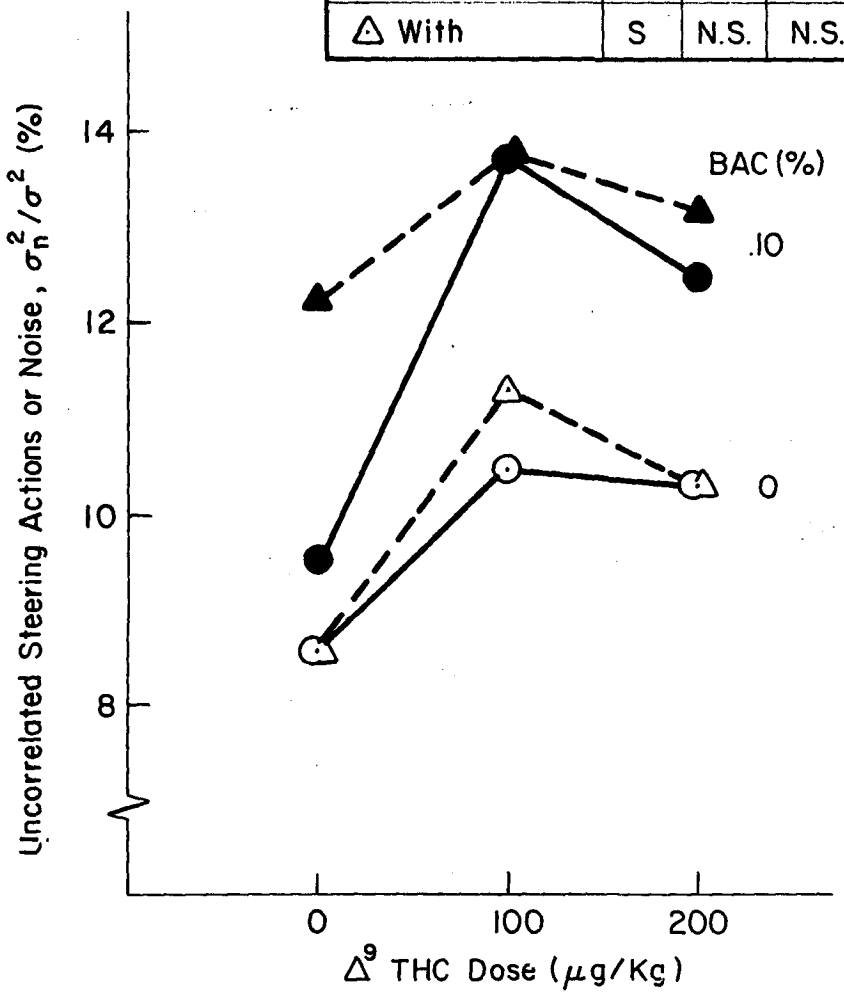

Figure 28. Treatment Effects on Uncorrelated Steering Actions

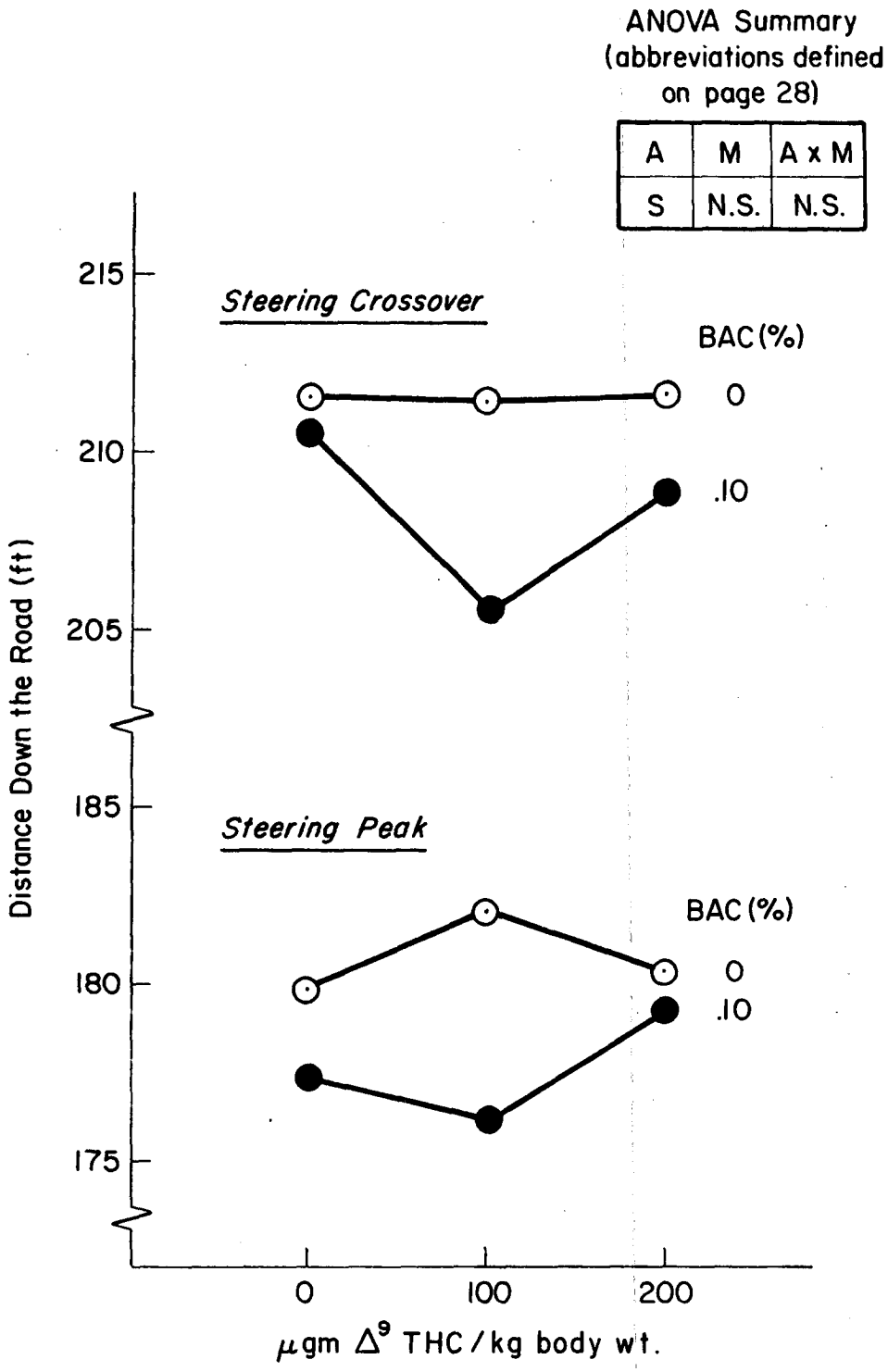

Figure 29. Treatment Effects on Timing of Transient Steering Events During Fixed Obstacle Task (See Appendix B for Definition of Steering Events)

6. Subjective Ratings and Physiological Response

Subjective data were obtained from the subjects to determine their self reported levels of alcohol and marihuana intoxication (the rating form is found in Fig. 30); and as a check on the viability of the placebo condition. This also provided further insight into the strength of the drug treatments. Subject ratings were obtained just prior to entering the simulator, which was 10 minutes after completion of the marihuana cigarette and 30 minutes after completion of the last drink. Figure 31 shows that subjects consistently rated the 0.10 alcohol level as greater than the placebo level; and that the placebo was effective because the ratings are above "sober". The same is true for the marihuana ratings (Fig. 32). Subjects were able to differentiate between the active and detoxified marihuana; and again the placebo received a positive rating. It also appears that subjects were unable to account for differences between the two active levels of marihuana. This may be due to a difference in absorbtion rates, but in the absence of blood plasma Δ^9 THC levels this is only speculation.

Heart rate was measured immediately after completion of the marihuana cigarette, and just prior to the 1 minute blood draw. Figure 33 shows the expected dose response relationship between marihuana and heart rate; that is, as marihuana dose increases, so does heart rate.

No unusual or otherwise unexpected reactions were seen due to the combined drug administration. Subjective ratings and comments seem to indicate that both alcohol and marihuana doses were typical of the subjects prior experiences.

7. Summary

A summary of the experimental results is found in Table 4. The presentation and discussion began with the ultimate traffic safety indications of driver impairment, accidents and tickets. We then proceeded to discuss some of the basic underlying causes for the observed impairments by explaining specific degraded performance during the various tasks.

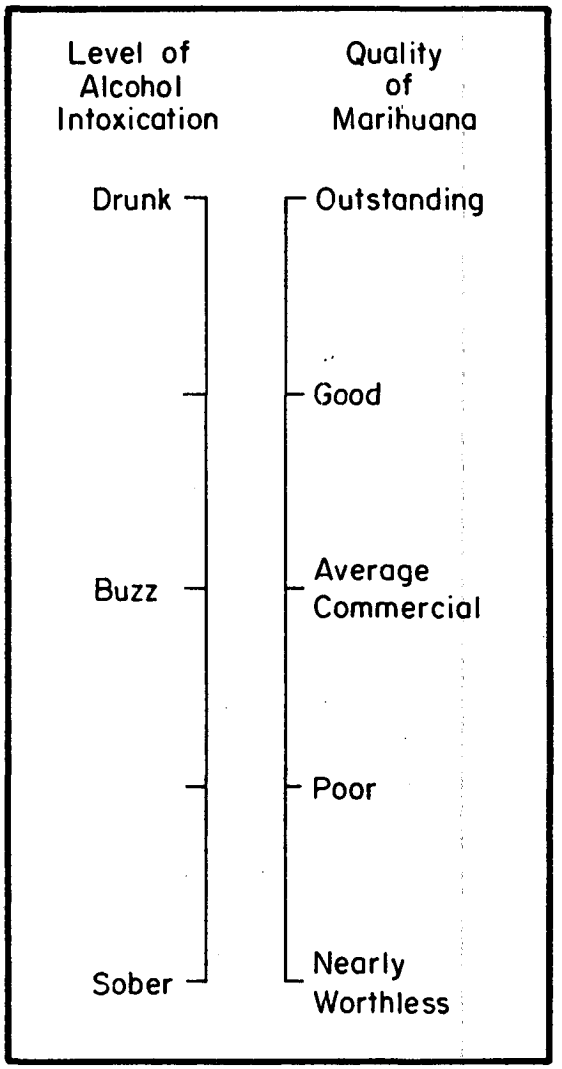

Figure 30. Rating Scales for Alcohol Intoxication and Marihuana Potency

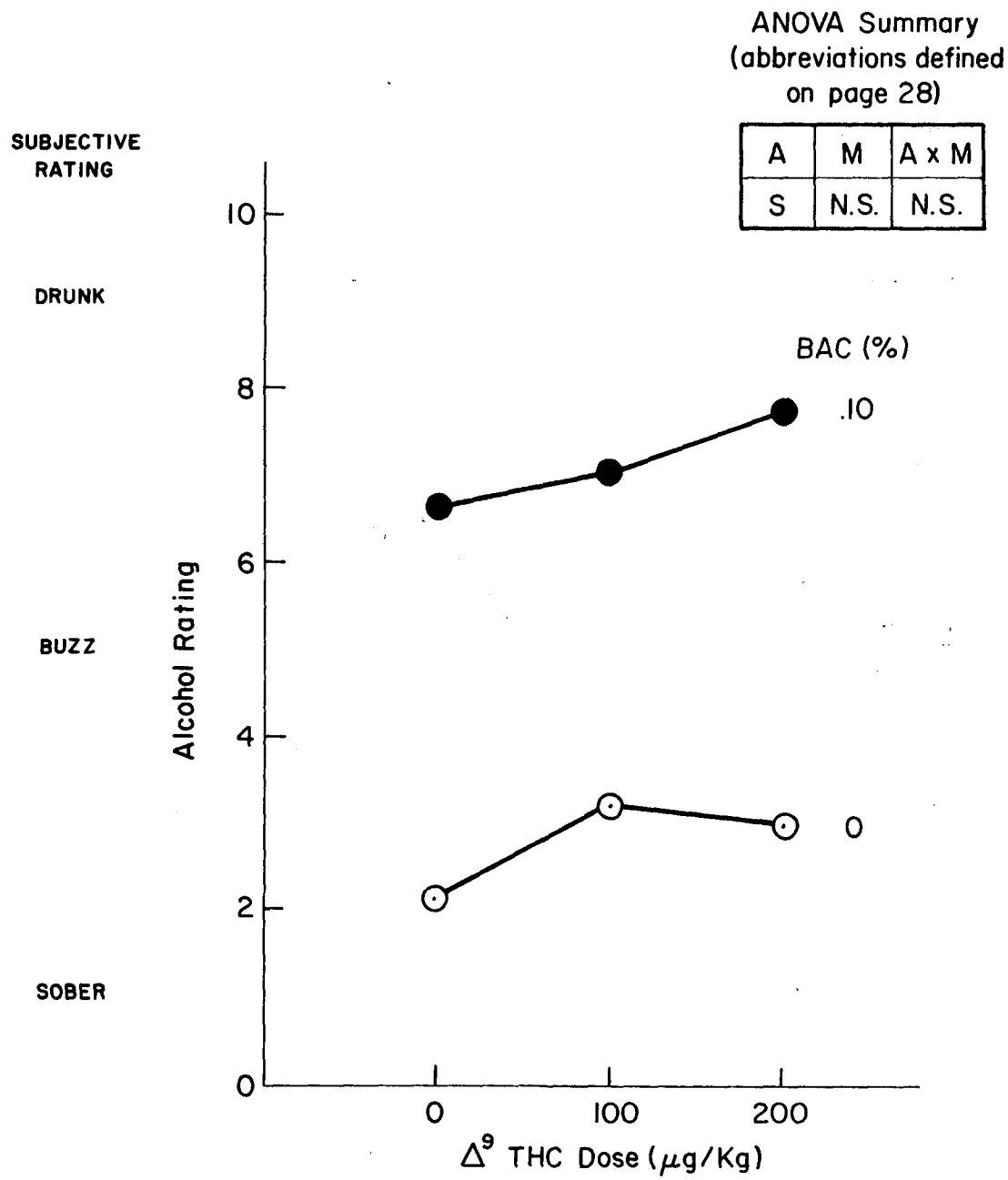

Figure 31. Alcohol Rating

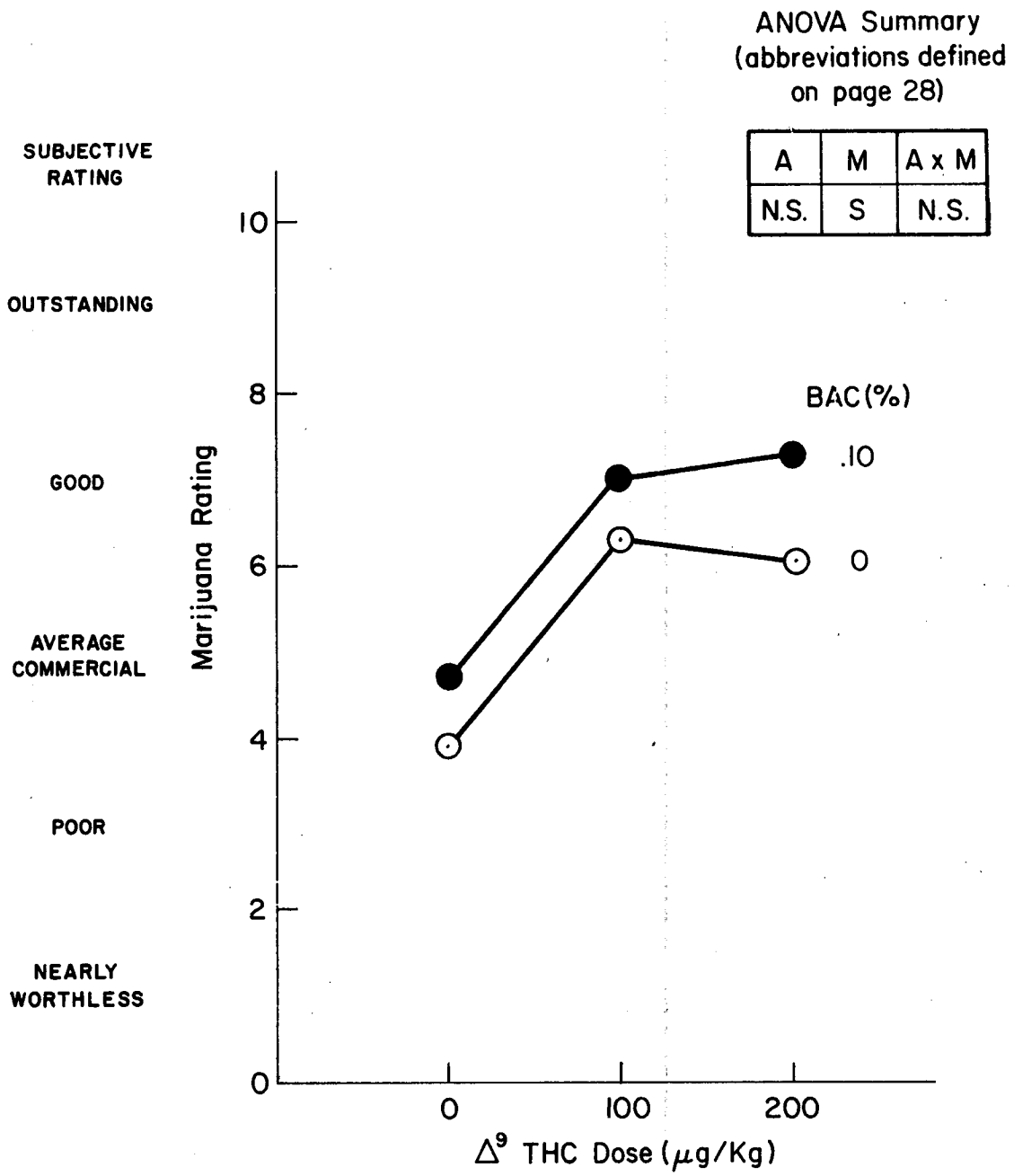

Figure 32. Marihuana Rating

ANOVA Summary
(abbreviations defined
on page 28)

A	M	A x M
N.S.	S	N.S.

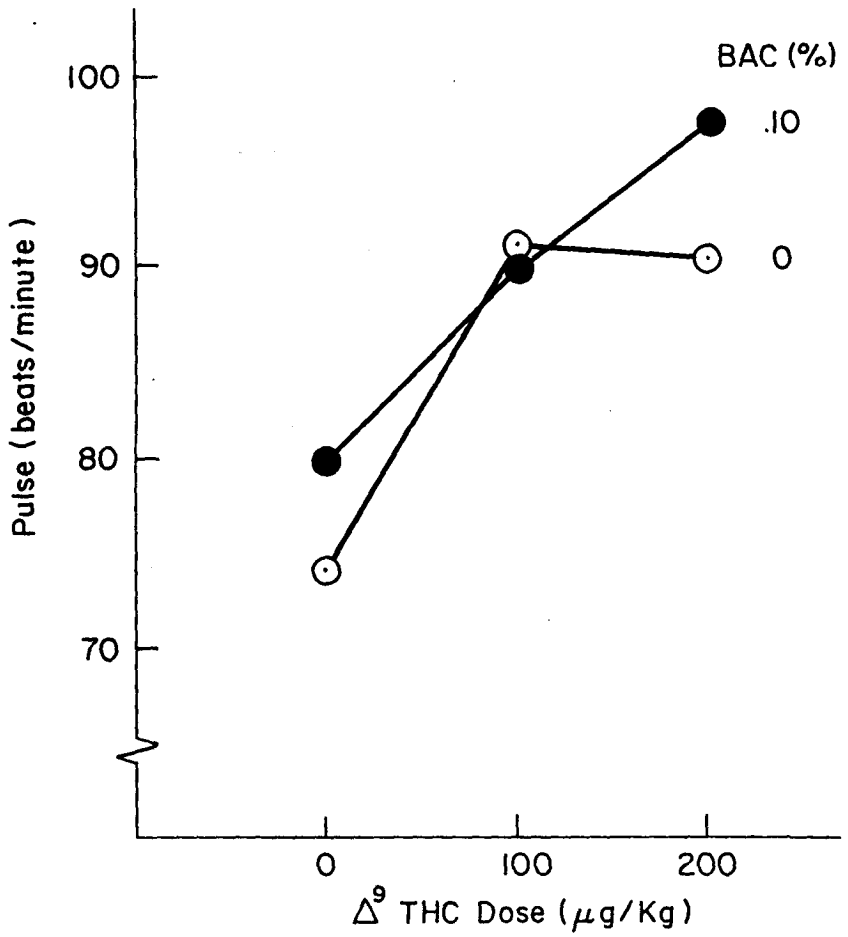

Figure 33. Pulse Rate as a Function of Dose

TABLE 4. STATISTICAL ANALYSIS SUMMARY

CLASS	MEASUREMENT	ALCOHOL EFFECTS	MARIHUANA EFFECTS	COMBINED EFFECTS
Scenario Performance (Traffic Safety)	Accidents	↑	NS	↑
	Tickets	NS	NS	NS
	Driving Time	NS	↑	NS
	Payoff	↓	NS	↓
Divided Attention Tracking Task	Speed	NS	↓	NS
	Speed Variability	NS	↑↓	NS
	Lane Position Variability	↑	NS	NS
	Sign Reaction Time	↑	NS	NS
	Reaction Time Variability	↑	NS	NS
Curve Control	Average Speed	NS	↓	NS
	Speed Variability	↑	NS	NS
Obstacle Avoidance	Average Speed	NS	↓	NS
	Speed Variability	↑	NS	↑
	Lane Deviation	↓	NS	NS
	Lane Deviation Variability	↑	NS	NS
Steering Control	Driver Aim Point	↑	NS	NS
	Heading Error	NS	NS	↑↓
	Uncorrelated Steering Activity (Signs)	↑	NS	NS
	Uncorrelated Steering Activity (No Signs)	↑	↑	NS
	Steering Peak (Mean Distance)	↓	NS	NS
	Steering Axis Crossing Dist.	↓	NS	NS
Driver Reaction	Alcohol Rating	↑	NS	NS
	Marihuana Rating	NS	↑	NS
	Heart Rate	NS	↑	NS

↑ = Increased ($p < 0.10$), ↓ = Decreased ($p < 0.10$),
↑↓ = Counteracting ($p < 0.10$), NS = Not Significant

Finally, we used manual control theory to point out steering control deficiencies.

In general we found that alcohol caused an increase in accidents, an increase in the driver's vehicle control variability, and an increase in reaction time. These results were consistent throughout the experimental tasks, and accounted for the majority of the observed driver impairment.

The alcohol results come as no surprise, as they are consistent with the results found in the extensive literature concerning alcohol effects on human performance.

The marihuana literature is nowhere near as complete, and thus direct comparisons are more difficult. The major result of the effect of marihuana on driving has been a decrease in speed, and this was our primary finding also. Sharma and Moskowitz (1972) found that marihuana caused a decrease in a persons ability to perform divided attention tasks. Our findings provide minimal support for this. The only marihuana impairment we observed, other than the speed reduction, was during the divided attention tracking task. During this task we observed effects on both speed variability and uncorrelated steering activity.

While there is still very little research on marihuana alone, the prior research on the combined effects of alcohol and marihuana is almost non-existent. To date only 3 prior studies have been conducted: Attwood, et. al., (1981), Sutton (1980), and Allen, Stein, and Hogue (1982; Phase I of this project). In all prior research, little was found to indicate any impairment due to combined effects. This project has come to the same basic conclusion, with one major exception. We found a combined effect that resulted in an increase in accidents, there is little to explain this finding in the intervening variables, but the fact that the major effect was found is an important result. While there is no way of knowing, it is possible that this result is due to the fact that this research has used combined alcohol and marihuana levels much greater than in any prior work.

SECTION V

CONCLUSIONS AND RECOMMENDATIONS

The experimental methodology has been discussed in Section III, and the results presented and discussed in Section IV. In this section we give a summary of the major findings of alcohol and marihuana on driving safety, and list recommendations for future research.

1. Conclusions

- Alcohol at a BAC of 0.10 percent impairs the drivers ability significantly and consistently. These impairments account for the majority of the observed impairment.

- Alcohol impairment is evidenced by an increase in accidents resulting from an increase in driver speed and steering control variability and an increase in reaction time.

- Marihuana doses of 100 and 200 μg Δ^9 THC/kg body weight do not lead to any consistent driver impairment. They do, however, lead to a general decrease in vehicle speed. Because of the relatively small absolute speed difference, these results may not be of practical significance, however.

- The combined effects of alcohol and marihuana at the highest dose combination increased accidents, a primary traffic safety issue.

- No adverse subject reactions were observed at any of the doseage combinations.

2. Recommendations

- Because of the findings concerning the 0.10 percent BAC plus 200 μg/kg Δ^9 THC dose we recommend that further study be conducted to validate and explain the increased accident rate. The measures tested in this experiment were unable to explain the accident increase, thus other driver/vehicle measures should also be examined.

- Any further research should include Δ^9 THC blood plasma concentrations as an independent variable. Enough blood should be drawn to allow for back-up plasma in the event of analysis difficulties.

- The major driver impairments observed were an increase in variability and reaction time. Countermeasures should address these impairments through road and vehicle designs that allow for these impairments. More importantly, drivers should be made aware of the impairing effects of alcohol, and the combination of alcohol and marihuana in an effort to reduce the number of drivers choosing the drive in an impaired state.

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APPENDIX A

DRIVING SIMULATION

A functional description of the driving simulator is illustrated in Fig. A-1. Control signals from the car cab (i.e., steering, accelerator, and brake) are fed to automobile equations of motion which are mechanized on an analog computer. These equations then drive the cab instruments and interactive display generator which presents road delineation cues via a CRT display. The equations of motion and roadway display generator have been described in some detail elsewhere (Allen, Hogge, and Schwartz, 1975; Allen, Hogge, and Schwartz, 1977).

The roadway display observed by the driver consisted of three components. The CRT image mentioned above was optically combined with two slide-projected images through a combining glass as shown in Fig. A-1. One slide image consisted of a sign projected through a zoom lens which was controlled to simulate apparent increasing sign size as the driver approached the sign. The other image was a fixed size horizon scene which provided a visual texture background for the sign images. Both the sign and horizon images were horizontally deflected by a servo-controlled mirror which was moved proportionally to vehicle heading consistent with the CRT delineation image. The resulting roadway display image viewed by the driver is shown in Fig. A-2.

The driving scenario or sequence of events encountered by the driver was controlled by a digital minicomputer as shown in Fig. A-2. The computer controlled road curvature, placement of "police" for detecting speeding violations (55 mph or 90 km/hr speed limit), and sign presentation. The sign slides were presented with a random access projector controlled by the minicomputer. Several different randomized versions of the scenario event sequence were stored in the minicomputer and could be called up from a keyboard control at the beginning of a run.

The minicomputer controlled the sign projector lens zoom ratio based on distance from the sign in order to achieve proper apparent sign size.

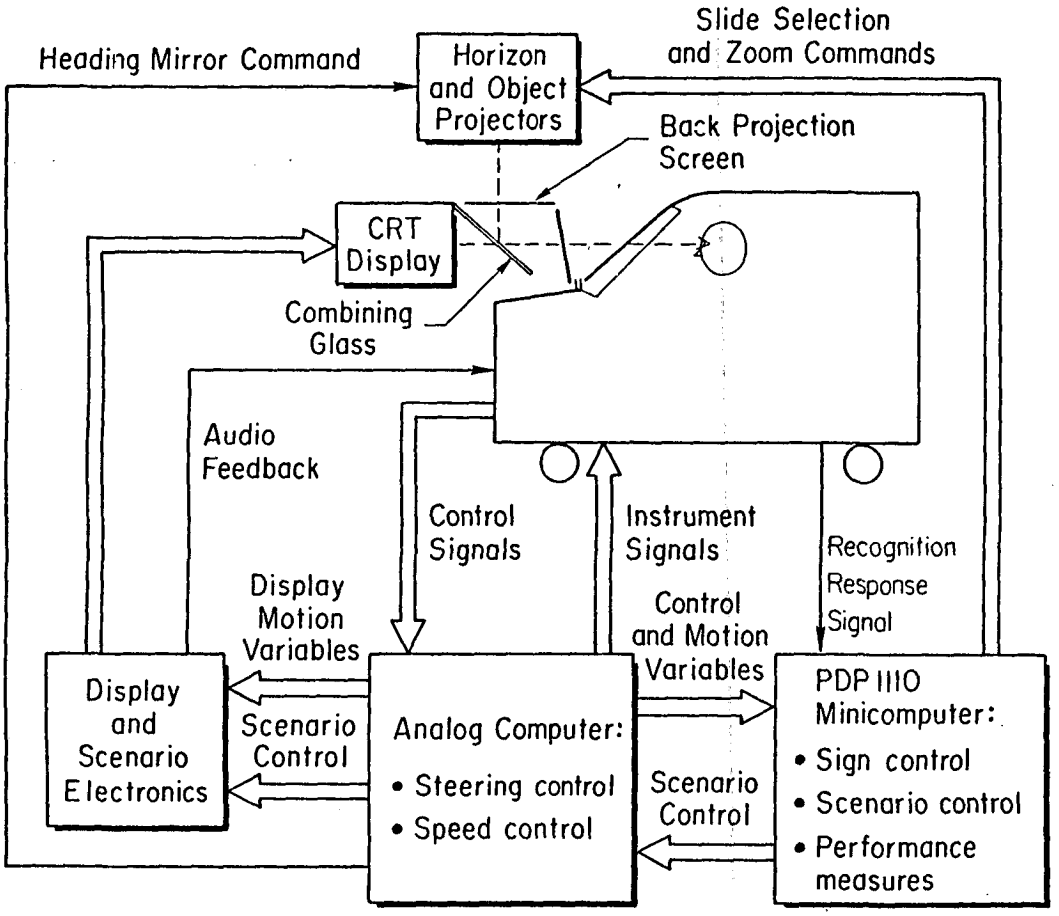
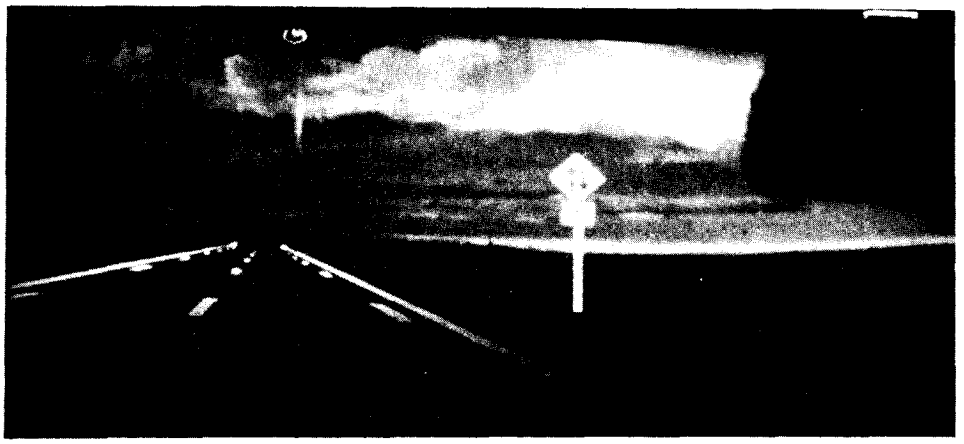


Figure A-1. Functional Block Diagram of Driving Simulator

a) Sign at 300 ft (91.4 m)

b) Sign at 150 ft (45.7 m)



c) Sign at 75 ft (22.9 m)

Figure A-2. Simulator Display as Viewed by the Driver Showing a Horizon Scene and a Sign at Various Locations Down the Road

The minicomputer also automatically computed performance measures and stored data on floppy disks. Performance measurement details are discussed in Section III and Appendix B of this report, and in the Phase I report on this project (Allen, Stein, and Hogue, 1982). The experimental data base was subsequently transferred to a larger computer where statistical analysis was performed.

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APPENDIX B

DRIVER CONTROL MODEL AND MEASUREMENTS

A. OVERALL BEHAVIORAL MODEL

A control feedback model of driver steering behavior is shown in Fig. B-1. This model relates primarily to the "control level" of driver steering performance. The Fig. B-1 model was actually developed for an FHWA delineation research program (Allen, O'Hanlon, et al., 1977) and has more recently been shown to agree with field test and simulation data (Allen, 1982a, Allen, 1982b). This model can give some insight into the effect of alcohol and marihuana on driver control behavior that is required for maintaining lane position and avoiding obstacles as discussed below.

In the Fig. B-1 model the driver bases his steering action (δ_{sw}) on his perception of lateral lane position (y), heading error (ψ_e) relative to the road alignment, and commanded curvature, C_c. Also, the model judges lane position error (y_e) from a nominally desired path (Allen, 1982b). Adequate perception of lane position, heading and road curvature are important, and past delineation research (Allen, O'Hanlon, et al., 1977) has shown that steering performance deteriorates when delineation visibility recedes much below 100 feet.

A further perceptual interpretation of the Fig. B-1 model is illustrated in Fig. B-2. Here we show the driver controlling to an aim point down the road. The aim point concept requires the driver to perceive only a single quantity, the aim point error (ψ_A), which replaces the separate perceptions of lane position and heading errors. The "aim point control" concept thus allows perceptual economy for the driver. A review of past driver control studies has shown measured equivalent aim point look-ahead distances within the range of 60-120 feet (Allen, 1982b). This range is consistent with past driver eye movement research that shows the driver looks down the road 100 feet or more (Mourant, 1970) and is also consistent with the delineation visibility work

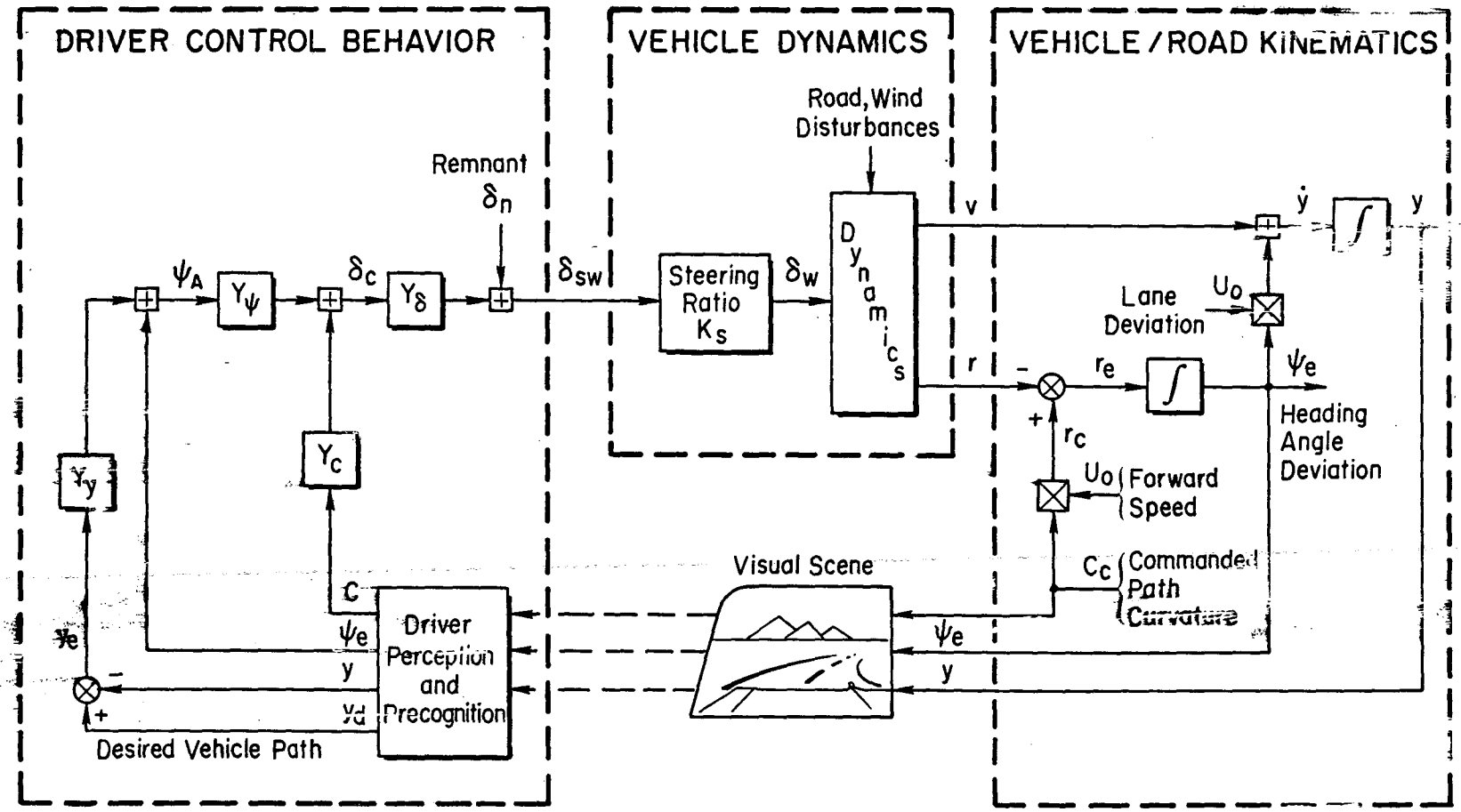

Figure B-1. Driver/Vehicle Steering Control Model

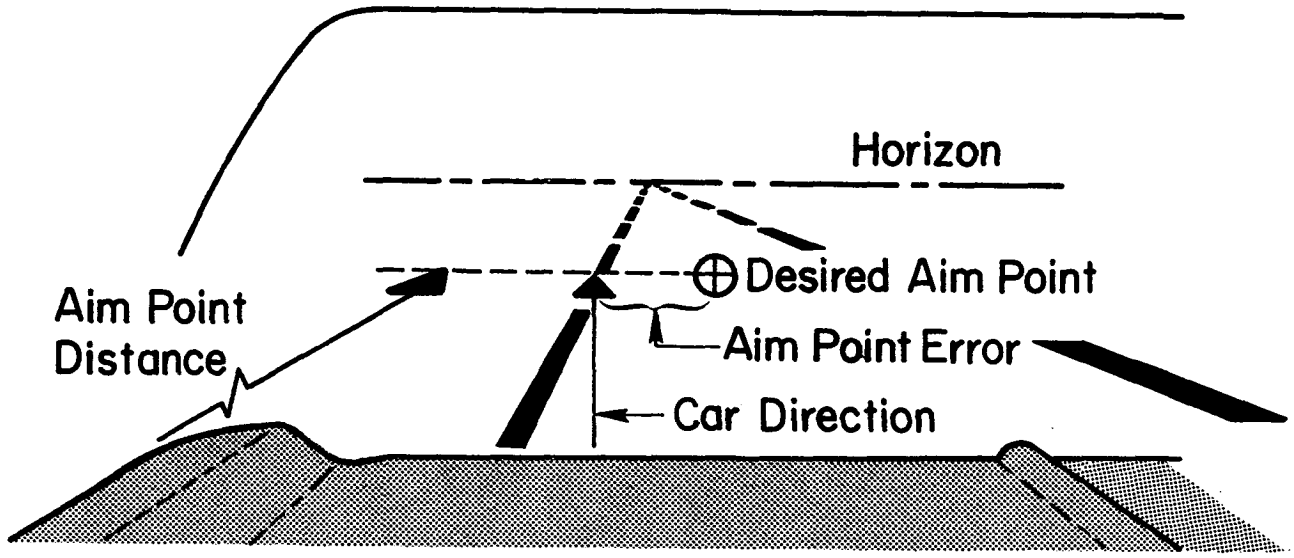

Figure B-2. Visual Perceptual Inputs for Driver Aim Point Control Law

mentioned above which has shown deteriorated steering performance for visibility ranges much below 100 feet (Allen, O'Hanlon, et al., 1977).

B. MODEL RESPONSE TO RANDOM INPUTS

Using the steering disturbance signal shown in Fig. B-1 as a system stimulus (δ_d), the driver's compensatory control behavior can be measured by describing function techniques described in McRuer, Weir, et al., 1975. The describing function can be fit with model parameters as discussed in Allen, 1982a. In the time domain these model parameters describe driver control actions as a delayed sum of two components:

$$\delta_w(t) = [y_e(t - \tau)K_y + \psi_e(t - \tau)]K_\psi$$

where

$\delta_w(t)$ = driver's wheel response

$y_e(t - \tau)$; $\psi_e(t - \tau)$ = time delayed lane position error and heading angle error respectively

τ = driver's visual motor time delay

K_y = driver gain or control weighting applied to lane position errors

K_ψ = driver gain or control weighting applied to angular errors with respect to an aim point ahead of the car

The gain K_y can actually be interpreted perceptually as the reciprocal of the distance to the effective control aim point as discussed above (Allen, O'Hanlon, et al., 1977; Allen, 1982b). Thus K_y^{-1} is the distance to the aim point as illustrated in Fig. B-2, and K_ψ is the gain or control weighting the driver applies to these aim point errors.

Normally, increasing K_y and K_ψ would imply better driver tracking performance. There is a limit to this effect, however, as the closed loop stability limit of the control system is approached. The system can then become quite oscillatory, with performance deterioration and potential loss of control.

A final control parameter that is of use in describing driver steering behavior is the percentage of remnant or noise in the driver's steering actions. Remnant is defined as the proportion of steering action that is linearly uncorrelated with the original system disturbance (in this case δ_d). Then by definition the remnant does not act to reduce the effect of the disturbance on system error performance, and in fact adds to the magnitude of system error. Impairments to driver behavior such as intoxication and reduced visibility have been shown to increase driver steering remnant in past studies (Allen, Jex, et al., 1975; Allen, O'Hanlon, et al., 1977 respectively).

C. TRANSIENT MANEUVERS

The Fig. B-1 model can also accommodate transient maneuvers such as the obstacle avoidance situations used in this experiment (Allen, 1982a). The obstacle avoidance tasks require the subject to steer to the left to move into the left lane, then steer to the right to return to the right lane. Some example steering and lane position time traces are shown in Fig. B-3 for a fixed obstacle encounter. Note that a characteristic "M" shaped steering profile is required for the subject to avoid the three obstacles in Fig. B-3. To achieve any precision at all during obstacle avoidance, the subject/driver must fairly carefully adhere to the example steering profiles illustrated in Fig. B-3. This requirement is consistent with the Fig. B-1 driver/vehicle model (Allen, 1982a).

Noting the above obstacle avoidance steering requirements, the simulator performance measurement computer was programmed to sample characteristic points in the steering and lane position profiles as illustrated in Fig. B-3. Ensemble averages and standard deviations of the amplitude and distance coordinates for each point were obtained over

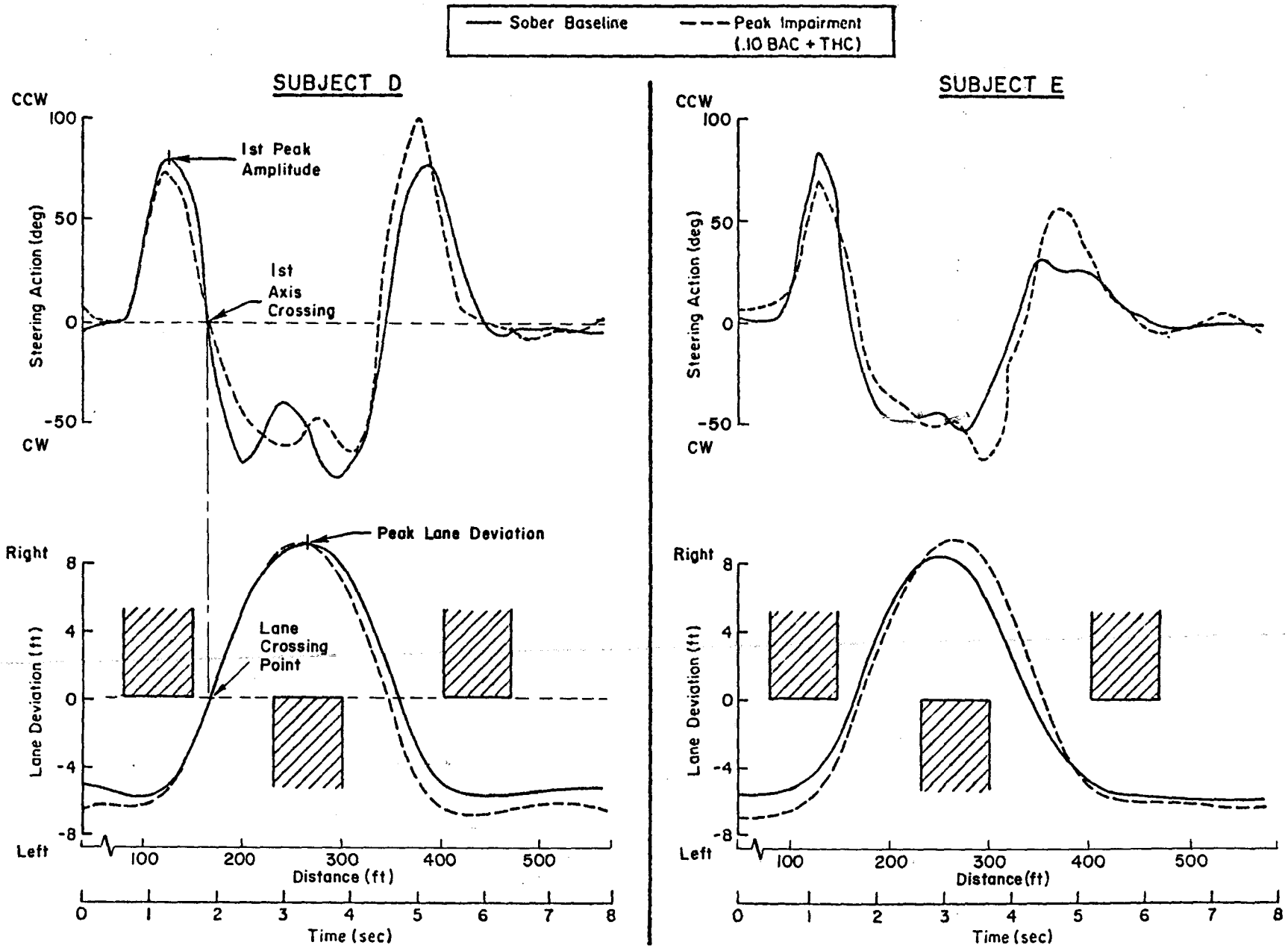

Figure B-3. Ensemble Average Time Responses for a Double Lane Change Maneuver Assuming an Average Speed of 46 mph (68 ft/sec)

several encounters within each run. The steering profile data then allows analyzing the precision with which steering actions are performed during obstacle encounters.

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APPENDIX C

EXCERPTED FROM:

THE EFFECTS OF MODERATE LEVELS OF ALCOHOL AND MARIHUANA, ALONE AND IN COMBINATION, ON CLOSED-COURSE DRIVING PERFORMANCE.

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INTRODUCTION

Over the past two decades, the use of marihuana and hashish, drugs derived from the cannabis sativa plant, has grown markedly among driving-aged Canadian adults. Le Dain (1972) published the results of a national survey which examined the non-medical use of drugs in Canada. The data indicated that the percentage of respondents who had used marihuana or hashish increased 5 times over a 3-year period between 1967 and 1970. The magnitude of the increase varied with the age of the respondents, but overall, in 1970, about 3.4 percent of the national household sample reported that they had used marihuana.

By 1978, even the 1970 figures had changed drastically. The results of a Gallup poll (Rootman, 1978) suggested that about 17.2 percent of the 1,057 adult householders questioned nationwide had used marihuana or hashish. In the 18-29 age range over 39 percent had used the drug. Of the total sample, 9.7 percent reported using marihuana or hashish in the past twelve months and 3.6 percent reported using it at least once per week in the past 30 days. Although the Gallup and Le Dain samples were not exactly the same, the difference between the 1970 and 1978 results suggests that marihuana use increased substantially among the Canadian public during the eight year period.

In the U.S., the data show similar trends though they were sampled from different populations. According to a 1971 survey conducted among U.S. college students, 41 percent of those interviewed had smoked marihuana at least once in the previous 12 months (Mortimer, 1976). The results of a similar study performed in 1975 at another U.S. college indicated that 51 percent of the respondents had used marihuana. Similar results were obtained by Waller et al. (1974) in a 1972 survey of freshmen and transfer students at a northern U.S. university. Their data revealed that about 49 percent of the respondents had used marihuana in the last year. The data also revealed that about 57 percent of those who admitted to smoking marihuana (27 percent of all respondents) reported driving soon after using the drug. Clearly, vehicles are being operated while their drivers are under the influence of marihuana, but the proportion of drivers under its influence and the extent of their intoxication are not known precisely.

Glauz and Blackburn (1975) reported the results of a roadside survey in which motorists were randomly stopped and asked to provide blood, urine and breath samples and lip swabs for drug analysis. Although the authors cautioned against placing too much trust in the analyses, they indicated that between three and nine percent of the drivers showed evidence of recent marihuana use. Additional data collected during the same study, but at different locations across the country, suggested that about 22 percent of the fatal drivers examined showed recent marihuana usage. Again, the data should be treated with caution.

Along the same lines Sterling-Smith (1974) reported a Boston study that examined the marihuana involvement of 267 drivers who were most responsible for accidents in which they killed pedestrians or were injured or killed themselves. Forty-six percent of this sample were alcohol involved and 54 percent of those under the influence of alcohol were known to be regular marihuana users. Of the 145 drivers that were not alcohol involved 38 percent were classed as regular marihuana users. Moreover, 16 percent of the total sample were known to have been smoking marihuana just before their crashes and many others were suspected. The above data suggest that marihuana might be a factor in motor vehicle crashes. But, as mentioned above, until good exposure data are available little can be inferred from post-crash data about the contribution of the drug to vehicle crashes.

In addition to evidence indicating significant marihuana use among the general Canadian population, there is some indication that marihuana is over-represented in traffic accidents. A recent study by Cimburra et al. (1980) reported the drugs present in a sample of drivers and pedestrians who were killed in Ontario between April 1, 1978 and March 31, 1979. The sample consisted of all fatalities over 14 years of age, on which both bloods and urines were available and who died within one-hour of the crash. Body fluids were screened for a number of licit and illicit drugs including alcohol and marihuana. Results indicated that alcohol was present in 41 percent of the victims. Moreover, cannabinoids could be detected in the urines of 12 percent of the sample and in 46 percent of those in whom drugs other than alcohol were detected. Sixty-nine percent of the sample who tested positive for cannabinoids had also consumed alcohol. The mean blood alcohol concentration (BAC) of this subset was approximately 150 milligrams alcohol per 100 millilitres blood (150 mg%). In 27 percent of the cannabis cases, THC was detected in blood, providing evidence of recent use.

In addition to epidemiological evidence, there is some suggestion that intoxication with marihuana can affect the human abilities related to driving in much the same way as with alcohol. Moskowitz (1976) reports an unpublished experiment in which subjects performed a tracking task under the influence of either marihuana, at dose rates of 200 micrograms (ug) delta-9, tetrahydrocannabinol (delta-9-THC) per kilogram (kg) body weight, or alcohol at BAC of 75 or 150 mg%. Results indicated that performance under the effects of marihuana intoxication fell to a level midway between the performance levels obtained at the moderate and high alcohol doses. But, the effects of marihuana do not always parallel those of alcohol. Sharma and Moskowitz (1973), for example, stu-

died the effects of both alcohol and marihuana on a vigilance or watchkeeping task. At dose rates of 200 ug, delta-9-THC/kg, vigilance performance declined over the entire one hour session. However, at dosages of 0.69 grams (gm) alcohol per kg body weight, vigilance performance was not affected.

Studies more directly related to driving have also demonstrated some effects under marihuana intoxication. Rafaelsen et al. (1973) conducted a simulator experiment which required subjects to simultaneously perform a tracking task while monitoring light signals. Performance after orally ingesting doses of 8, 12, or 16 milligrams (mg) delta-9-THC was compared with that after taking a 500 millilitre (ml) mixed drink containing 70 gm alcohol. Results indicated that discrete reponses to stop and start light signals increased significantly under the effects of the two larger doses of marihuana and under alcohol. Alcohol also caused a small increase in the number of gear changes made during the 'driving' portion of the procedure.

Ellingstad et al. (1973) compared the effects of marihuana intoxication with those of alcohol on laboratory tasks that simulated several aspects of a two-lane passing situation. Results indicated that doses of 11.25 mg and 22.5 mg THC adversely affected the accuracy with which subjects judged proper passing distances. But BACs of 50 and 100 mg% BAC did not affect passing judgements. Under marihuana, however, subjects did not exhibit the more risky behaviour that was evident under alcohol.

Moskowitz et al. (1976) conducted an experiment which required subjects to smoke marihuana cigarettes with controlled doses of 0, 50, 100 or 200 ug, delta-9-THC/kg and then 'drive' an automobile simulator over a 31-mile course. Data were recorded on the use of vehicle controls and from a signal detection task which was performed as the subjects operated the car. Results indicated that none of the measures derived from the manipulation of the automobile's controls showed any decrement from marihuana intoxication. However, detection responses did show a dose-related decrement.

A number of studies have examined the effects of marihuana intoxication on driving performance. Hansteen et al. (1976) conducted a closed-course driving experiment for the Le Dain Commission inquiry into the non-medical use of drugs. Subjects drove over a 1.1 mile course six times after smoking marihuana in doses of 21 and 88 ug, delta-9-THC/kg, or after taking alcohol to a BAC of 70 mg%. Increases were reported in the number of cones overturned in the slalom portion of the course for the high marihuana dose, but observers were unable to notice any increase in 'rough handling' behaviour due to marihuana. Alcohol, on the other hand, adversely affected both of the above performance measures.

In another road study, Klonoff (1974) had subjects perform closed-course manoeuvres and drive in live traffic after smoking marihuana cigarettes containing either 4.9 or 8.4 mg delta-9-THC. Results from a complex set of closed-course tasks showed some detrimental performance effects at the higher marihuana dose. In live traffic, the subjective data provided by license examiners suggested that marihuana could cause deterioration of performance in

judgement, care and concentration aspects of the task. But, the results were not conclusive since the performance of some subjects was judged to be improved after taking marihuana.

Smiley et al. (1974) compared the effects of five drug doses on several closed-course driving tasks. The doses included a placebo condition, alcohol at a BAC of 60 mg%, alcohol at a BAC of 60 mg% combined with three, 0.5 mg 'joints' of marihuana and alcohol at 60 mg% combined with either diazepam or diphenhydramine. Subjects performed the driving tasks once per day for five consecutive days. Each day they received one of the drug doses. Results indicated that the accuracy with which drivers were able to stop at a line adjacent to the traffic signal was significantly poorer under the alcohol condition. There was no reason to believe, however, that alcohol and marihuana together had any effect on stopping accuracy. In fact, with only one exception, alcohol and marihuana together had less adverse effect on each of the driving performance measures than alcohol alone. The one exception was a significant reduction in response times to a light that flashed at random times throughout the trial.

Casswell (1977) was one of the first researchers to report a driving study that examined the effects of moderate levels of marihuana and alcohol, given alone and in combination on several closed-course manoeuvres. However, drug doses were given at staggered intervals throughout the test period, so it is difficult to estimate precisely what the drug concentrations were at the time of test. Results indicated, nevertheless, that the effects of alcohol, both alone and in combination with marihuana, were similar to those reported by other researchers. Under alcohol, fine steering reversals decreased from the placebo level indicating a shift to more coarse steering corrections. Vehicle velocity tended to increase under alcohol and under the alcohol plus marihuana conditions and the lateral position of the vehicle in the roadway tended to become more variable. In contrast, under the effects of only marihuana the number of coarse steering corrections decreased along with the average vehicle speed. The author suggested that drivers under marihuana appeared to compensate for what they saw as the adverse effects of the drug by maintaining control effort and decreasing speeds thus reducing the rate of information processing required. In contrast, alcohol appeared to result in more risky behaviour.

Except for performance on some tasks that are reported to be representative of driving, there is no consistent evidence that normal social levels of marihuana seriously affect driving performance. There is some indication, however, that the effects of marihuana and alcohol are additive when taken together though the evidence is by no means clear. Considering the high proportion of people who report driving after taking marihuana and alcohol together (Waller et al., 1974), the problem deserves additional attention.

The experiment reported herein will compare the effects of alcohol and marihuana, alone and in combination, on driving performance in a number of closed-course tasks. The tasks that were employed are representative of routine driving and do not include slalom-type courses or other abnormal ma-

noeuvres. The techniques used to detect differences between drug conditions assume that driving is a complex, highly overlearned task that can best be described in terms of multivariate descriptors (Attwood, 1975).

In a previous experiment (Attwood et al. 1980), subjects performed similar tasks to those employed in this experiment when sober and when intoxicated to nominal blood alcohol concentrations of 40, 80, and 100 mg%. Information on control position and on vehicle parameters such as velocity and lane position were collected with an on-board, computer-based system. Both univariate and multivariate analyses were performed on the data. Results indicated that univariate analyses were unable to consistently discriminate between sober and drunk (80 mg% BAC) performance. Multivariate analyses, however, produced linear weighted functions of up to four different performance variables that were able to discriminate between sober and drunk driving performance. Moreover, on two of the tasks, the functions were able to correctly classify all drivers as intoxicated from the performance data obtained at the 100 mg% BAC.

Similar results were obtained from a second study that compared the driving performance under a 90 mg% BAC condition with that obtained after ingestion of 10 mg diazepam (Attwood et al, in preparation).

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APPENDIX D

SUBJECT FORMS

PERSONAL DATA

Name _____ Telephone No(s) _____

Address _____

Sex _____ Age _____ Birthdate _____ Height _____ Weight _____

Code _____

TELEPHONE SCREENING SHEET FOR POTENTIAL ALCOHOL/MARIHUANA TEST SUBJECTS

Date _____ Time _____ Code Number _____

Source _____ Accepted/Rejected _____

Have you every been involved in an alcohol or drug related rehabilitation program? _____

Present _____ Past _____

DRIVING DATA

Do you drive a car? Y / N How long have you been driving? _____

Do you have a current driver's license? Y / N

Have you ever had an alcohol or drug related arrest? Y / N Explain: _____

PHYSICAL CONDITION

Are you in good health? Y / N If no, explain _____

_____

_____

Do you have full use of both arms and legs? Y / N

Have you ever had ...	Yes	No
Diabetes		
Hepatitis		
Liver disease		
Kidney disease		
Heart trouble		
Convulsions		
Epilepsy		
Ulcers		
High or low blood pressure		
Respiratory problems . . .		

If the answer to any of these is yes, explain

_____

_____

_____

_____

Are you currently taking any drugs or medication? Y / N If yes, explain _____

_____

_____

Are you colorblind? Y / N Do you have full vision in both eyes? Y / N If no, explain

_____

Do you wear glasses or contact lenses? Y / N if yes, which? _____

If glasses, how well can you see without your glasses? _____

Code Number _____

ALCOHOL AND DRUG DATA

What is your usual drink? _____

If not hard liquor, do you drink hard liquor (whiskey, gin, etc.)? _____

How much (of what) do you usually have when you drink? _____

What is the most you ever drink? _____

After drinking have you ever experienced:

Nausea _____ Vomiting _____ Dizziness _____

If yes, last time? _____ How often? _____

Have you ever had problems in school or on the job because of your alcohol or drug use? _____

How often do you smoke marihuana? Times/week _____ Joints/use _____

How long have you used marihuana? _____

Last use? _____

After using marihuana have you ever experienced:

Nausea _____ Vomiting _____ Dizziness _____

If yes, last time? _____ How often? _____

Have you ever used, when not prescribed by a doctor:

	Yes	No	Last Use	How Often
Cocaine				
Hallucinogens (LSD, peyote, mescaline)				
Barbiturates (Secanol, "reds," "downers")				
Amphetamines (Methadrine, Dexadrine, "speed")				
Tranquilizers (Valium, Quaaludes)				
Opiates (heroin, opium, synthetics such as methadone)				
Glue or aerosols				
PCP or Angel Dust				
Other drugs (What? _____)				

Has your alcohol or drug use caused family problems? Past _____ Present _____

AVAILABILITY

If you are asked to take part in our alcohol/marihuana study, when would you be available? _____

Specifically, on what days of the week, and for what times on those days, are you available?
Fill in table: ✔ = available; "no," "works," etc., if not available.)

	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Morning							
Afternoon							
Evening							

How long will you be availabe on this schedule (specific dates)? _____

CONFIDENTIAL MEDICAL HISTORY

Code _____

Age _____ Birth Date: Month Day Year _____ Sex _____

When is the last time you had a complete medical check-up? Month_____ Year_____
My general state of health now is: Excellent_____ Good_____ Fair_____ Poor_____ Very Po_____

Name and address of your family physician or clinic:

_____

_____

_____

FAMILY HISTORY

RELATION	AGE	STATE OF HEALTH	IF DEAD, CAUSE OF DEATH	AGE AT DEATH
FATHER				
MOTHER				
BROTHERS				
SISTERS				
HUSBAND OR WIFE				
CHILDREN				

Do you know of any blood relative who has or had: (Circle and give relationship)

Cancer_____
Allergy_____
Gout_____
Diabetes_____
Anemia_____
Obesity_____
Alcoholism_____
Migraine_____
Asthma_____
Glaucoma_____
Heart disease from birth_____
Birth defect_____

Arthritis_____
Hay fever_____
Bleeding tendency_____
Suicide_____
Colitis_____
High blood pressure_____
Rheumatism_____
Drug Addiction_____
Convulsions_____

Epilepsy_____
Goiter(thyroid)_____
Rheumatic heart_____
Tuberculosis_____
Nervous breakdown_____
Stomach ulcers_____
Kidney disease_____
Sickle cell anemia_____
Stroke_____
Duodenal ulcer_____
Leukemia_____
Low blood sugar_____

CHILDHOOD ILLNESS (BIRTH THROUGH AGE SEVENTEEN)

Give the age at which you had any of the following illnesses.

____Eczema
____Chickenpox
____10 day measles
____German measles (Rubella)
____Mumps
____Polio
____Rheumatic fever
____Heart murmur
____Asthma
____Meningitis
____Scarlet fever
____Whooping cough
____Pneumonia
____Infection of mastoid bone
____Bronchitis
____Blood transfusion

Other childhood illnesses not listed include:_____

Please give the age at which you had any of the following illnesses.

____Tuberculosis
____Pneumonia
____Rheumatic fever
____Gonorrhea
____Syphilis
____Eye disease
____Asthma
____Rheumatism
____Bleeding tendency
____Bladder trouble
____Mononucleosis
____High blood pressure
____Blood transfusion
____Blood clots in leg
____Varicose veins
____Yellow jaundice
____Cataract
____Allergies
____Epilepsy
____Anemia
____Gout
____Stomach ulcer
____Thyroid disease
____Pancreatitis
____Liver disease
____Diverticulosis
____Hernia
____Emphysema
____Malaria
____Glaucoma
____Arthritis
____Cancer or tumor
____Kidney trouble
____Stroke
____Duodenal ulcer
____Nervous breakdown

MEDICATIONS

Are you presently taking any of the following medications? (Circle)

Aspirin, bufferin or anacin	yes	no	Tranquilizers	yes	no
Blood pressure pills	yes	no	Diet pills	yes	no
Cortisone	yes	no	Dilantin	yes	no
Cough medicine	yes	no	Antibiotics	yes	no
Digitalis	yes	no	Birth control pills	yes	no
Glaucoma medicine	yes	no	Water pills (Diuretics)	yes	no
Hormones	yes	no	Blood thinning medication	yes	no
Insulin or diabetes pills	yes	no	Barbiturates	yes	no
Iron or poor blood medications	yes	no	Amphetamines	yes	no
Laxatives	yes	no	Codeine, morphine, etc.	yes	no
Sleeping pills	yes	no	Breathing medicines	yes	no
Thyroid medication	yes	no	Any injections	yes	no
Heart pills	yes	no			

Write the names of drugs (prescribed and/or unprescribed) that you are presently taking.

1._____
2._____
3._____
4._____
5._____
6._____
7._____
8._____

ALLERGIES AND SENSITIVITIES

Name any drugs to which you are allergic
1. _____
2. _____
3. _____
4. _____

Are you allergic to dust or pollens? yes no
If yes, have you been skin tested? yes no

Are there any chemicals, fabrics, soaps, etc. which cause you to itch or break out in a rash? yes no
If yes, please name them.
1. _____
2. _____

Are you allergic to surgical tape (adhesive tape)? yes no

Have you ever had an allergic reaction that required a doctor to give you a shot or administer oxygen? yes no
If yes, what caused it?
1. _____
2. _____

Do allergies tend to run in your family? yes no

Have you ever had an allergic reaction to any of the following medicines? (Please check)

____Penicillin
____Sulfa drugs
____Tetracycline
____Erythromycin
____Heart pills
____Blood pressure pills
____Antibiotics
____Water pills
____Sleeping pills
____Aspirin
____Codeine or morphine
____Eye drops
____Ear drops
____Tranquillizers
____Anti-depressants
____Diabetes medicine
____Birth control pills
____Barbiturates

PERSONAL HABITS

Did you ever smoke tobacco?	yes no
If yes, for how many years	____
Half pack or more per day	yes no
Do you drink alcoholic beverages?	yes no
If yes, do you drink:	
3 or more glasses of wine per day?	yes no
3 or more glasses of beer per day?	yes no
3 or more cocktails a day?	yes no
Does your husband/wife think you drink too much?	yes no
Do you think your husband/wife drinks too much?	yes no
Do you sometimes drink alcoholic beverages in the morning?	yes no
Do you sometimes get drunk on work days?	yes no
Do you brush teeth daily?	yes no
Do you use a water pik?	yes no
Do you use dental floss?	yes no
Do you drink more than six cups of coffee per day?	yes no

BLEEDING AND TRANSFUSION HISTORY

	(CIRCLE)	
Have you ever received a blood or plasma transfusion?	yes	no
Do you have a tendency to bleed easily?	yes	no
Have you had more than one nose bleed per month lasting longer than 10 minutes since you were seventeen?	yes	no
Do you often develop bruises larger than 1 inch in diameter?	yes	no
Have you ever had bleeding into any of your joints?	yes	no
Have you bled more than 3 days after a tooth extraction?	yes	no
Have you bled for more than 3 days after tonsillectomy?	yes	no
Does any blood relation have a severe bleeding problem or hemophillia?	yes	no

SERIOUS ILLNESSES, - SURGERY

Write in the names of any diseases you have had which required hospitalization:

1. _____ year _____

2. _____ year _____

3. _____ year _____

4. _____ year _____

5. _____ year _____

Have you ever had a surgical operation? yes no
If yes, write in dates next to type of operation.

____Appendix
____Gallbladder
____Stomach
____Kidney
____Tonsils
For Men____Prostate

____Colon (large intestine)
____Thyroid
____Breast
____Rupture (hernia)
____Varicose veins
For Women_____womb removal (hysterectomy)

Have you ever had a serious accident (broken bones, etc.)? (CIRCLE) yes no
If yes, describe injury below

1. _____

2. _____

3. _____

Write in the names of any serious illness you have had which did not require hospitalization

1. _____

2. _____

3. _____

4. _____

PRESENT COMPLAINTS AND CONDITIONS (PLEASE CHECK)

GENERAL
____Fever
____Chills
____Night sweats
____Weight change (1 year)
____Syphilis or positive blood test
____Loss of appetite
____Lack of exercise
____Fatigue
____Constant hunger
____Armpit swelling
____Groin swelling
____Nail biting

SKIN
____Abcesses
____Infected veins
____Nail hemorrages
____Skin rash
____Itching
____Lumps or growths
____Changes in color
____Any other skin condition

HEAD
____Fainting
____Dizziness
____Seizures
____Blackouts
____Sinus trouble
____Migraine headaches
____Tension headaches
____Vertex
____Temples
____Occipital
____Headache with nausea

EYES
____Wear glasses
____Double vision
____Itching or pain
____Eye trouble
____See halos
____Color blind
____Weak eye muscles
____Loss of vision

EARS
____Hearing trouble
____Ringing in ears
____Motion sickness
____Discharge from ears
____Pain in ears
____Deafness

NOSE
____Nosebleeds
____Running nose
____Congested nose
____Hay fever
____Broken nose
____Use nose sprays often

MOUTH
____Dental problems
____Swellings on gums or jaws
____Wear dentures
____Sore tongue
____Gums bleed
____Taste changes
____Mouth dry
Last saw dentist_____

THROAT
____Hoarseness
____Sore throat
____Trouble swallowing
____Post nasal drip

NECK
____Thyroid trouble
____Neck pain

LUNGS-HEART
____Frequent cough
____Cough blood
____Shortness of breath
____Heart disease
____Irregular heart beat
____Cough mucous or pus
____History of endocarditis
____Heart murmur
____Chest pain with exercise or hard work
____Pain in calf when walking
____Fainting spells
____History of tuberculosis
____Ankle swelling
____Diabetes
____Have had heart attack
____Have had an infection of my heart
____Chest pain after heavy meal
____Palpitations
____Sleep on two or more pillows
____Chest pain in cold weather
____Chest pain helped by nitroglycerin
____Chest pain during sexual intercourse
____Chest pain that radiates to neck or one
____Ankles swollen in the morning
____Ankles swollen at the end of day

LUNG-HEART (CONTINUED)

____Ever have blood clot in the lung
____Leg cramps at rest
____Leg cramps at night when in bed
____Were you once told your heart was enlarged
____Coughed up blood in the last 6 months
____Are you bothered by your heart beating very fast at times
____Frequent chest colds
____How many colds this year____
____Trouble breathing

GASTROINTESTINAL

____Eat alot of fatty or fried food
____Eat alot of vegetables and salads
____Alot of belching
____Have an ulcer
____Which has bled____
____Which required surgery____
____Lost weight recently (more than ten pounds)

HAVE YOU RECENTLY HAD STOMACH PAIN WHICH: (CHECK)

____Occurs 1-2 hours after a meal
____Is caused by fried or fatty foods
____Awakens you at night
____Is relieved by antacids
____Is relieved by milk or eating
____Is relieved by a bowel movement
____Occurs while eating
____Occurs immediately after eating
____Loss of appetite
____I had yellow jaundice
____I had pancreatitis
____I have cirrhosis of liver

IF YOU HAVE HAD A CHANGE IN BOWEL HABITS RECENTLY, ANSWER THE FOLLOWING:

____Crampy pain in abdomen
____Alternating diarrhea and constipation
____Pain during or after bowel movement
____Mucous in the stool
____Red blood mixed with stool
____Red blood covering stool
____Black tarry stools
____Require use of enemas or laxatives
____Have colitis
____Brownish urine
____Bloated after eating

KIDNEYS, BLADDER, PROSTATE

____Pain on urination
____Kidney trouble
____Bladder trouble
____Prostate trouble (men only)
____Blood in urine

KIDNEY, BLADDER, PROSTATE (CONTINUED)

____Pus in your urine
____Protein in urine
____Episode of blood in urine
____Penile discharge (men only)
____Get up at night to urinate
____Ever had kidney stones
____Told you had a stricture of urethra (men only)
____Hernia or rupture
____Trouble holding urine
____Trouble starting urine
____Urine stream is weak

MUSCULOSKELETAL SYSTEM
(Have you had recently)

____Low back pain
____Mid back pain
____Upper back pain
____If so, how long?____
____Arthritis or rheumatism
____Foot trouble
____Stiff hands in the morning
____Varicose veins
____Phlebitis or inflammed leg veins
____Your hands turning bluish in cold weather
____Have pain in joints or muscles

WOMEN ONLY
(Have you had recently)

____Irregular menstrual periods
____Painful menstrual periods
____Heavier menstrual periods
____Bleeding between periods
____Feel bloated or moody before period
____Have had infection in tubes
____Been through menopause
____Pap smear in last year
____Vaginal bleeding since menopause
(Skip if does not apply)
____Number of pregnancies
____Number of miscarriages
____Number of still births
____Number of abortions
____Number of cesarean operations
____Ever have a blue baby
____Ever have a premature baby

Method of birth control I use now is: (CIRCLE) Rhythm, IUD, Foam or jelly, pills, shots, mate uses rubbers, diaphragm

Write in the date of your last period

_____

CENTRAL NERVOUS SYSTEM

Do you have headaches which are:

____Like a tight band around your head
____Usually occur in the evening
____Usually in the back of the head
____Usually pounding
____Usually pressure
____Usually on one side
____Make you sick or nauseated
____Usually on the top of your head
____Preceeded by flashing lights or loss of vision
____Which aspirins help usually
____That seemed to be caused by certain foods
____Are you caused by sinus trouble
____Any fainting spells
____Any history of seizures
____Ever lost consciousness due to a drug or medicine
____Hands shake for no apparent reason
____Have numbness or tingling feeling often in hands and/or feet
____Any unusual weakness in your arms or legs
____Ever hallucinated
____Ever seen a psychiatrist
____Ever have a stroke
____Has your handwriting changed lately
____Are you depressed
____Are you nervous
____Are you bored
____Any trouble sleeping
____Take pills to get to sleep
____Have narcolepsy
____Often have nightmares?
____Ever sleep walk
____Can't keep awake during the day
____Awaken rested in the morning
____Wake up very early in the morning and can't get back to sleep
____Requiring more sleep lately
____Requiring less sleep lately
____Number of hours I sleep at night

NUTRITION

____Take vitamins
____On a special diet
____Don't eat well
____Eat alot but don't gain
____Am a vegetarian
____Eat a fair amount of fruit
____Eat a fair amount of vegetables
____Eat very little fruits or vegetables
____Drink alot of soda pops
____Eat alot of candy
____Love fatty and fried foods
____Certain foods make me ill
____Have hypoglycemia

I gained ____ pounds in last year
I lost ____ pounds in last year
What is your favorite food_____

_____

What is your favorite beverage

_____

How many meals do you eat a day_____
How many snacks_____
Do you want to gain or lose weight

_____

DRUG HISTORY

Have you ever used without a prescription:

			Last Time	How Often
Hallucinogens (LSD, mescaline, peyote)	Yes	No		
Barbiturates (Secanol, "reds, "yellows")	Yes	No		
Tranquilizers (Valium, librium)	Yes	No		
Amphetamines (Methadrine, dexadrine, "speed", "whites")	Yes	No		
Opiates (Heroin, opium, methadone)	Yes	No		
Cocaine	Yes	No		
Amyl Nitrate	Yes	No		
Glue or Aerosols	Yes	No		
Other Drugs (what_____)	Yes	No		

INJECTION HISTORY (CIRCLE)

Have you injected drugs?	yes no (IF "NO" GO TO THE NEXT PAGE).
Intravenously?	yes no
In the muscle?	yes no
Skin pop?	yes no
If you have injected drugs which method do you prefer?	_____
Do you always use a sterile outfit?	yes no
Do you think dirty needles cause physical illness?	yes no
Do you only use a needle once and then discard it?	yes no
Do you share your needle with your friends sometimes?	yes no
Do you always sterilize your outfit before injecting?	yes no

If no, what percentage of the time_____%

Please describe below the method you use to make sure that things are sterile

_____

_____

_____

_____

_____

_____

Please describe your technique for cooking your dope. (How long, etc.)

_____

_____

_____

_____

_____

OCCUPATION RELATED HISTORY

(CIRCLE)

Have you worked in, or been in a place, in the past year, where you:

Often or every day breathed dust from sandblasting, grinding or drilling of rock or coal; or dust, silica, or sand?	yes	no
Have you worked or been in a place, in the past year, where you were often exposed to x-rays or radioactivity or radiation of any kind?	yes	no
Have you been in, or worked in, a place where you were often or daily around plastic or resin fumes?	yes	no
Have you often, in the past year, used or worked with insect or plant sprays, or rat poisons?	yes	no

IMMUNIZATIONS AND VACCINATIONS

In the past five years have you had:	yes	no
A tetanus (lockjaw) booster shot or series?	yes	no
A smallpox vaccination?	yes	no
A diphtheria booster shot or series?	yes	no
All three polio vaccinations by mouth?	yes	no
Measles immunization?	yes	no
Mumps immunization?	yes	no
Gamma globulin shot?	yes	no

The foregoing statements and answers are complete, true, and correctly recorded.

Dated at _____, California on _____ 1980

_____ _____

Legal Signature of Proposed Test Subject Witness

DIET INSTRUCTIONS FOR BLOOD TESTING

1. For 3 days prior to your testing day eat the following diet. This diet is designed to provide the proper amounts of food needed to obtain accurate test results. It is very important you eat at least the amounts shown. You may add to the diet any other foods you desire. Snacks are permitted.

2. The night before your test, and the morning of your test, eat and drink nothing but water after your evening meal (8:00 P.M.).

BREAKFAST:

Cereal, 1/2 cup (cooked or dry)
Milk, 1 cup
Sugar, 2 tbsp.
Bread, white, 2 slices

LUNCH AND DINNER:

Meat, cheese, or egg sandwiches, 2
Fruit
Cake or cookies
Candy bar

-OR-

Meat
Potato, 1 medium
Bread, white, 2 slices
Vegetable, 1/2 cup, cooked
Pie or cake
Sugar, 2 tbsp.

MEDICAL AUTHORIZATION

TO WHOM IT MAY CONCERN:

The undersigned hereby authorizes SYSTEMS TECHNOLOGY, INC. ("STI") to employ and consult for and on my behalf duly licensed medical personnel and/or medical facilities for the treatment of any condition resulting from or occurring during or in connection with my participation in tests or experiments conducted by STI. This authorization is to be used in the event I am unable to give the necessary consent to medical treatment due to my physical or psychological condition.

DATED: _____

_____
Signed

INFORMED CONSENT FORM

Please read the following carefully.

The experiment in which you will participate is a investigation of the effects of alcohol and marihuana, separately and in combination, upon performance in a driving simulator. At each session you will be asked to drink some liquid and smoke a cigarette. The liquid which you will be asked to drink may or may not contain alcohol. If it does contain alcohol, the maximum dose will be approximately 0.9 grams alcohol per kilogram body weight or about 6 ounces of whiskey for an average weight individual. Past experience with such doses, given at the rate we suggest for drinking, has usually produced no difficulties, although some subjects have occasionally experienced temporary discomfort. It should be noted that long-term use of large quantities of alcohol can lead to a variety of problems including alcoholism, liver and heart disease, and emotional problems.

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

You are cautioned that because the combined effects of the above dosages of alcohol and marihuana are not completely understood, you should not drive UNTIL THE DAY FOLLOWING THE EXPERIMENT.

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

No combination of alcohol and marihuana will be greater than an alcohol dose of roughly 0.9 grams alcohol per kilogram body weight and a marihuana dose of 200 micrograms delta-9 THC per kilogram body weight. While there has been only limited research in the combined administration of these two drugs, the few studies performed have reported no special problems of discomfort to the subjects.

The experiment in which you will participate will be directly supervised by our research psychologist Anthony C. Stein. If any problem related to the experiment should arise which you or the experimenters feel requires assistance by a physician, Neil Fond, M.D., or some other medical doctor will be available.

You will be given a list of persons to contact at any time after you leave our premises for assistance should you feel any discomfort.

It will be necessary for you to observe the instructions given to you pertaining to the experiment. Your participation will involve at least 10 hours/session and you should not make appointments which will require your presence until that time has elapsed or until the experimenter discharges you.

Our understanding is that participants are immune from prosecution for using marihuana in this experiment. The data obtained from the investigation may be used for medical and other scientific purposes and may be made available for publication, but the identity of the subjects will not be revealed. You will be paid, but participation in the experiment cannot be expected to benefit you as an individual beyond the payment which you will receive. You will be free to withdraw from the experiment at any time without prejudice. If you have any questions, please feel free to ask them before or after you consent to participate.

I have read the foregoing information and received a copy.

Subject	Date
Witness	Date