DATE: July 23, 1969

TO: Members of the Seminar
Undergraduate Special on Drugs and Society

FROM: David Dorosin, M.D.

SUBJECT:

Bob Hunter

I apologize for not getting your grades and papers back to your earlier. I hope it hasn't been too great an inconvenience.

Have a very good summer.

A PILOT STUDY
OF
THE EFFECTS OF MARIHUANA
ON
DRIVING ABILITY

by

Robert Hunter

for

Drug Use, Users, and Society

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INTRODUCTION

Why investigate the effects of marihuana on driving ability?

Despite the incredibly harsh penalties for marihuana use, more and more Americans are accepting "grass" as a pleasant and seemingly harmless means of intoxication. The mushrooming use of marihuana by students, blue collar workers, and many professional people suggests that President Nixon's "silent majority", the great middle class, is beginning to "turn on". This interesting phenomenon has several implications. The first is that the combination of harsh penalties and social acceptance has forced many humane law-enforcement officers to "look the other way" when they discover its being used. If marihuana use does adversely affect driving ability, then are not the harsh laws indirectly endangering lives?

Another implication of this phenomenon is that the breakdown of the myths of the "evils" of marihuana could possibly lead to its legalization. This possibility alone should be enough to stimulate research on the effects of marihuana on driving ability by those professions involved in traffic safety, namely engineering and medicine. Yet another implication is that hundreds and maybe even thousands of users are very possibly driving "under the influence" in America right now. Should not the facts of the effects of marihuana use on driving ability be made known at least to them?

SCOPE

The scope of this investigation will be severely limited in that no actual experimentation will be done. One definite aim, however, is to stimulate such research. This report consists of four parts. The first is a fairly simplified, theoretical analysis of the process of driving. It attempts to answer the questions: What are the critical tasks of driving? What are the critical faculties needed to perform these tasks? The second part of the report lists and discusses the effects of marihuana on these isolated faculties. To clarify some of these effects and to give the reader a fairly well established frame of reference, the effects of marihuana will be compared to those of our national drug, alcohol. The third part consists of the design of an experimental procedure to test the effects of marihuana on driving ability. The fourth part contains recommendations concerning the medico-legal problem of marihuana intoxication and driving.

PART I - ANALYSIS OF THE DRIVING PROCESS

To study the process of driving is to be aware that it is a beautifully complicated phenomenon. The ability to drive consists of much more than accomplishing certain tasks: the whole consists of parts in relationship. Some simplication, however, is necessary for description, if not for understanding. To this end the following idealized model of the driving process was developed.

CRITICAL TASKS

The successful completion of the driving process involves perception of stimuli relevent to driving, decisions concerning these perceptions, and actions on these decisions. These are the critical tasks of driving. (1)

and of about 10 million other activities; how is driving different from/similar to others?

CRITICAL FACULTIES

Some of the measurable faculties involved in perception are the following: attention, depth perception (distance judgment), glare tolerance, visual acuity, hearing, equilibration, and sense of time.

Some of the measurable faculties involved in decision making are the following: cognitive function (concentration), memory, judgment (risk taking), and mood.

Some of the measurable faculties involved in action are the following: coordination, strength, and simple and complex reaction times.

PART II - THE EFFECTS OF MARIHUANA ON THE CRITICAL FACULTIES INVOLVED IN DRIVING

The following is a very qualitative discussion of the specific effects of both alcohol and marihuana on what this author feels are the critical faculties involved in driving. Since the effects of both of the drugs are highly dependent on dosage, an attempt was made to standardize the dosage of each drug at normally accepted values.

The effects of alcohol mentioned are those observed in drivers whose blood contains a concentration of .15 per cent (sometimes expressed as 150 mg. per cent). At this point a driver is "presumed to be under the influence of alcohol in those states that have chemical-test laws which are generally modeled after Sec. 11-902 of the Uniform Vehicle Code."(2) It is interesting to note that some investigators feel that a driver whose blood contains this concentration of alcohol has a 150 per cent greater chance of accident involvement than one whose blood is alcohol free or below the .05 per cent level.(3)

The dosages used to produce the effects of marihuana in the several studies mentioned in this report were much less consistent. The dosages ranged from two grams smoked (4) to five grams ingested (5), but all dosages caused "common marihuana intoxication" in regular users as it is described in Goodman and Gilman's textbook of pharmacology.(6)

COMPARISON OF EFFECTS

Perception

1. Attention

Alcohol tends to make the driver oblivious to many important features of his environment, by narrowing the scope of attention and by increasing the time for the shift of attention from one thing to another. (7)

Marihuana seems not to affect a subject's capacity for sustained attention as measured by the continuous performance test (4), though the phenomenon of "grooving", that is, allowing oneself to become fascinated by a particular stimulus, has been reported. (4,5)

2. Depth Perception

Alcohol often adversely affects distance judgment as evidenced by decreased ability in the Keystone Depth Perception Test and the Army Rod Test. (8)

Depth perception measurements after marihuana ingestion were highly variable and showed no consistent trend. (5)

3. Glare Tolerance

Alcohol causes about a 20% loss in glare tolerance. (7)

The effect of marihuana has not been directly tested. The myth that marihuana causes pupil dilation, which might cause a loss in glare tolerance, was dispelled by Weil, Zinberg, and Nelsen. (4) Ames' finding that many subjects seemed to experience a greater intensity and duration of after-images, especially when objects such as windows had been looked at just before eye-closure, suggests that

a lessening of glare tolerance might result from marihuana intoxication. (9)

4. Visual Acuity

Alcohol has been shown to cause a significant loss of vision (greater than 5%) in more than three-fourths of intoxicated subjects as measured with both the Keystone Telebinocular and the Snellen chart. (8) Alcohol had the same effect on vision as the setting of a gray glass in front of the eyes, or driving with sun glasses in twilight or darkness: a stronger illumination is needed for distinguishing objects. Dimly lit objects will not be distinguished at all. (10) The effect of marihuana on visual acuity has not been tested. However, the fact that an effect has not been mentioned in the literature suggests that the effect is not significant enough to perceive.

5. Hearing

Alcohol's effect on hearing is not noticeable.

Marihuana does not affect the accuracy of perception of auditory frequencies. (5)

6. Equilibration

Alcohol usually causes a considerable loss in static equilibrium.

Static equilibrium may be adversely affected to a considerable degree by marihuana. (11)

7. Sense of Time

Alcohol seems to, in general, decrease awareness of external stimuli and, therefore, to "compress" time.

Loomis and West found that all subjects whose blood alcohol concentrations were .05% or higher were aware of an apparent compression of time during the driving period. This observation is best described by typical remarks at the completion of a test run: "Am I done already?" or "I barely got started!" (2)

During marihuana intoxication, however, time appears to be markedly lengthened. (12) Weil found that more than one third of his naive subjects overestimated the length of a five minute verbal sample by more than 100%. (4)

Decision

1. Cognitive Function

   Alcohol caused a 13% loss in performance on a test of concentration by Lauer. (7)

   With marihuana, Weil found that regular users started with good base line performance and improved slightly on the digit-symbol substitution test, while performance of first time users was grossly impaired. (4)

2. Memory

   Alcohol makes remembering the details of the driving procedure increasingly difficult. (2)

   Loss of recent memory or rather a difficulty in recall is one of the more striking effects of marihuana. One experimenter commented: "Because of this, conversation became bizarrely disconnected. If a subject was asked a question about a statement he had made a few seconds earlier, he was often unable to answer because he had forgotten what he had just said." (9)

3. Judgment-Risk Taking

Alcohol's effect on critical judgment, considered more dangerous than its effect on perception and motor skills, is obvious. Drivers indulge in excessive speed, take chances, and allow themselves to be preoccupied with events other than those on the road. (8)

Weil found that after smoking marihuana many of the regular users expressed anxiety at the start of their first battery of tests. They expressed surprise during and after the tests when they judged (correctly) that their performance was as good or better than it had been before taking the drug. He asserted that this is very much the opposite of the false sense of improvement felt while under the influence of some psychoactive drugs that actually impair performance. (4)

4. Mood

Alcohol usually results in increased talkativeness and release of inhibitions. Loomis found that about half of the subjects showed a tendency to become argumentative over minor topics of discussion. (2)

The effect of marihuana on mood is less consistent. Weil found that many, if not most, people do not become "high" on their first exposure to marihuana even if they smoke it correctly. (4) With regular users, marihuana is a mild euphoriant, although sometimes subjects become "suspicious" (9) with a "paranoid distrustful attitude". (12)

(2) Again, are these the same tests? A complex driving-simulator may be more difficult to perform than a simple pursuit rotor.

Action

1. Coordination

   Alcohol caused a 15% loss in muscular coordination as measured by a driving simulator. (8) (2)

   Marihuana caused a significant decrement in performance of naive subjects on the pursuit rotor. Regular users did not seem to have experienced as great a decrement. (4) (2)

2. Strength

   Alcohol caused a 6.5% loss in grip strength in Lauer's studies. (7)

   Marihuana causes a similar slight loss in strength. (11) Hollister, Richards, and Gillespie found that after ingesting fairly large doses of THC subjects exhibited strength loss as evidenced by a 36% increase in ergograph decrement scores after two hours. (21)

3. Reaction Time

   Alcohol caused a 31% increase in the simple foot reaction time of one of Loomis' subjects (2) and a 19% increase in Lauer's subjects. (7)

   Marihuana caused a 9% increase in simple reaction time in one of Clark's subjects, but a 44% increase in complex (choice) reaction time. (5)

TABLE OF EFFECTS

Faculty	Alcohol	Marihuana
Attention	narrows scope slows shifting	none, except "grooving"
Depth Perception	adversely	no trend
Glare Tolerance	20% loss	possible loss
Visual Acuity	significant loss	not mentioned in literature
Hearing	none	none
Equilibration	considerable loss	adversely to a considerable degree
Sense of Time	compresses time	extends time
Cognitive Function	13% loss	FTU-grossly impaired RU-improve slightly
Memory	forget details	loss of recent memory
Judgment-Risk Taking	take more chances preoccupied sense of improvement	loss in confidence no sense of improvement
Mood	increase taking release of inhibitions argumentative	FTU-no effect RU-mild euphoriant suspicious
Coordination	15% loss	FTU-significant loss RU-possibly no effect
Strength	6.5% loss	similar slight loss
Reaction Time		
Simple (foot)	approx. 25% increase	9% increase
Complex (choice)		44% increase

FTU = first time users
RU = regular users

DISCUSSION OF EFFECTS

Timothy Leary and Richard Alpert, in the foreword of The Joyous Cosmology by Alan Watts, commenting on the "effects" of the more powerful psychedelics wrote

> From our observations, from interviews and reports, from analysis of questionnaire data, and from pre- and post-experimental differences in personality test results, certain conclusions have emerged. (1) These substances do alter consciousness. There is no dispute on that score. (2) It is meaningless to talk more specifically about the "effect of the drug." Set and setting, expectation and atmosphere, account for all specificity of reaction. There is no "drug reaction" but always setting-plus-drug. (13)

There is evidence that marihuana also has this important characteristic.

Weil, Zinberg, and Nelsen in their report, "Clinical and Psychological Effects of Marihuana in Man," emphasized over and over again "the apparently enormous influence of set and setting on the form of the marihuana response". (4) The cautious reader would do well to keep these warnings in mind during any discussion of the "effects of marihuana". Weil and his associates also pointed out another important factor in marihuana intoxication, that of suppressibility:

> One impetus for reporting the finding of differences between chronic and naive subjects on some of the tests, despite the fact that the experimental designs were not the same, is that this finding agrees with the statements of many users. They say that the effects of marihuana are easily suppressed--much more so than those of alcohol.
>
> Our observation, that the chronic users after smoking marihuana performed on some tests as well as or better than they did before

> taking the drug, reinforced the argument advanced by chronic users that maintaining effective levels of performance for many tasks--driving, for example--is much easier under the influence of marihuana than under that of other psychoactive drugs. (4)

Interestingly, in apparent contradiction to this, McGlothin and West in "The Marihuana Problem: An Overview," reported on 32 respondents who used marihuana ten or more times during the period 1955-61:

> Inquiry was made concerning the effect of marihuana on driving competence. Of the 32 respondents, eight stated that they never drove under the influence of marihuana. Twenty of the remaining 24 felt that their driving competence was impaired. The reasons given were: perceptual distortion, speed distortion, slower reaction time, less alert, disoriented, poor judgment, and less careful. (14)

In a study of the driving records of persons arrested for illegal drug use in King County, Washington, Crancer and Quiring found that <u>suspected</u> marihuana users had 39% more accidents than a corresponding group in King County of the same age and sex composition. Four types of violations on the records of each illegal drug users were found in a higher proportion than on the records of all King County drivers. They were the following: reckless driving, negligent driving, hit and run, and defective equipment. The following three types of violations were underrepresented on the records of each illegal drug group: speeding, failure to stop, and failure to yield. The marihuana group had the lowest percentage of both drunken driving violations and injury accidents, compared to other suspected drug users. In fact, this group was the only illegal drug group to have

a percentage for drunken driving lower than the King County population. (15)

What, then, does this rather fragmented description of the effects of marihuana on the various faculties necessary for driving suggest about the effect of marihuana on driving ability? The following is a somewhat speculative answer to this question based on this author's interpretation of the available data and on personal observation, as limited as they both are.

It is the hypothesis of this author, which he hopes will soon be tested by experiment, that the effect of marihuana on the driving ability of regular users is slightly adverse, but much less so than the effect of alcohol. (An investigation of the effect of marihuana on simulated driving ability by the Washington Department of Motor Vehicles, unavailable to the author at the time of this writing, seems to support this idea.) This hypothesis is based on the following characteristics of marihuana intoxication:

1. The apparent suppressibility of the effect. Conscious effort is required here, however, and distractions, such as conversation and music, make it more difficult.
2. The effect seems to be concentrated on the higher, more conscious part of the mind. (4) Driving, to a large degree, seems to be controlled by subconscious habit patterns. If driving does indeed consist of few conscious choices, then the considerable increase in complex reaction time is less important than it might seem. ③

③ How so? Are choices always "conscious"?

3. If the mind measures time by the "amount" of stimuli it receives during a certain "length of existence", then the time extension effect of marihuana suggests that "more" stimuli are received. If this "more" is quantitative (ie., breadth, number), rather than, or at least in addition to, being qualitative (ie., depth, suchness), then the "stoned" driver can perceive quantitatively more stimuli in his environment. This presumedly would allow him to make better decisions: first, in that more data is available, and second, in that there is more "time" to decide. This argument taken to the extreme, however, also suggests that an observer might be "swamped" with stimuli, an effect which could cause confusion and inaction. Fortunately, this is not what happens in "common marihuana intoxication". The time extension effect also helps to explain why "stoned" drivers find themselves driving more slowly.

4. The loss of immediate memory, that is, memory over the past few seconds (19), seems to have no effect on performance. Weil and Zinberg quoted two subjects:

> I'll come to a stop light and have a moment of panic because I can't remember whether or not I've just put my foot on the brake. Of course, when I look down, it's there, but in the second or two afterwards I can't remember having done it....
> I would keep forgetting what I was doing, especially on the continuous performance test, but somehow every time an "X" (the critical letter) came up, I found myself pushing the button. (19)

Strange as it may seem, although a driver might momentarily forget his destination, the evidence seems to suggest that he would get there.

5. The loss in self-confidence and the suspicion of other drivers encourages careful, defensive driving.

dangerous suggestion — what about drives on the L.I. Expressway at 6:00

PART III - DESIGN OF EXPERIMENTAL PROCEDURE

The previous discussion has helped to point out some of the characteristics of marihuana that could possibly jeopardize the internal and external validity of an experimental determination of the effect of intoxication on driving ability. The problems of experimental design will be discussed under the headings: subjects, administration of the drug, and testing procedure. This discussion will concentrate on the problems specific to marihuana, although the experiment should compare normal ability, ability during marihuana intoxication, and ability during alcohol intoxication. The aspects of the procedure concerning alcohol have been well investigated by Lauer (7), Loomis and West (2), Newman, Fletcher, and Abramson (8), and many others.

SUBJECTS

Weil concluded that "it is feasible and safe to study the effects of marihuana on human volunteers who smoke it in a laboratory." (4) Since the subjects' set, or psychological expectations, are very important, pre-test interviews should determine each subject's outlook. Experimenters should also take care to present a neutral attitude to the subjects. Because of the differences in effect on marihuana naive versus regular users, this variable should be controlled. Two groups of marihuana intoxicated subjects, a marihuana naive group, and a regular user group, would probably reveal interesting differences. Subjects that have an acute reaction to nicotine

should be eliminated, if tabacco is used to plug the ends of all the cigarettes to disguise the placebos.

ADMINISTRATION OF THE DRUG

It is important that the marihuana be administered by smoking, as this is the way nearly all Americans use it. (4) The amount of tetrahydrocannabinol (THC), thought to be the active part of the resin, can be found by assaying samples spectrophotometrically. As Weil pointed out, however, since "THC has not been established as the sole determinant of marihuana's activity" (4), it would be prudent to have regular users sample and rate the marihuana used. Placebo cigarettes should contain "the chopped outer covering of mature hemp plants" (4), devoid of THC, to control for the characteristic smell of marihuana smoke. Marihuana and placebos should be administed in a double-blind fashion, that is, neither the experimenters nor the subjects should know which kind of cigarette is being smoked. This will help to neutralize the effect of any expectations either the subject or the experimenter might have. The method of smoking, such as the amount of each cigarette that is to be smoked and the amount of time the smoke is to be held in the lungs, should be standardized and controlled. A normal dose of marihuana of average strength would be one or two cigarettes. The effects of an inhaled dose of marihuana appear to reach maximum intensity within one half hour of inhalation, so testing should start about one half hour after smoking.

TESTING PROCEDURE

Probably the most difficult factor to control that might jeopardize the external validity, or representativeness, of the experiment will be the effect of the testing procedure on the outcome. (16) The all important contribution of the setting to the effects of marihuana has been mentioned several times in this report.

There are two methods currently in use for measuring driving ability: driving simulation and practical road tests. The advantages of using driving simulation for our purposes are safety, relative low cost, and the possibility of high internal validity, that is, the possibility of highly accurate, quantitative measurement of errors. The advantage of practical road tests is a closer approximation of a real driving situation, and, therefore, greater external validity.

Due to safety considerations, this author favors the use of a simulation apparatus similar to that used by Loomis and West for testing the effects of alcohol, a barbiturate, and some tranquilizers on driving ability for preliminary investigations. (2,17) This apparatus is described in the appendix. If the effects of marihuana on this task are as minor as this analysis seems to suggest, practical road tests should then be attempted to increase external validity. The "Oval-Eight Driver Test Course" that will probably be built at Pennsylvania State University's transportation and traffic safety center this summer seems ideally suited to this problem. (18) Under this system, instead of examiners riding with the driver, electronic devices will analyze the driver's performance and automatically record scores.

Just how these "electronic devices" would "analyze" the driver's performance, which determines the internal validity of the test, has not appeared in the literature.

DIAGRAM OF A SIMULATED DRIVING EXPERIMENT

	R	O		O
	R	O	Xa	O
FTU	R	O	Xm	O
RU	R	O	Xm	O

DIAGRAM OF A ROAD DRIVING EXPERIMENT

	R			O
	R		Xa	O
FTU	R		Xm	O
RU	R		Xm	O

---

where

X = exposure of group to experimental variable
a = alcohol
m = marihuana

O = process of observation or measurement

R = random assignment to separate treatment group

In later experiments it would be interesting to increase the sophistication of the tests by adding distractions, such as music or conversation, by introducing emergency situations, or by inducing anxiety or stress in the subjects before driving.

PART IV - RECOMMENDATIONS

TO USERS

1. If at all possible, do not drive while "stoned". Let someone else do the driving.
2. If driving is unavoidable, let a regular user do the driving, and keep distractions to a minimum.

TO TRAFFIC ENGINEERS

3. Transcend the old taboos that surround drug use and establish the facts about the effects of marihuana on driving ability.
4. Use simulation techniques in preliminary investigations, and, if possible, practical road tests later.

TO THE MEDICO-LEGAL PROFESSIONS

5. Encourage research to find out the facts about marihuana, and work for laws that reflect these realities.
6. If marihuana is dangerous, find ways to prove a driver is experiencing marihuana intoxication.

COMMENTS ON THE WASHINGTON STATE INVESTIGATION

Because Crancer's study, "The Effects of Marihuana and Alcohol on Simulated Driving Performance" (20), arrived after this report was written, and, perhaps more significantly, after it was typed, his study was mentioned only in passing (see page 13). Some comment on this very important and very well designed study is necessary and, therefore, follows. This discussion will be limited to pointing out some of the weaknesses in the design that might jeopardize the internal or external validity of this essentially very well done experiment. The report is included in the appendix.

SUBJECTS

Since all Crancer's subjects in his main study were experienced marihuana smokers, it is probably safe to assume that they were "set" to perform as well as possible while "stoned". The fact that they did not perform better immediately before they were given the marihuana (p. 7) does not imply that there was no subject bias. Interviews to determine biases might have revealed correlations between biases and individual results.

Interestingly, the four additional marihuana naive subjects became "subjectively 'high'" (p. 8). To this author that fact suggests that even the naive subjects were biased toward marihuana. The lack of change in their scores is less surprising if they actually did want to do better after marihuana.

Crancer stated that "the environmental setting was conducive to good performance of all treatments" (p. 7). If marihuana heightens suggestibility, as some authors indicate (11), then a setting conducive to good performance normally, might be conducive to better performance after marihuana.

ADMINISTRATION OF THE DRUG

Crancer decided that using placebos in a double-blind procedure was "not applicable" because in Weil's study even "inexperienced subjects correctly appraised the presence or absence of a placebo in 21 of 27 trails" (p. 7). This author thinks that not using a placebo was a mistake for two reasons. First, the number of subjects "fooled" by the placebo procedure in Weil's study was about 22%. Since the largest difference in errors in Crancer's experiment was only 15.4% (for alcohol), the effect of the placebos on 20% of the subjects might have been significant. Second, a double-blind procedure helps to control experimenter as well as subject bias. An important part of the "all important setting", that is, the experimenter's effect on the subject, was not sufficiently controlled in Crancer's study. He also seems to have failed to control how the cigarettes were smoked, an important factor in determining how much THC reaches the brain.

TESTING PROCEDURE

Crancer's study, on the whole, was a very good investigation of the effects of marihuana and alcohol on simulated driving performance. The external validity, or representativeness,

of this kind of experiment is impossible to prove. It can, however, be logically implied and, at best, statistically correlated. Crancer had previously correlated performance on his driving simulator to five-year driving records of normal drivers. He points out, however, that since "the simulator task is a less complex but related task" (p. 6) it would be unsafe "to assume that nondeterioration in simulator performance implies nondeterioration in actual driving" (p. 7). This is especially true with marihuana because of the large increase of complex over simple reaction time. (5) It suggests that either the simulator task should be complicated or else some means of correlating simulator performance to actual performance after marihuana should be found. Unfortunately, the latter alternative necessitates knowing what we want to find out.

Very good job.

Excellent! Critical, shows work you put in on it + knows well. D.D.

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APPENDIX

SIMULATED AUTOMOBILE DRIVING APPARATUS (LOOMIS AND WEST)

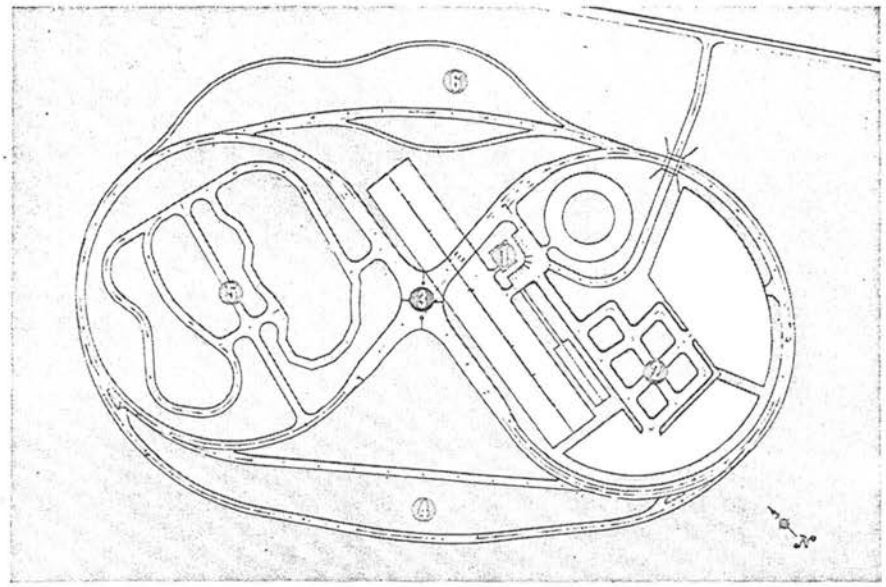
APPARATUS AND METHODS. The apparatus consisted of a conventional automobile steering wheel, and the brake and accelerator pedals which could be operated in a manner similar to that of driving a standard automobile. The steering apparatus was arranged to operate a model auto as it passed over a transparent, moving nylon belt which was 150 feet long and 30 inches wide. On the surface of the entire length of the belt was a continuous, inch wide, opaque strip which simulated a road bed. As the belt moved beneath the auto, the road bed moved randomly but smoothly from side to side. Movement of the belt at a pre-set speed was actuated by foot pressure on the accelerator pedal. In order to stop the movement of the belt, it was necessary for the subject to apply foot pressure to the brake pedal. In this manner the subject could start the belt moving, steer the auto over the road as the road moved beneath the auto and stop the belt by conventional automobile driving procedures.

A photoelectric cell which was mounted beneath the auto was in the direct beam of a light source located beneath the belt so that the light source moved with the auto. The photo cell actuated a cumulative interval timer and a signal light. When the auto was not centered over the road the "time off the road" was accurately recorded and the signal light above the auto was illuminated, indicating to the subject that the auto was off the road. Located 14 inches above and centered over the belt was a black box with a translucent plastic surface facing the subject. Within the box were three colored lights (green, red and amber). Timed illumination of the lights was controlled automatically from a synchronous cam-switching mechanism. Cumulative interval timers were arranged to record the time interval between the appearance of the red light and application of pressure on the micro-switch attached to the brake pedal, and between the appearance of the amber light and the release of pressure on the micro-switch attached to the accelerator pedal.

A test was performed in the following manner. The road belt was placed at the starting position with the subject seated at the driving apparatus. The operator closed the "start test" switch which actuated the entire mechanism for a period of exactly four minutes. When the green light appeared the subject depressed the accelerator pedal and the road started moving. When the light turned to an amber color, the accelerator pedal was to be released. When the light turned red the brake pedal was to be depressed which also stopped movement of the road. The auto could be steered whether the road was stationary or moving, and the subject attempted to keep the auto centered over the road at all times. The amber, red and green lights were automatically illuminated in the following sequence: green 12 seconds, amber 3 seconds, green 12 seconds, red 3 seconds, which was repeated so that each amber and red light was illuminated 8 times of 3 seconds' duration during the four-minute test period. The following data were obtained from each test period. 1) The amber light reaction time in milliseconds. Since the amber light always followed a green light this represents the interval of time between the appearance of the amber light and the release of foot pressure on the accelerator pedal. 2) The red light reaction time in milliseconds. Since the red light also always followed a green light this is the interval of time between the appearance of the red light and the application of pressure to the brake pedal. 3) The accumulated time during which the auto was not centered over the road bed. 4) The time that the road was in motion was also recorded but was not used in the final calculations of the data because of mechanical failure of this timer late in the course of the experiments. This is an index of how efficiently and rapidly the subject reapplied foot pressure to the accelerator pedal when the green light reappeared after each red light. Each subject was acquainted with the measurements which were being recorded.

All subjects were trained before starting the study. Each subject was repeatedly tested at two-day to weekly intervals until his control ability reached a plateau of over-all efficiency so that repeated tests gave scores which did not vary more than 20 per cent. This usually required a set of 5 to 10 training tests.

PRACTICAL ROAD TEST COURSE (PENN STATE)



OVAL-EIGHT driver test course has central control tower (1) from which examiners direct and score drivers through residential area (2), major traffic intersection (3), steep hill (4), meandering rural roads (5) and freeway ramps (6).

Drivers Tested by Remote Control

Pennsylvania State University's transportation and traffic safety center hopes this summer to start building a $1-million vehicle-driver test track that designers believe may be the prototype for future test sites.

The entire course, consisting of a 1-mile oval and 2.6-mile figure-eight roadway, will be supervised from a central control tower atop the administration building. Instead of examiners riding with the driver, they will communicate with vehicles by walkie-talkie from the tower. Electronic devices will then analyze the driver's performance and automatically record scores.

The test track's primary function will be to help testing examiners determine whether more sophisticated testing techniques can lead to improved traffic safety. It is designed to raise the qualifications of drivers by helping them spot deficiencies before being licensed.

Safety center engineers designed the experimental facility under a $30,000 state grant. They are now awaiting a U.S. Department of Transportation grant to get the project started, with a completion date scheduled for the fall. The track will be built on a 72-acre site on the main campus at University Park. The state will pay construction costs not covered by the federal grant.

The course includes a four-lane, four-way intersection with traffic lights, a six-block residential area complete with curbs, entrance and exit ramps similar to those on freeways, meandering rural roads and a hill with 6% grade.

Other features include T and Y intersections, an area where the operator will drive through 6 to 8 in. of water to learn how water affects a vehicle's braking system and a skid pad to demonstrate what happens when a car goes out of control.

The administration building will also include a small theater for driving instruction and a vision screening area to test the driver's lateral vision.

Called the Oval-Eight, the track is designed to test up to 10 vehicles at once over a 15-minute period, with autos reaching top speeds of 40 mph at various stages in the course. There will be separate areas for testing operators of trucks, buses and motorcycles.

Daniel J. Evans, Governor

Douglas Toms, Director

The Effects of Marihuana and Alcohol on Simulated Driving Performance

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ABSTRACT

The effects of marihuana, alcohol, and control treatments on simulated driving performance were determined for experienced marihuana smokers. Subjects experiencing a "social marihuana high" accumulated significantly more speedometer errors on the simulator than under normal control conditions, while there were no significant differences in accelerator, brake, signal, steering, and total errors.

The same subjects intoxicated from alcohol accumulated significantly more accelerator, brake, signal, speedometer, and total errors than under normal conditions, while there was no significant difference in steering errors.

The study also suggests that impairment in simulated driving performance is not a function of increased marihuana dosage or inexperience with the drug.

A COMPARISON OF THE EFFECTS OF MARIHUANA AND ALCOHOL ON SIMULATED DRIVING PERFORMANCE

INTRODUCTION

The major objective of this study was to determine the effect of a "normal social marihuana high" on simulated driving performance among experienced marihuana smokers.

Anticipating an impairment due to smoking marihuana, we compared the degree of impairment to the effect on driving of a recognized standard--legal intoxication at the presumptive limit of 0.10 percent alcohol concentration in the blood. The effect on simulated driving performance of an alcohol intoxication was used only as a reference point of impairment. We were comparing the effects of two very different drugs--not the drugs themselves. One drug (alcohol) is commonly used in social environments, while the other drug (marihuana) is fast approaching common use in some social environments.

This study focused attention on the effect of smoking marihuana containing Δ^9THC (the principal active ingredient) rather than on the effect of ingesting Δ^9THC. The primary reason was that the new social phenomenon sweeping the country is smoking marihuana and not "dropping" Δ^9THC. Further, we felt that initial research should be directed toward investigating this phenomenon in as natural a setting as possible so that the results could be easily understood and related.

PERTINENT RESEARCH

Research on the physical and psychological effects of marihuana is scarce. Perhaps the most pertinent study is the research recently completed by Weil (1), who studied the clinical and psychological effects of smoking marihuana on both experienced and inexperienced subjects. This research is especially pertinent to our study because it concludes that it is feasible and safe to study the effects of smoking marihuana. Weil also suggests that experienced smokers "high" on marihuana show no significant impairment when taking selected performance tests and also establishes the existence of physiological changes that are useful in determining if a subject smoking marihuana is "high". Further, Weil suggests that the effect of smoking marihuana on driving performance is of high medico-legal priority. Another study, the "LaGuardia Report" (2), concluded in part that "Under the influence of marihuana, changes in personality as shown by alterations in test performance are slight." In reviewing the literature, we found no report of studies relating driving performance to marihuana intoxication.

A review of research literature relating alcohol to fatal accidents, Haddon (3), McCarroll (4), Birrell (5), Neilson (6), shows that nearly half of the drivers fatally injured in an accident were found to have an alcohol concentration in the blood of 0.05 percent or more. We have no report of experimental research which studied driving impairment as a function of specific blood alcohol concentration.

The ability of a driving simulator to distinguish among levels of driving performance has been studied by Crancer (7). Findings indicate that the simulator test studied is valid using a five-year driving record as the criterion.

The simulator test was chosen because current research by Wallace (8), indicates that a behind-the-wheel road test (used in driver licensing examination) is not significantly correlated to driving performance. The difference between these driver testing procedures is probably due to the simulator's ability to present a programmed series of emergency situations, which is impractical and dangerous in actual road tests.

SUBJECTS

Initial selection of subjects was carried out on the basis of three criteria. Subjects were required to be (1) experienced marihuana smokers who had been smoking marihuana at least twice a month for the past six months, (2) licensed as a motor vehicle operator, (3) engaged in a generally accepted educational or vocational persuit, and (4) familiar with the effects of alcohol--there were no teetotalers or chronic alcoholics in the study.

Qualified subjects were further screened in the following manner: (1) a physical examination was given to exclude persons currently in poor health or under medication; (2) a written personality inventory (Minnesota Multiphasic Personality Inventory) was administered to exclude persons showing a combination of psychological stress and inflexible defense patterns. Seven of the 36 subjects were females and 29 males, with a mean age of 22.9.

EXPERIMENTAL DESIGN

This experiment was designed to compare the effects of three treatments on simulated driving performance: marihuana high, alcohol intoxication, and no treatment. We investigated the time response effects of each condition.

A Latin square analysis of variance design (Edwards (9)) was chosen in order to account for the effects of treatments, subjects, days, and the order in which the treatments were given. In order to measure the time response effects of each treatment, simulator scores were obtained at three constant points in the course of each experimental period. A sample of 36 subjects was determined to be sufficient in size to meet the demands of this experimental design.

The three treatments were given to each subject and defined in the following manner:

1. Treatment M (Normal social marihuana high) - subjective evaluation by an experimental subject that he was experiencing the physical and psychological effects of smoking marihuana in a social environment comparable to his previous experiences. This subjective evaluation of "high" was confirmed by requiring a minimum consumption of marihuana established with a separate test group, and by identifying an increase in pulse rate. (Weil (1), Page 1239, reported a significant pulse rate increase when subjects became high on marihuana.)

The treatment consisted of consuming two marihuana cigarettes of approximately equal weight and totaling 1.7 grams. Subjects completed smoking in about 30 minutes and were given their first simulator test 30 minutes later.

The marihuana cigarettes were prepared by using a standard gram scale and a "Top" brand hand rolling machine.

The marihuana was an assayed batch (1.312% Δ^9THC) from the National Institute of Mental Health through the cooperation of Dr. John A. Scigliano, Executive Secretary of the Ad Hoc Marihuana Review Committee.

Some confirmation that the amount of marihuana smoked was sufficient to produce a high is found in Weil's (1) study. His subjects smoked about 0.5 grams of marihuana of 0.9 percent Δ^9THC.

2. Treatment A (Alcohol intoxication) - evaluation by means of a Breathalyzer establishing approximately a 0.10 percent concentration of alcohol in the blood.

   Treatment A consisted of consuming two drinks containing equal amounts of 95 percent laboratory alcohol, mixed with either orange or tomato juice according to the subject's preference. Dosage was regulated according to the subject's weight with the intended result of a 0.10 percent blood alcohol concentration determined by a Breathalyzer reading (Kelner (10)). A Breathalyzer reading was obtained for each subject about one hour after drinking began with most subjects completing their drinking in 30 minutes. The earliest readings were obtained after 45 minutes for those subjects that completed drinking in 15 minutes.

   A subject weighing 120 pounds received 84 ml. of 95 percent laboratory alcohol equally divided between two drinks. This was equivalent to about 6 oz. of 86 proof liquor. The dosage was increased 14 ml. or 1/2 ounce for each additional 15 pounds of body weight.

   A standard Breathalyzer was used to determine the percent level of alcohol in the blood.

3. Treatment C (Control/no treatment) - subjective evaluation by an experimental subject that his physiological and psychological condition was normal. Subjects were requested to refrain from all drug or alcohol use during the time they were participating in the experiment.

   Treatment C consisted of waiting in the lounge with no treatment for the same period of time required for Treatments M and A.

DRIVER SIMULATOR

A driver training simulator was specially modified to obtain data on the effect of the treatments. The car unit itself was a console mock-up of a recent model car containing all the control and instrument equipment

relevant to the driving task. The car unit faced a 6 foot x 18 foot screen upon which the test film was projected. The test film gave the subject a driver's-eye view of the road as it led him through normal and emergency driving situations on freeways, urban, and suburban streets. From the logic unit, located to the rear of the driver, the examiner started the automated test, observed the subject driving, and recorded the final scores.

A series of checks was placed on the twenty-three minute driving film which monitored driver reactions to a programmed series of driving stimuli. The test variables monitored were: Accelerator (164 checks), brake (106 checks), turn signals (59 checks), steering (53 checks), and speedometer (23 checks). There was a total of 405 checks, allowing driver scores to range from a low of zero to a maximum of 405 errors per test. Errors were accumlated for each test variable as follows:

Speedometer errors. Speedometer readings outside the range of 15 to 35 m.p.h. for city portion of film and 45 to 65 m.p.h. for freeways. Example, speedometer readings below the range for freeway driving. Note: The speed of the filmed presentation is not under the control of the driver. Therefore, speedometer errors are not an indication of speeding errors, but of the amount of time spent monitoring the speedometer.

Steering errors. Steering position in other than the appropriate position. Example, steering right when the appropriate response is to steer left or center.

Brake errors. Not braking when the appropriate response is to brake or braking at an inappropriate time.

Accelerator errors. Acceleration when the approprate response is to decelerate or deceleration when it is appropriate to accelerate.

Signal errors. Turn signal in an inapproprate position. Example, no turn signal response when preparing to turn left.

Total errors. An accumulation of the total number of errors on the five test variables.

SETTING

Two rooms in the Department of Pharmacology, University of Washington, were used for the experiment. One room, which we call the lounge, was designed to provide a familiar and comfortable environment for the subjects. The lounge was approximately 12 feet square and contained six casual chairs, a refrigerator, a desk, and several small movable tables. The room was lighted by a red lava lamp and one indirect red light. Colorful posters were placed on the walls, snacks and soft drinks were available, and contemporary rock music was played on a stereo tape recorder. Ash trays, waste baskets, and a supply of cigarettes were readily available to the subjects. Subjects remained in this room except during simulator test.

The driving simulator was located in a larger room about 50 feet from the lounge. The simulator room was approximately 20 feet x 30 feet and was kept in almost total darkness to minimize external distractions.

EXPERIMENTAL PROCEDURE

In addition to the physical and psycological screening procedures described above, each subject took three preliminary tests on the driving simulator. This was to familiarize the subject with the equipment and to minimize the effect of learning through practice during the experiment. Subjects whose error scores varied by more than 10 percent between the second and third tests were given subsequent tests until the stability criterion was met.

The experiment was conducted over a six-week period. Six subjects were tested each week. One week's procedure is outlined below:

Day 1. A group of six subjects reported to the laboratory at noon. Each took one test on the driving simulator to assure recent familiarity with the equipment. A "normal" pulse rate was recorded, and each was given two marihuana cigarettes of approximately 0.9 grams each. Subjects smoked the marihuana in the lounge in order to become acquainted with the surroundings and other test subjects, and with the potency of the marihuana. A second pulse reading was recorded for each subject when he reported that he was high in order to obtain an indication of the expected rate increase during the experiment proper. They remained in the lounge for approximately four hours after they had stared smoking.

Days 2 through 7. Three of the subjects were scheduled for testing in the early evening on days 2, 4, and 6; the remaining three subjects for Days 3, 5, and 7. A single treatment was given each evening. Within a given week, all subjects received treatments in the same order. Treatment order was changed from week to week to meet the requirements of a Latin square design. Procedure for each evening was identical, except for the specific treatment.

Subject 1 arrived at the lab and took the simulator warm-up test. Treatment A, M, or C was begun at zero hour and finished about one-half hour later. One hour after treatment began, Subject 1 took simulator Test 1, returning to the lounge when he was finished. He took Test 2 two and one-half hours after treatment began, and Test 3 four hours after treatment began. Pulse or Breathalyzer readings, depending on the treatment, were taken before each simulator test.

Subject 2 followed the same schedule, beginning one-half hour after subject 1; Subject 3 began one-half hour after Subject 2. Time used in testing one subject each evening was four and one-half hours, with a total elapsed time of five and one-half hours to test three subjects.

RESULTS

Analysis of Total Errors by Time Periods

The three simulator tests taken after each treatment established a time response effect for the treatment. For each treatment the total error scores for each time period were subjected to an analysis of variance. Table 1 presents the analysis of variance for Period 1 scores. Results comparable to these were obtained for scores in Periods 2 and 3.

The results of the analysis of variance listed in Table 1 indicate no significant difference in simulated driving scores for subjects experiencing a normal social marihuana "high" and the same subjects under control conditions. However, there are significantly more errors ($P < .01$) for subjects intoxicated at about the 0.10 percent level of blood alcohol concentration than for those subjects under control conditions (difference of 15.4 percent). This finding is consistent with the mean error scores of the three treatments: Control = 84.46 errors; marihuana = 84.49 errors; alcohol = 97.44 errors.

As indicated in Figure 1, the time response effect of marihuana and control is comparable. In contrast, subjects accumulated significantly more total errors ($P < .01$) when under the influence of alcohol. These higher error scores for alcohol persist across all three time periods with little evidence of the improvement shown under the other two treatments.

Analysis of Errors by Test Variables

A separate Latin square analysis of variance was completed for each test variable to supplement the analysis of total errors and is summarized in Table 2.

For the comparison of alcohol versus control, significant differences ($P < .05$) were found for accelerator errors in Periods 1 and 2; signal errors in Periods 1, 2, and 3; braking errors in Periods 2 and 3; and speedometer errors in Period 1. For the comparison of marihuana versus control, a significant difference ($P < .05$) was found for speedometer errors in Period 1. In all of these cases, the number of errors for the drug treatments exceeded the errors for the control treatment.

Other Sources of Variation

The above analysis has concentrated on the significance of treatment effects. Other main effects are Latin squares, subjects, and days. In all of the analyses, the effect of subjects and Latin squares (representing groups of subject) were significant at the 0.05 level. In contrast, the effect of days were not significant, indicating that no significant amount of learning was associated with repeated exposure to the test material.

DISCUSSION

Generalization of Results

For normal drivers, Crancer (7) found a significant correlation ($P < .05$) between three simulator test variables (signals, accelerator, and total errors) and driving performance. An increase in error scores was associated with an increase in number of accidents and violations on a driving record. In the same study error scores for brake, speedometer, and steering were not correlated with driving performance.

We must exercise caution in directly relating the above results to the findings reported here. It may not be valid to assume the same relationship for persons under the influence of alcohol or marihuana until this has been established. However, we feel that since the simulator task is a less complex but related task, that deterioration in simulator performance implies deterioration in actual driving performance. We are

less willing to assume that nondeterioration in simulator performance implies nondeterioration in actual driving.

We therefore conclude that significantly more accelerator, signal, and total errors by intoxicated subjects imply a deterioration in actual driving performance.

Relating speedometer errors to actual driving performance is highly speculative since Crancer (7) found no correlation for normal drivers. This may be due in part to the fact that the speed of the filmed presentation is not under the control of the driver. However, speedometer errors are related to the amount of time spent monitoring the speedometer. The increase of speedometer errors by subjects intoxicated or high probably indicates that the subject spent less time monitoring the speedometer than under control conditions.

This study could not determine if the drugs would alter the speed at which subjects normally drive. However, comments by marihuana users may be pertinent. They often report alteration of time and space perceptions, leading to a different sense of speed which generally results in driving more slowly. In addition, they report that acceleration is often associated with a feeling of anxiety.

Subject Bias

Weil (1) emphasizes the importance and influence of both subject bias (set) and the experimental environment (setting). For this study, the environmental setting was conducive to good performance of all treatments.

Traditional methods for controlling potential subject bias by using placebos to disguise the form or effect of the marihuana treatment were not applicable. This is confirmed by Weil (1)--inexperienced subjects correctly appraised the presence or absence of a placebo in 21 of 27 trials.

The nature of selection probably resulted in subjects who preferred marihuana to alcohol, and therefore, had a set to perform better with marihuana. The main safeguard against bias was that subjects were not told how well they did on any of their drive tests, nor were they acquainted with the specific methods used to determine errors. Thus, it would have been very difficult to intentionally and effectively manipulate error scores on a given test or sequence of tests.

A further check on subject bias was made by comparing error scores on the warm-up tests given prior to each treatment. We found no significant difference in the mean error scores preceding the treatments of marihuana, alcohol, and control. This suggests that subjects were not "set" to perform better or worse on the day of a particular treatment.

In addition, an inspection of chance variation of individual error scores for Treatment M shows about half the subjects doing worse and half better than under control conditions. This variability in direction is consistent with findings reviewed earlier, and we feel reasonably certain that a bias in favor of marihuana did not influence the results of this experiment.

Dose Response

A cursory investigation of the dose response issue was made by retesting four subjects after they had smoked approximately three times the amount of marihuana used in the main experiment. None of the subjects showed a significant change in performance.

Four additional subjects who had never smoked marihuana before were pretested to obtain control scores, then given marihuana to smoke until they were subjectively "high" with an associated increase in pulse rate. All subjects smoked at least the minimum quantity established for the experiment. All subjects showed either no change or negligible improvement in their scores. These results suggest that impairment in simulated driving performance is not a function of increased marihuana dosage or inexperience with the drug.

Other Variation

A significant difference ($P < .01$) was found between pulse rates before and after the marihuana treatment. Similar results were reported by Weil (1) in research with both experienced and inexperienced marihuana subjects. There was no significant difference in pulse rates before and after drinking.

SUMMARY

Marihuana wise subjects experiencing a social marihuana high accumulated significantly more speedometer errors on the simulator than under control conditions, while there was no significant difference in accelerator, brake, signal, steering, and total errors.

The same subject intoxicated from alcohol, accumulated significantly more accelerator, brake, signal, speedometer, and total errors than under control conditions, while there was no significant difference in steering errors.

The study also suggests that impairment in simulated driving performance is not a function of increased marihuana dosage or inexperience with the drug.

Further study is needed to determine the applicability of these results to actual driving.

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FIGURE 1.

TIME RESPONSE EFFECT ON
SIMULATED DRIVING ERROR SCORES

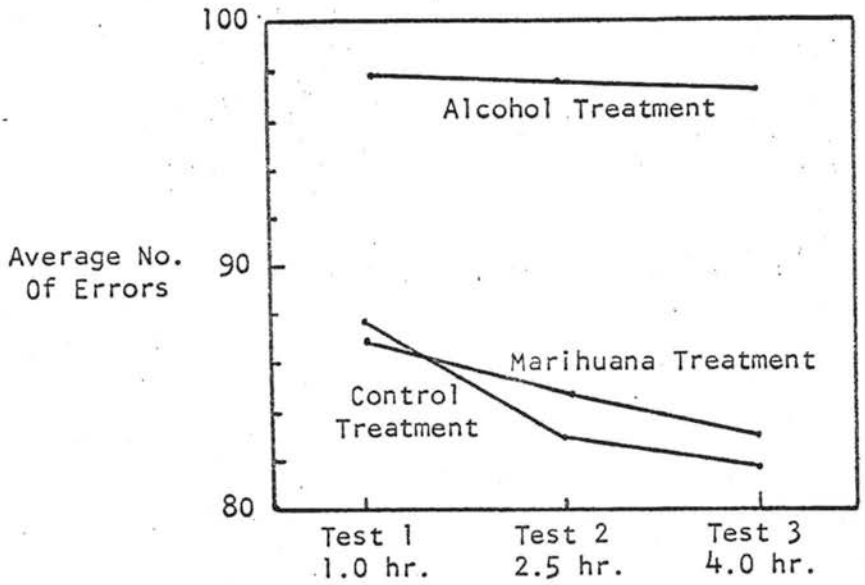

TABLE 1
ANALYSIS OF VARIANCE: TOTAL DRIVING SIMULATOR
ERROR SCORES FOR THREE TREATMENTS

SOURCE OF VARIATION	SUM OF SQUARES	DF	MEAN SQUARE	F
Treatments[1]	2,595.1	2	1,297.5	6.7[2]
M versus C	(11.7)	(1)	11.7	0.1
A versus M, C	(2,583.4)	(1)	2,583.4	13.3[3]
Days	738.5	2	369.3	1.9
Subjects	40,872.5	24	1,703.0	9.7[3]
Squares	13,708.5	11	1,247.2	6.4[3]
Pooled Error	13,253.8	68	194.9	
TOTAL	71,168.4	107		

[1]M, C, A: Treatments for marihuana, control and alcohol.

[2]Significant F, $P < .05$

[3]Significant F, $P < .01$

TABLE 2
SIGNIFICANT TREATMENT DIFFERENCES[1]

SIMULATOR TEST	TEST VARIABLE ERRORS[2]					
	ACCELERATOR	SIGNAL	TOTAL	BRAKE	SPEEDOMETER	STEERING
Period 1	A > C[3]	A > C	A > C	None	A > C M > C	None
Period 2	A > C	A > C	A > C	A > C	None	None
Period 3	None	A > C	A > C	A > C	None	None

[1]Significant F's from Latin square analysis of variance, $P < .05$.

[2]Accelerator, signal, and total errors are significantly correlated with driving performance for normal drivers. No correlation was found for brake, speedometer, and steering errors.

[3]A > C, M > C indicate error scores for alcohol (A) or marihuana (M) treatment are greater than control (C).