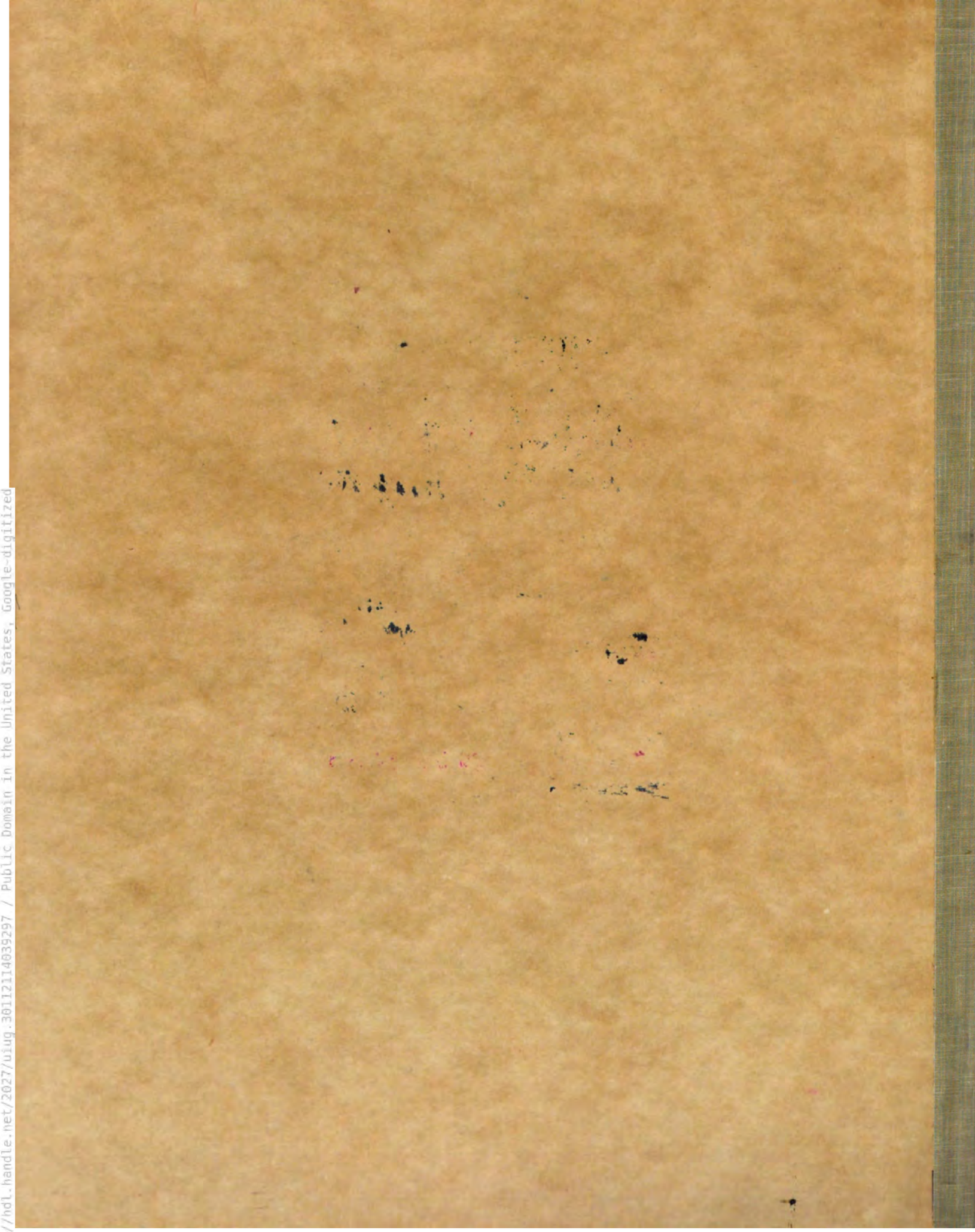
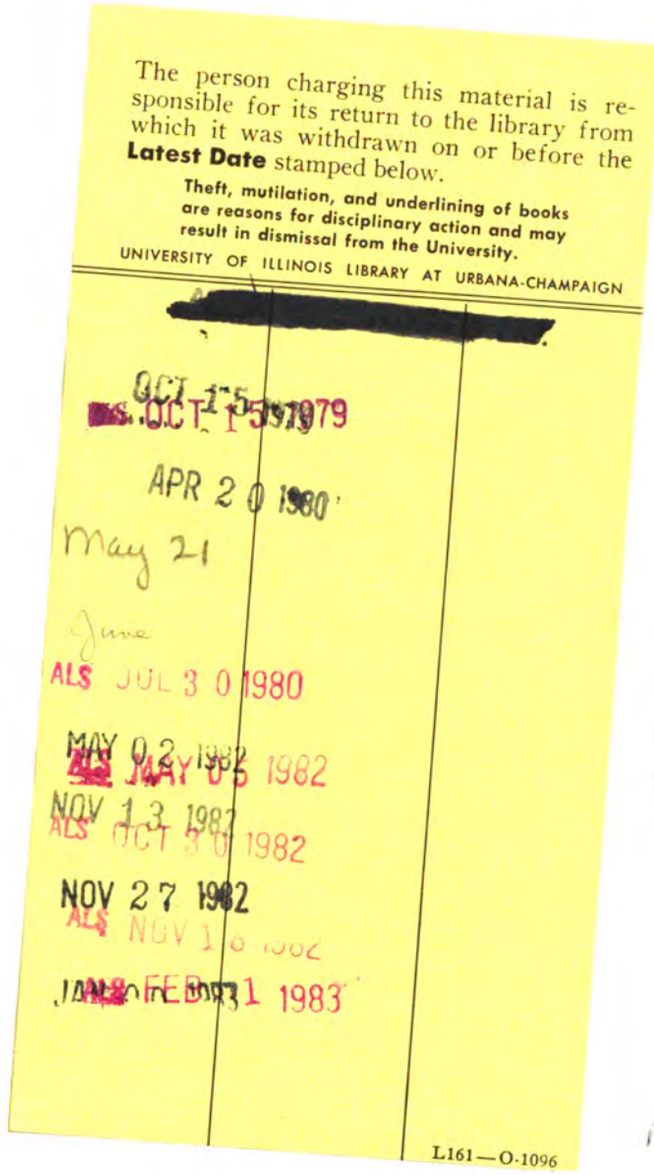
THE EFFECTS OF MARIHUANA AND ALCOHOL ON SIMULATED DRIVING PERFORMANCE





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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

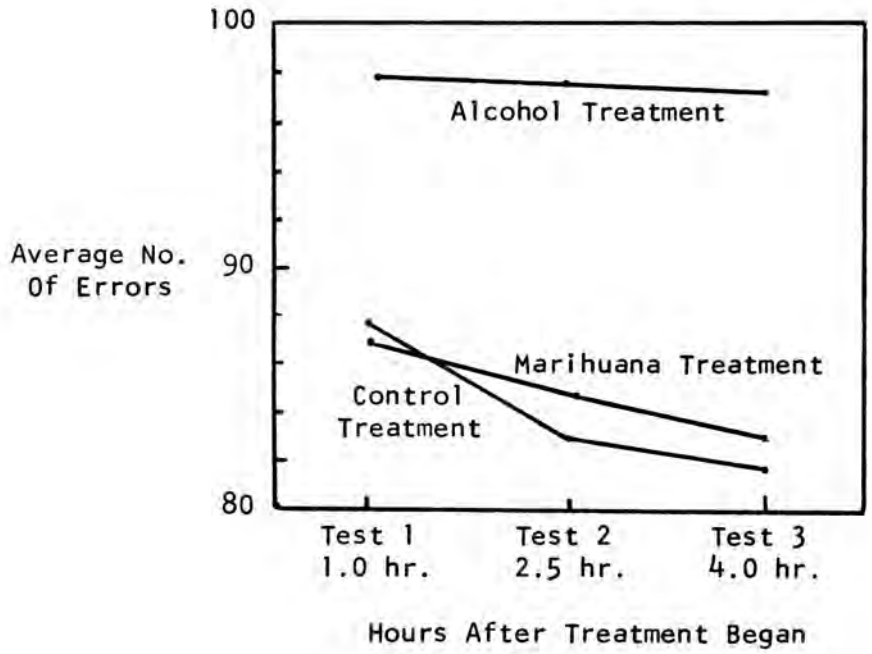

TABLE 1
ANALYSIS OF VARIANCE: TOTAL DRIVING SIMULATOR
ERROR SCORES FOR THREE TREATMENTS

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).