DOT HS-800 951

THE EFFECT OF MARIHUANA DOSAGE ON DRIVER PERFORMANCE

Contract No. DOT HS-150-2-236
October 1973
Final Report

PREPARED FOR:
U.S. DEPARTMENT OF TRANSPORTATION
NATIONAL HIGHWAY TRAFFIC SAFETY ADMINISTRATION
WASHINGTON, D.C. 20590

TECHNICAL REPORT STANDARD TITLE PAGE

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
DOT HS-800 951		

4. Title and Subtitle	5. Report Date
THE EFFECT OF MARIHUANA DOSAGE ON DRIVER PERFORMANCE	October, 73
	6. Performing Organization Code
7. Author(s)	8. Performing Organization Report No.
H. Moskowitz, W. McGlothlin, S. Hulbert	UCLA-ENG-7341
9. Performing Organization Name and Address	10. Work Unit No.
Institute of Transportation and Traffic Engineering, University of California Los Angeles, California 90024	11. Contract or Grant No. DOT HS-150-2-236
	13. Type of Report and Period Covered Final Report 7/1/71 - 8/31/72
12. Sponsoring Agency Name and Address U.S. Department of Transportation National Highway Traffic Safety Admin Washington, D.C. 20590	14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract

Performance in a complex driving simulator under 4 marihuana dose levels was examined. Car control and tracking appeared to be uninfluenced, but significant dose-related impairment was found on a visual recognition task simulating the search-and-recognition aspects of driving. An additional study of sensory signal detection supported the view that the perceptual deficit induced by marihuana involves a decrease in discrimination sensitivity.

17. Key Words	18. Distribution Statement
Human Factors, Marihuana, Drugs, Perception, Signal Detection, Driving Simulators	Unlimited available through the National Technical Information Service Springfield, Virginia 22151

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	63	

Form DOT F 1700.7 (8-69)

ACKNOWLEDGMENTS

This work was made possible by funds from several governmental agencies. Appreciation for this support is expressed to the National Highway Traffic Safety Administration, U. S. Department of Transportation, the Center for Narcotic and Drug Abuse, NIMH, HEW, and the National Institute on Alcoholism and Alcohol Abuse, NIMH, HEW.

The assistance of Dr. A. Ahumada, University of California at Irvine was invaluable in the execution of the statistical analysis.

Data processing was made possible through use of the facilities of the Health Sciences Computing Facility and the Central Computing Network, UCLA.

SUMMARY

There are inadequate epidemiological data to establish whether using marihuana will increase the probability of driving accidents.

As a means of assessing the potential effects of marihuana upon driving safety, this study included two experiments involving administration of marihuana to subjects who were required to perform tasks assumed important for driving. The first experiment examined performance in a complex driving simulator, the second performance of a sensory signal detection task.

In both studies 23 subjects were examined in replications of Latin square designs with marihuana treatments containing 0, 50, 100 or 200 micrograms delta-9 tetrahydrocannabinol per kilogram bodyweight.

The simulator study utilizes an actual car mounted on a chassis dynamometer, facing a 160 degree screen on which is projected a filmed ride of 31 miles. The speed of the film projection is controlled by the accelerator and brake pedals. The subject must manipulate the steering wheel appropriately as the scene pivots laterally in response to a program describing the contours of the road.

While tracking the filmed scene the subject is also required to respond as rapidly as possible to a visual recognition subsidiary task within the car. This subsidiary task simulates the search-and-recognition component of the actual driving function.

Results suggest little effect of marihuana upon the car control aspects of the driving simulator. However, there was a statistically significant and clearly dose-related impairment of the subsidiary task with both an

increase in errors of recognition and a delay in response to the visual recognition task.

The results of the study are discussed in relation to the experimental literature on the effects of marihuana. In studies of the effects of marihuana upon tracking, inconsistent evidence for an impairment by marihuana has been reported. On the other hand, there is considerable evidence that marihuana does produce an impairment of sensory perceptual functions.

The second experiment examined an auditory signal detection task in conditions of both concentrated and divided attention under marihuana. The technique employed permitted the use of signal detection theory. Again, a clearly dose-related significant impairment of performance under marihuana was found. The signal detection theory analysis made it clear that the performance deficit was related to a true change in discrimination sensitivity and was not merely a change in criterion. These results support the finding of the previous experiment that marihuana affects the perceptual functions in driving and may therefore constitute a danger to driving safety.

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PART I

THE EFFECTS OF MARIHUANA UPON PERFORMANCE IN A DRIVING SIMULATOR

H. Moskowitz

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INTRODUCTION

On-site investigations of driving accidents and fatalities have demonstrated the threat to driving safety produced by the use of alcohol. The increasing widespread use of marihuana suggests the need for an evaluation of its effects on driving performance. Unfortunately, due to technical difficulties in determining whether drivers in accidents are under the influence of marihuana, there is little epidemiological data bearing on the relationship between traffic safety and marihuana use. (Nichols, 1971).

Evaluation of the relationship between marihuana use and driving must, therefore, depend upon studies which examine the effects of marihuana upon skills assumed to be important for driving. These studies include those which have examined performance in a driving simulator under marihuana. (Crancer, et al. 1969, Rafaelsen et al. 1973). Disparate results from these two studies suggested the value of further examination of this issue in a more complex driving simulator.

The following investigation was a double blind examination of the effects of three doses of marihuana and a placebo upon performance in a driving simulator which uses a film projection system. The results which were obtained are discussed with reference to an accompanying study which examined the effect of marihuana upon a signal detection task.

METHOD

Subjects

The experimental design required 24 subjects to be exposed to 4 treatments in 6 replications of a 4 × 4 Latin square design. However, since participation in this study was restricted to those subjects who had completed a previous study involving 4 experimental treatments with marihuana, only 23 subjects were available. They were male college students between 21 and 32 years of age with a mean age of 24 years.

Subjects were recruited by advertisements in the college newspaper and placement center. The notices solicited paid volunteers for a behavioral study, and potential subjects were not informed that the experiment involved marihuana until after appearing for a screening interview. Subjects were screened for emotional or health abnormalities and cooperative attitudes by an interview and the Minnesota Multiphasic Personality Inventory. Only applicants with at least ten prior experiences with marihuana were accepted. Applicants currently using marihuana more frequently than three times a week or with a history of extensive use of other drugs were excluded.

Apparatus

The experiment utilized the UCLA driving simulator which has an actual car mounted on a chassis dynamometer facing a 20-foot wide cylindrical screen. The screen subtends a 160 degree view from the driver's eye position. A film photographed from a car during approximately 31 miles of travel is projected on the screen. The subject can proceed over this journey at his own rate since the speed of the film projector is controlled by the subject's use of the brake

and accelerator. The subject is required to manipulate the steering wheel in an appropriate fashion as the projected scene moves laterally to follow the contours of the road. The movement is produced by a heading rotation of the projector which is controlled in part by an input from a paper tape recorder. A tape record of the angular movements of the road is synchronized with the film presentation. The final angle of display is a joint function of the inputs from the tape recorder and the subject's use of the steering wheel.

Data produced by transducers which measure the steering wheel, accelerator and brake positions are recorded on analogue tape for subsequent computer analysis. These measures are transformed into 25 performance scores designed to describe aspects of driver control and tracking behavior.

The study utilized three films, a training drive and two test drives. The two test films contained about 85% of common footage. Film sections occurred in different sequences in the two films to minimize driver boredom. The study restricted its analysis to 36 segments of the drive which occurred in both films, so that all subjects were examined for the same driving segments on all sessions. These segments, called "events" in the computer output, occupied about 50% of the driving time. They represented a sample of all the driving conditions found on the film.

For the 36 segments the following 25 performance scores are examined:

7 speed scores (speed at beginning of segment
speed at end of segment
minimum speed
maximum speed
average speed in film frames per time unit
average speed in miles per hour
number of speed reversals of at least 5 mph)

6 accelerator scores (number of reversals of 2% of total possible travel
number of reversals of 5% of possible travel
average accelerator position
maximum position
time to first accelerator let-up of 3%
time to first complete accelerator let-up)

3 brake scores (maximum brake pressure
time to first brake use
time from accelerator let-up to first brake pressure)

5 steering wheel scores (average position
average rate of change
number of reversals of 5 degrees
number of reversals of 10 degrees
number of reversals of 15 degrees)

4 tracking scores (length of path of the car ride
ratio of path driven to minimum possible path
average difference between steering wheel heading and the heading of the real car path
maximum difference between steering wheel heading and the heading of the real car path)

A fuller description of the simulator is found in Moskowitz (1971).

In addition, subjects were requested to respond to a visual subsidiary task. The purpose of this task is to present the driver with a demand for joint information processing similar to that found in actual driving. In driving, attention is shared between a road tracking task and a search and recognition task. The information needed for tracking and car control in the simulator comes from the filmed scene. However, there is less need for the wide ranging search and recognition task found in actual driving in the

simulator films because the subject soon realizes that he is unlikely to experience traffic signals, cars crossing his path, pedestrians or any of the other potential dangers found in driving. The subsidiary task is intended as a substitute sample of the greater search-and-recognition task demands of the actual driving situation.

The subsidiary task required one of four possible lever responses corresponding to four possible light signals. The light signals appeared in 2 boxes mounted near the sun visor of the car, approximately 13 inches in front of the subject at 15 degrees to each side and 12 degrees above the eyes. Each box contained two colored lamps, amber and green. Responses were made using turn signal levers mounted on both sides of the steering column. A correct response was made by pressing the lever on the same side as the light signal presented, either down for green or up for amber. The light went off after a correct response. If an incorrect response was made to the appearance of a light, it was recorded but the light remained on until either a correct response was made or 10 seconds had elapsed. The reaction time recorded was for the final correct response only.

There were 50 light presentations during the 36 drive segments and the reaction time to the lights for the correct response was automatically recorded to an accuracy of .1 milliseconds.

These light presentations were keyed to the film frames and always occurred at exactly the same point in the drive. This ensured that they appeared to all subjects under the same conditions of joint information processing with stimuli from the road scene. A wide variety of representative situations on the film were selected for the subsidiary task presentations. Generally, reaction times were greatest at those points which required the greatest attention to the road scene.

Treatments

The 4 × 4 Latin square experimental design required four test days for each subject. The four treatments were a placebo and three active marihuana dosages. The placebo and active marihuana treatments were administered by requiring each subject to smoke two cigarettes of approximately 1/2 gram each. Each cigarette was composed of a mixture of marihuana containing 1.4% delta-9 tetrahydrocannabinol (THC) and detoxified marihuana.

The delivered doses were 0, 50, 100 and 200 micrograms delta-9 THC per kilogram bodyweight (kg. B.W.). The marihuana cigarettes were prepared by a person having no contact with the subjects. They were delivered to the experimenters in envelopes with the name of the subject and the date of administration. Thus, all persons in contact with the subjects were unaware of the dosage level, and the experiment was conducted as a double blind study.

The subjects had been instructed in the required smoking procedure during the training period for the preceding study. They were requested to inhale fully, and to hold the smoke in their lungs for a 15 second period. Inhalations occurred at 35 second intervals. The butt of the cigarette was placed in a glass holder to permit the entire amount to be smoked. It was required that both cigarettes be consumed within 20 minutes. Subjects were monitored for procedure throughout the smoking period by an experimenter with a stop watch.

Procedure

Subjects participated in one training and four experimental test sessions. The treatment sessions for an individual subject occurred at weekly intervals, and at the same time of day.

At the training session subjects were instructed in the car handling procedures, given practice on the subsidiary task alone, and then drove the

simulator vehicle over a filmed road scene for approximately 20 minutes. The road scenes used in the training session were not included in the test films. The training drive included the presentation of the visual subsidiary task.

On experimental test days subjects were requested to first relax in a comfortable chair for 15 minutes. Their pulse rates were then taken, followed by the experimental treatment. Smoking required 20 minutes, after which the post-smoking pulse rate was taken. Subjects immediately entered the driving simulator and drove the 31 mile drive which required between 45 and 70 minutes depending on the speed of driving. After finishing the drive, pulse rates were again taken. Subjects remained in the laboratory until both subjective and objective indices of drug effect were absent.

RESULTS

Table 1 shows the characteristic dose-related increment in pulse rate following marihuana administration. Mean pulse rate changes of 27%, 35% and 40% were found for the 50, 100 and 200 mcg delta-9 THC/Kg.B.W. treatments. The placebo treatment exhibited a 14% increase. The previous study utilizing the same subjects also showed a clear dose-related response in terms of self-rating of intoxication level, and a subjective drug effects questionnaire.

The results for the car control and tracking aspects of the driving simulator are summarized in Tables 2 and 3. Table 2 presents the mean performance scores and Table 3 the mean within subject variability on these scores. This latter is of considerable importance for driving since inconsistency of response can represent a potential threat to safety. Moreover, inconsistency of performance has often been a characteristic of performance under alcohol treatments (Moskowitz, 1971). Tables 2 and 3 are based on the results for 21 subjects — tape recorder failure occurred during two subject runs.

Examination of the mean and variability scores for the 25 response measures fails to reveal any consistent trend. This impression was supported by the statistical analysis. Data were analyzed both by an analysis of variance (Computer program BMD 05V, Health Sciences Computing Facility, UCLA, described in Dixon, 1970) and by paired comparisons between the placebo and other treatment scores using Student's t test. (Examples of the statistical procedures are illustrated in Appendix A.) None of the analyses of variance were statistically significant for treatment effects. Of the 150 paired comparisons (25 mean and 25 variability measures compared for the placebo versus

Table 1
Mean Pulse Rate Before and After Smoking Marihuana

	PLACEBO	MARIHUANA DOSE mcg. delta-9 THC/Kg. B.W.		
	0	50	100	200
Before Smoking	76.7	79.8	79.0	79.3
After Smoking	87.6	101.4	106.3	111.1
After Driving	74.0	83.0	83.4	87.0

Table 2
Mean Performance Scores for 36 Segments (Events) of the Driving Simulator
Runs Under 4 Marihuana Treatments
(mcg. delta-9 THC/Kg. B.W.)

	PLACEBO 0	50	100	200
Speed at the Beginning of the Event (MPH)	37.211	36.877	37.220	36.050
Speed at the End of the Event (MPH)	37.314	36.652	37.018	36.225
Minimum Speed During the Event (MPH)	32.630	31.926	32.354	31.379
Maximum Speed During the Event (MPH)	41.722	41.484	41.678	40.724
Speed Revs of 5 MPH Per 25 Film Frames	0.052	0.067	0.047	0.053
Average Speed During the Event (MPH)	37.515	36.797	37.221	36.127
Average Speed During the Event (Film Frames/Sec)	25.359	24.273	24.980	23.422
Acc. Revs of 2 Percent per 25 Film Frames	0.132	0.156	0.170	0.156
Acc. Revs of 5 Percent per 25 Film Frames	0.048	0.056	0.059	0.058
Time To 1st Complete Acc. Let-up (Secs)	1.435	1.505	1.580	1.777
Average Acc. Position (Percent Depressed)	5.228	4.879	5.025	4.805
Time to 1st Acc. Let-up of 3 Percent (Secs)	1.519	1.601	1.730	1.607
Maximum Position of Acc. (Percent Depressed)	8.547	8.503	8.636	8.231
Time From Acc. Let-up to 1st Brk Prs. (Sec)	-0.070	-0.077	-0.164	-0.199
Time to 1st Br. Prs. From Start of Evt. (Sec)	0.178	0.360	0.171	0.323
Maximum Amount of Brk Prs. (Percent of Maximum)	2.874	4.963	3.496	2.476
Average Position of the Steering Wheel (Degrees)	-18.086	-17.344	-16.176	-19.600
Average Rate of Chg. of Steering Wheel (Degree/Sec)	163.381	159.653	161.372	159.088
Steer Revs. of 5 Degrees per 25 Film Frames	0.445	0.437	0.482	0.417
Steer Revs of 10 Degrees per 25 Film Frames	0.235	0.237	0.235	0.236
Steer Revs of 15 Degrees per 25 Film Frames	0.162	0.174	0.168	0.168
Len. of Pth. of Car in Event (Eq. Film Frames)	317.184	319.689	330.608	320.088
Ratio of Eq. Film Frames to Real Film Frames	1.050	1.048	1.046	1.054
Average Dif. Between Steering and Steering Comp. (Degrees)	23.182	22.157	22.666	25.394
Maximum Dif. Between Steering and Steering Comp. (Degrees)	51.878	52.996	53.973	57.573

Table 3
Mean Within Subject Standard Deviation of Performance Measures for 36 Segments (Events) of the Driving Simulator Runs Under 4 Marihuana Treatments
(mcg. delta-9 THC/Kg. B.W.)

	PLACEBO 0	50	100	200
Speed at the Beginning of the Event (MPH)	7.368	7.391	7.545	7.567
Speed at the End of the Event (MPH)	7.423	7.562	7.858	7.824
Minimum Speed During the Event (MPH)	7.481	7.476	7.789	7.638
Maximum Speed During the Event (MPH)	7.385	7.395	7.810	7.600
Speed Revs of 5 MPH Per 25 Film Frames	0.080	0.104	0.080	0.087
Average Speed During the Event (MPH)	7.890	7.447	8.256	7.397
Average Speed During the Event (Film Frames/Sec)	5.697	5.355	7.713	4.810
Acc. Revs of 2 Percent per 25 Film Frames	0.128	0.154	0.180	0.151
Acc. Revs of 5 Percent per 25 Film Frames	0.076	0.084	0.091	0.088
Time to 1st Complete Acc. Let-up (Secs)	3.135	3.531	3.749	3.965
Average Acc. Position (Percent Depressed)	2.364	2.314	2.351	2.269
Time to 1st Acc. Let-up of 3 Percent (Secs)	3.096	3.380	3.804	3.732
Maximum Position of Acc. (Percent Depressed)	3.232	3.424	3.086	3.167
Time From Acc. Let-up to 1st Brk Prs. (Sec)	1.388	1.256	0.963	1.400
Time to 1st Br. Prs. From Start of Evt. (Sec)	0.891	1.135	0.716	1.206
Maximum Amount of Brk Prs. (Percent of Maximum)	11.913	13.657	10.105	9.506
Average Position of the Steering Wheel (Degrees)	15.859	16.301	17.553	16.266
Average Rate of Chg. of Steering Wheel (Degree/Sec)	14.854	12.041	13.707	10.935
Steer Revs. of 5 Degrees per 25 Film Frames	0.419	0.406	0.409	0.362
Steer Revs of 10 Degrees per 25 Film Frames	0.249	0.251	0.240	0.251
Steer Revs of 15 Degrees per 25 Film Frames	0.188	0.210	0.194	0.196
Len. of Pth. of Car in Event (Eq. Film Frames)	243.338	238.214	243.298	238.594
Ratio of Eq. Film Frames to Real Film Frames	0.119	0.115	0.133	0.094
Average Dif. Between Steering and Steering Comp. (Degrees)	7.971	9.000	9.036	9.579
Maximum Dif. Between Steering and Steering Comp. (Degrees)	33.067	33.315	34.285	35.931

the 3 active drug treatments) only 7 or 4.7% were statistically significant beyond the 5% level of confidence. Such a finding for post hoc comparisons would be expected by chance. Thus, the data provide no evidence that marihuana significantly affects the car control performance as measured by the UCLA driving simulator.

The mean reaction times and within-subject standard deviations for the subsidiary task light presentation are shown in Tables 4 and 5. These data are for all 23 subjects. The data in both tables are presented for various response categories: a) all responses including omissions counted as 10 second responses, b) all responses excluding omissions, c) only those responses which were initially correct, and d) only those responses which were initially wrong and then corrected. There was only one incorrect response in the entire experiment which was not corrected, and it was dropped from the analysis. Table 4 also presents the number of omissions and wrong responses.

The data suggest a dose-related impairment of reaction times to the subsidiary task. For the category of all responses including omissions, the 3 active drug treatments produced increases in mean reaction times of 5.3%, 10.6% and 11.6%. Relative changes in the category of all responses excluding omissions were 5.3%, 10.0% and 11.1%. Initially correct responses had increased reaction times of 3.0%, 10.3% and 9.1%. These changes were subjected to a 4×4 Latin square analysis of variance using the BMD 05V computing program. All 3 ANOVA's proved statistically significant with the levels of confidence shown in Table 4.

While Table 5 shows a trend toward increasing within-subject reaction time variability as a function of marihuana dose, this did not prove to be statistically significant (F_{MAX} test for homogeneity of variance and BMD 05V computer program for trend). Table 6 shows the distribution of all individual reaction

Table 4
Mean Reaction Time to the Subsidiary Task Under Marihuana (Secs.)

	MARIHUANA DOSE: mcg. delta-9 THC/Kg. B.W.				STATISTICAL SIGNIFICANCE LEVEL
	PLACEBO 0	50	100	200	
All Responses Including Omissions	1.0601	1.1160	1.1727	1.1829	.05
All Responses Excluding Omissions	1.0460	1.1017	1.1510	1.1620	.01
Initially Correct Responses	1.0261	1.0573	1.1220	1.1194	.01
Initially Incorrect Responses	1.3354	1.5007	1.3965	1.5064	Not tested due to unequal subject numbers
Omissions	2	2	3	3	Not tested due to small number in the category
Number of Initially Incorrect Responses	73	110	90	124	.05

Table 5
Mean Within Subject Standard Deviation on the Subsidiary Task (Secs.)

	MARIHUANA DOSE: mcg. delta-9 THC/Kg. B.W.				STATISTICAL SIGNIFICANCE LEVEL
	PLACEBO 0	50	100	200	
All Responses Including Omissions	.3755	.5065	.5315	.5715	Not significant
All Responses Excluding Omissions	.3238	.4387	.4649	.4767	Not significant
Initially Correct Responses	.2698	.3296	.4302	.3771	Not significant
Initially Incorrect Responses	.1976	.5380	.3214	.4135	Not significant

Table 6
Distribution of Reaction Times to the Visual Subsidiary Task Under Marihuana

MARIHUANA DOSE: mcg. delta-9 THC/Kg. B.W.	SECONDS										
	<.50	.5-1.0	1.0-1.5	1.5-2.0	2.0-2.5	2.5-3.0	3.0-3.5	3.5-4.0	4.0-4.5	4.5-5.0	>5.0
Placebo	0	646	404	64	9	1	1	1	2	0	5
50	8	608	361	80	16	11	4	4	2	1	7
100	2	587	396	82	27	11	7	4	1	1	11
200	6	559	404	86	38	14	5	6	1	0	9

times for the four treatments. It indicates that the increase in mean reaction time is accompanied by a flattening out of the distribution with increasing dose. The marihuana treatment data exhibit increased anticipatory short responses and, more often, an increased number of long reaction times. Of course, this distribution represents the effects of both within- and between-subject variability.

In summary, the data clearly indicate a dose-related increase in errors and reaction time to the visual subsidiary task under marihuana. There is no evidence of a marihuana influence upon the car control and tracking aspect as measured by the driving simulator.

DISCUSSION

The present study found a marihuana dose-related impairment in responses to the subsidiary task which was intended to represent the search and recognition aspect of driving. No significant impairment was found in the car control and tracking measures. Are these results consistent with the existing scientific literature?

Unfortunately, there are no experimental data relating the number or type of driving accidents to the use of marihuana. The only comparative data comes from studies of the effect of marihuana on simulator performance and various skills required for driving. Finding a perceptual deficit in the simulator under marihuana is consistent with the experimental literature. In the most closely related laboratory study of visual signal detection under marihuana, Moskowitz, Sharma, & McGlothlin (1972) found large dose-related decrements in peripheral signal detection while fixating upon a central visual task.

Other examples of perceptual deficits under marihuana are found in Moskowitz and McGlothlin (1973) which reported dose-related deficits in auditory signal detection, and Cappell, et al. (1972) which found dose correlated deficits in timing behavior.

The increased reaction time to the subsidiary task is unlikely to be a function of delayed motor responsiveness. If there were motor response interference, the car control scores might have exhibited a deficit. Moreover, in a study which separated perceptual from motor response factors, Moskowitz, Sharma, & McGlothlin (1972) found no impairment in reaction times.

This study failed to find any decrement in car control and tracking measures. The study bearing most directly on this issue (Reid, et al., 1973 summarized in LeDain, et al., 1972) used a single axis compensatory tracking task on an oscilloscope to derive human operator describing functions for alcohol and marihuana. In such a study the frequency response demands often exceed any found in driving. Blood alcohol levels of .03% and .07% were compared with marihuana doses of 21 and 88 mcg. delta-9 THC/Kg.B.W. While there was a trend towards increased tracking errors for both drugs, only the effect for the larger alcohol dose was statistically significant. For marihuana the only effect appeared to be an increase in random output unconnected with input. There was little evidence for any effect of marihuana upon the amplitude or phase characteristics of the tracking response in contrast to the deficits shown under alcohol.

On the other hand, Manno et al. (1970, 1971) found strong evidence for performance decrements on a complex pursuit tracking task for a 5 milligram delta-9 THC marihuana treatment. Similar results for the same task were also obtained for a drug dose replication with treatments ranging from 6.25 to 50 mcg. delta-9 THC/Kg.B.W. (Kiplinger, et al., 1971).*

Perhaps the difference in results between these studies and Reid's can be accounted for by the greater perceptual complexity of the pursuit tracking task, which may make it more susceptible to drug influence. In general, pursuit tracking has been more susceptible to alcohol influence than has compensatory tracking. (Moskowitz, In Press).

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*These dose levels were estimated by the authors on the assumption that only 50% of the smoked marihuana is actually absorbed by subjects. The administered treatments contained twice the stipulated doses, and it is this double figure which is necessary for comparisons with other studies.

Thus, the laboratory investigations of tracking behavior under marihuana indicate a potential decrement, but its degree appears related to complexity of the tracking task, and direct translation of its possible effect in typical driving situations is not clear.

Car handling and tracking were also examined in an on-the-road test using a closed course (LeDain, 1972). This study compared 21 and 88 mcg. delta-9 THC/Kg.B.W. marihuana doses with a blood alcohol level of .07%. The experiment involved 6 circuits of a 1.1 mile course through lanes marked with cones and poles. Both forward and backward maneuvering were involved. The mean number of objects struck under a placebo treatment was 13.2. This rose to 16.8 for the higher marihuana dose and 17.4 for the alcohol treatment. The smaller marihuana dose had no effect.

Observer-raters posted on the course were unable to discriminate between the driving behaviors on the four treatment conditions. Clearly, the data suggest an effect on car control by marihuana, but its implications are somewhat limited by the artificially difficult character of the tracking task, which is not characteristic of normal driving.

Comparison of the results of this current study with other driving simulator studies is not easy. No available simulator is a truly complete sample of all the elements which enter into the demands of actual driving. Each simulator selects some sample of behavior which the investigator considers relevant to the driving task, and in this sense all are essentially part-task simulators. If disagreement in results arise, it can be due to dissimilar drug interactions with the differing elements contained in the various simulators.

Crancer et al. (1969) compared the effects of a 22 milligram delta-9 THC marihuana dose with a blood alcohol level of .10% The simulator utilized a 23

minute film projection over which the subject had no control. The subject sat in a car mockup with all the usual instruments. Although he was expected to manipulate the steering wheel and turn signals, and to brake and accelerate, these actions had no effect on the presentation of the ride. The accelerator did control the speedometer reading, and maintaining the speedometer reading within given limits was one of the response measures. The other response measure was responding appropriately to the film when it appeared to require a stop, a turn, or some other maneuver. Although the alcohol treatment affected 4 of the 5 response measures, the only measure influenced by marihuana was the speedometer measure.

It is difficult to evaluate this study since it is not obvious what the response scores, other than the speedometer, were measuring. Since there was no effect of the other responses upon the filmed drive, they scarcely can be described as measures of either car control or tracking. The speedometer measure was clearly an indication of the monitoring of the speedometer, and the evidence that this was affected by marihuana agrees with the previous evidence that marihuana affects perceptual processes. Moreover, a recent study by Sharma and Moskowitz (1973) demonstrates an extremely large and consistent effect of marihuana upon vigilance which would appear to agree with this finding.

There have been several criticisms of the Crancer et al. study (Kalant, 1969), one of which has raised questions as to the strength of the marihuana actually administered (Manno, et al., 1971). While the subjects reported "highs", it is clear that this is not a reliable index of marihuana treatment (Moskowitz and McGlothlin, 1973). However, the major criticism is that only one variable has some face validity as to meaning. Insofar as it does, the results are in agreement with the study under report.

The simulator in Rafaelsen, et al. (1973) used a car mockup which included a windshield on which was projected a moving landscape from a circular painting. The car mockup was equipped with a steering wheel, accelerator, brake, gear shift and clutch. The accelerator controlled the speed of the circular landscape and the steering wheel shifted the projected image on the windshield. Thus, the "car's" behavior was responsive to the driver's behavior. The car mockup was equipped with red and green lamps just above the windshield. If the red light was lit, the subject was to stop the car and start only on the re-appearance of the green light. The duration of the red light was always 10 seconds and it appeared 10 times at random intervals during the 10 minute drive. Response measures were brake time, start time, number of gear changes and mean speed. The brake and start times were the latency in responding to the appearance of the red and green lights. The study compared marihuana treatments of 8, 12 and 16 milligrams of delta-9 THC with 70 grams of alcohol. The marihuana was presented in a baked cake and is a dose only about 2/3 as effective as the same dose presented by smoking. Both alcohol and marihuana produced increases in latency of responses to the lights as measured in the brake and start times. The 8 mg. marihuana dose had no effect, but the 12 and 16 mg. doses produced large increases with the alcohol dose effect about midway between the two higher marihuana doses. The number of gear changes was unaffected by marihuana but was affected to a small but statistically significant degree by alcohol. Neither drug affected the mean speed.

The characteristics of the simulator used by Rafaelsen, et al. (1973) are more akin to those used in the current study with the driver in control of the speed of the drive and some lateral movement of the car relative to the road. Moreover, both studies included a visual task which is representative

of the demands for monitoring the other aspects of the road environment besides those involved in lane position or tracking.

Clearly the brake and start times in response to the lights are primarily determined by the perceptual monitoring of the lights, and both are affected by marihuana. This agrees with the current study and with all the other available literature. To the extent that gear shifting and speed represents aspects of car control and tracking, marihuana had no effect, which agrees again with the current study.

The conclusion would appear to be that there is strong evidence that marihuana interferes with the perceptual aspects of driving, the monitoring of the environment. This is supported by simulator and other laboratory studies as well as by subjective observations offered by some marihuana users.

Evidence for a loss of car control or of tracking under marihuana is uncertain. Moreover, to the extent that it is offered, it is not clear to what extent the car control and tracking tasks which have shown performance decrements under marihuana are representative of the car control and tracking demands of driving. At this point in the evaluation of experimental evidence, a plea of nolo contendere is perhaps best. It should however be noted that perceptual failures are listed as causes (Clayton, 1972) in nearly half the driving accidents attributed to human failures. Thus, the evidence that marihuana produces a perceptual deficit suggests that its use represents a potential for accident causation.

Many investigators of the effects of marihuana have included an alcohol control treatment. The implicit assumption has been that by establishing the relative impairment of the performance measure by the two drugs, alcohol and marihuana, it will be possible to proceed from the known relationship between accident probability and blood alcohol level to a judgment as to the probable

accident potential of marihuana use. The difficulty in this position is that it assumes that the effects of marihuana and alcohol differ in degree rather than in kind.

It now is clear that marihuana and alcohol differ strikingly in the nature of their effects, not merely in the degree of effect. Whereas alcohol does not impair either auditory or visual signal detection in situations where the rate of information being produced by the source is low, marihuana produces a large decrement (Moskowitz, Sharma & McGlothlin, 1972; Moskowitz & McGlothlin, 1973). Vigilance tasks with low rates of information processing are similarly unaffected by alcohol but strongly impaired by marihuana (Sharma & Moskowitz, 1973). Similar results also have been found for the visual autokinetic effect (Sharma & Moskowitz, 1972) and timing behavior (Cappell, et al., 1972). On the other hand, there are many situations where alcohol produces a greater impairment than marihuana. Examples are tracking (Reid, et al., 1973), car control and tracking on a closed course (LeDain, 1972), some simulator studies (Crancer, et al., 1969) and auditory signal detection under high information processing rates (Moskowitz & McGlothlin, 1973).

A decision as to the probable accident potential of marihuana in comparison to alcohol depends on the experimenter's viewpoint regarding the importance to driving safety of the response measure under investigation. Unfortunately, there is no universal agreement regarding the significance of various behavioral skills for driving.

In another publication, Moskowitz (1971) has argued that the key factor in alcohol accidents is the interference with the ability to divide attention between tracking and the search-and-recognition aspects of monitoring the driving environment. If this position is accepted, then it appears that

alcohol at the dose levels tested constitutes a greater danger than marihuana, because alcohol appears to produce a greater decrement in situations with demands for high rates of information processing as are often found in driving.

It should be noted that most alcohol treatments in the above studies have resulted in no more than .10% blood alcohol level. Yet the mean alcohol level of fatalities is in the region of .17%, and drivers frequently are found on the highway with BAL's above .25%. Marihuana studies often have given as high as 200 mcg. delta-9 THC/Kg.B.W. marihuana treatments; these are close to the limit beyond which most subjects either become ill or experience strong adverse reactions. Many comparisons then are between alcohol doses which are typical and usual for experienced heavy drinkers and marihuana doses which are unusual and large for typical users of marihuana in this country.

In the present simulator study, the driving demands did require a division of attention and moderate demands for information processing. The marihuana treatment results can be compared with a prior study of the effects of a .83 grams alcohol/Kg.B.W. dose given to two groups of drivers, moderate drinkers and alcoholics. (Moskowitz, 1971). The alcohol treatment produced less than .09% blood alcohol level, yet the performance decrement for all subjects including the heavy drinking alcoholics was greater than in this current marihuana study. The reaction times to the subsidiary light signals were more delayed, and there was a significant increase in both within and between subject variability. Moreover, there was a significant increase in variability of performance on the car control-tracking measures.

In summary, the comparison of studies from this simulator for the two drugs suggests that alcohol has a greater detrimental effect than marihuana with commonly used dose levels. Of course, this simulator is designed to measure the variables selected by the investigators, and other research might

not yield the same results if different behavior skills are required by another simulator or other experimental tasks. The overall conclusion of this study is that the use of marihuana by drivers is a threat to safety, because it impairs perceptual functions. The likelihood of an effect upon tracking ability is potentially present but the evidence is less clear. To establish the degree of driving performance impairment is difficult, because the mechanisms involved in the marihuana-induced perceptual deficits appear to differ from those affected by alcohol, the only drug for which we have reliable epidemiological data with which to establish drug-dose-accident probability correlations.

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PART II

THE EFFECTS OF MARIHUANA UPON AUDITORY SIGNAL DETECTION UNDER CONDITIONS OF CONCENTRATED AND DIVIDED ATTENTION

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William McGlothlin

INTRODUCTION

Few studies have investigated the effect of marihuana upon objective measures of perceptual performance. Those which have been reported primarily concern vision.

Apparently, marihuana does not affect visual brightness threshold (Caldwell, et al., 1969), depth perception or critical flicker fusion (Clark and Nakashima, 1968), nor dark adaptation or visual acuity (Moskowitz, Sharma and Schapero, 1972).

However, more complex functions such as visual autokinesis (Sharma and Moskowitz, 1972), central vision signal detection (LeDain, et al., 1972) and peripheral visual signal detection (Moskowitz, Sharma and McGlothlin, 1972) show large performance decrements under marihuana.

Three measures of auditory sensory performance (differential frequency and amplitude threshold, and absolute auditory threshold) have been examined under marihuana by Caldwell et al. (1969, 1970). Little effect on these sensory functions was found, but the study did not use equal doses for all subjects so the conclusion is somewhat obscured.

The present study examines the effect of marihuana upon a more complex auditory perceptual function than those previously reported. Performance changes in auditory signal detection are examined for conditions of both concentrated and divided attention under four dose levels of marihuana. The auditory task was designed to enable the use of signal detection theory. This analysis separates a change in performance due to a criterion shift from a true change in discrimination or sensitivity.

Signal detection performance was examined under two types of attention conditions, because earlier studies of alcohol effects suggest that some forms of drug impairment of perceptual functions are related to the attention conditions under which the perceptual task is performed (Moskowitz and DePry, 1968).

An earlier study of a single dose (smoked marihuana containing 15 mg. delta-9 THC) showed impairment of a signal detection task when performed alone or when performed with a digit recall task. It failed to affect the digit recall task performed alone. This study replicates the previous work and extends the drug dose range to 0 - 200 mcg. THC per kilogram of body weight.

METHOD

Subjects

The original plan called for 25 subjects exposed to 5 treatment conditions in a 5 × 5 Latin Square design. However, one subject discontinued, and another was dropped for failure to cooperate with procedures. Thus, 23 male college students, age 21-32, completed the experiment.

Subjects were recruited by advertisement in the college newspaper, and through the college placement center. The notice solicited paid volunteers for a behavioral study, and they were not informed that the experiment involved marihuana use until after appearing for a screening interview. Subjects were screened for emotional or health abnormalities and cooperative attitudes by an interview and the Minnesota Multiphasic Personality Inventory. Only applicants with at least ten prior experiences with marihuana were accepted. Applicants currently using marihuana more frequently than three times a week or with a history of extensive use of other drugs were excluded.

Apparatus

Subjects were seated in a comfortable chair inside a sound isolation chamber. They wore Fisher HP-100 earphones which were connected to the two channels of a stereo tape recorder. The tape recorder and the experimenter were outside the sound chamber and communicated with the subject by an intercom. All instructions and test materials were pre-recorded on tape.

The test tapes contained a digit recall task on one channel, presented to the right ear, and a signal detection task on the other channel, presented to the left ear. The signal detection task channel presented a series of

random noise bursts of three second duration each, separated by a seven second silent inter-trial interval. Half of the noise bursts contained a 1,000 Hertz signal of 1 second duration, 15 decibels below the level of the noise. The 1-second signal tone occurred randomly within the 3-second burst of noise, and those noise intervals containing the signal were distributed randomly in the series.

The digit recall task channel presented a series of lists of six random digits. These occurred at 1/2 second intervals during the same three seconds that the 3-second noise burst occurred in the other channel. Sound levels for the signal and the digits were set so as to appear subjectively equal in loudness.

Treatments

The 5 × 5 Latin Square experimental design required five test days for each subject. The five treatments were: placebo, three active marihuana treatments, and a test day with no treatment. The placebo and active marihuana treatments were administered by requiring the subject to smoke two cigarettes of approximately 1/2 gram each. Each cigarette was composed of a mixture of marihuana containing 1.4% delta-9 Tetrahydrocannabinol (THC) and detoxified marihuana.

The delivered doses were 0, 50, 100, and 200 micrograms delta-9 THC per kilogram bodyweight (Kg. B.W.). The no treatment test day was included in an effort to measure any marihuana placebo effect.

The marihuana cigarettes were prepared by a person having no contact with the subjects. They were delivered to the experimenters in envelopes with the name of the subject and the date of administration. All persons in contact with the subjects were unaware of the dosage level, and the experiment was conducted as a double blind study.

During the training session subjects were instructed in a standard smoking procedure. They were requested to inhale fully, and to hold the smoke in their lungs for a 15-second period. Inhalations occurred at 35-second intervals. The butt of the cigarette was placed in a glass holder to permit the entire amount to be smoked. It was required that both cigarettes be consumed within 20 minutes. Subjects were monitored for procedure throughout the smoking period by an experimenter with a stop watch.

Procedure

There was an instruction tape for each of the two attention conditions. For concentrated attention, the instruction tape demonstrated the noise bursts and the tones in the left ear. Digits were presented to the right ear but subjects were instructed to ignore the digits and to attend only to and report the presence or absence of the tone. Response on each trial was made during the seven second inter-trial interval.

For divided attention, the instruction tape demonstrated the noise burst, the tone, and the digits, and subjects were instructed to attend to both ears, reporting the presence or absence of the tone in the noise burst and also repeating the six random digits. Both instruction tapes presented 20 training trials with immediate feedback as to the correct response.

Test tapes, presenting noise burst, tone (with $p = .5$), and six digits, each contained 100 trials.

Subjects participated in one training session and five experimental test sessions. The treatment sessions for an individual subject occurred at weekly intervals, and at the same time of day.

At the training session, subjects received the concentrated attention instruction tape followed by an additional 100 concentrated attention test trials without feedback. Then the divided attention instruction tape was

played followed by 100 divided attention test trials without feedback. Any subject who failed to perform correctly at least 65% of the trials for both attention conditions was excluded from the study at this point.

Experimental test sessions followed the same procedure. The concentrated attention instruction tape served as a warm-up, and was followed by 100 concentrated attention test trials. The divided attention instruction tape then was played, followed by 100 divided attention test trials. The entire procedure required approximately 45 minutes.

On experimental test days subjects were requested to first relax in a comfortable chair for 15 minutes. Their pre-smoke pulse rates were taken, and they then received the experimental treatment. Smoking required 20 minutes, and on the 'no treatment' day the subject simply waited for the same period. At this time, the post-smoke pulse rate was taken. Subjects immediately entered the sound isolation chamber, and experimental testing began. A post-test pulse rate was taken after the test session, i.e., approximately 50 minutes after completing the marihuana smoking.

Following the test, subjects were asked to complete a questionnaire describing their subjective state during the test period. This consisted of the Subjective Drug Effect Questionnaire (SDEQ) (Waskow, et al., 1970) and questions concerning the substance they believe they received, plus ratings of the relative potency and their level of intoxication. Subjects were retained under the supervision of the experimenters until the subjective symptoms disappeared and the pulse rates had returned to normal.

RESULTS AND DISCUSSION

An increase in pulse rate is the most reliable physiological measure of marihuana effect. Table 7 shows the characteristics dose-related elevation over the pre-smoking level.

The 50, 100, and 200 mcg. delta-9 THC/Kg.B.W. doses produced post-smoke pulse rate increases of 37%, 49% and 56%, respectively. The placebo smoking treatment resulted in a 20% post-smoke pulse rate increase. This increase may have been due to the smoking procedure per se, anxiety about the treatment, residual active ingredients in the post-extracted placebo material,* or to some combination of these factors. The mean post-test pulse rate was below the pre-smoking level for the no-treatment, placebo and 50 mcg./Kg. doses, but remained elevated for the 100 mcg. and 200 mcg./Kg. doses. Data from Manno, et al. (1971) suggest peak effects about 30 minutes after smoking begins.

A clear dose-response relationship is also evident in the ratings of level of intoxication and the SDEQ scores shown in Table 8. It is of interest to note that the placebo condition evoked positive subjective responses as well as the post-smoking increase in pulse rate shown in Table 7. Of the 23 subjects 19 stated they believed the placebo to be marihuana; however, all but one rated it weaker than that normally smoked.

The measures of performance on the auditory signal detection task under conditions of concentrated attention and divided attention are presented in Tables 9 and 10, and Figure 1.

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*Analysis of the placebo material showed up to 0.05% THC, or 0.5 mg. for 1 gram of material.

Table 7
Mean Pulse Rate Before and After Smoking Marihuana

	NO TREATMENT	MARIHUANA DOSE: mcg. delta-9 THC/Kg. B.W.			
		0 PLACEBO	50	100	200
Before Smoking	76	75	76	76	74
After Smoking	76	91	103	113	116
After Testing	67	71	72	80	80

Table 8
Mean Subjective Ratings of Marihuana Effects

MEASURE	NO TREATMENT	MARIHUANA DOSE: mcg. delta-9 THC/Kg. B.W.			
		PLACEBO	50	100	200
Global Rating of Degree of Intoxication (0-100)		21	50	67	81
Subjective Drug Effects Questionnaire*	2	12	19	26	36

*Aggregate number of positive responses on 14 empirical scales (Waskow, et. al., 1970).

Table 9
Marihuana Treatment Means Under Concentrated Attention

	NO TREATMENT	MARIHUANA DOSE: mcg. delta-9 THC/Kg. B.W.			
		0	50	100	200
Signal Detection % Correct	86.1	87.6	84.9	81.8	78.0
Hits	41.7	41.6	42.0	40.1	39.4
False Alarms	5.7	4.0	7.1	8.3	11.4
d'	2.40	2.66	2.20	2.00	1.81
Beta	1.32	1.83	1.90	2.53	2.22

Table 10
Marihuana Treatment Means Under Divided Attention

	NO TREATMENT	MARIHUANA DOSE: mcg. delta-9 THC/Kg. B.W.			
		0	50	100	200
Joint Task Performance % Correct	80.6	81.0	76.2	69.9	64.7
Digit Recall No. Correct	92.3	93.7	91.7	89.7	87.7
Signal Detection % Correct	86.7	85.8	82.3	76.3	71.7
Hits	42.2	42.3	41.3	38.9	37.7
False Alarms	5.5	6.4	9.0	12.1	16.0
d'	2.40	2.36	2.04	1.66	1.37
Beta	.93	1.53	1.26	2.06	1.80

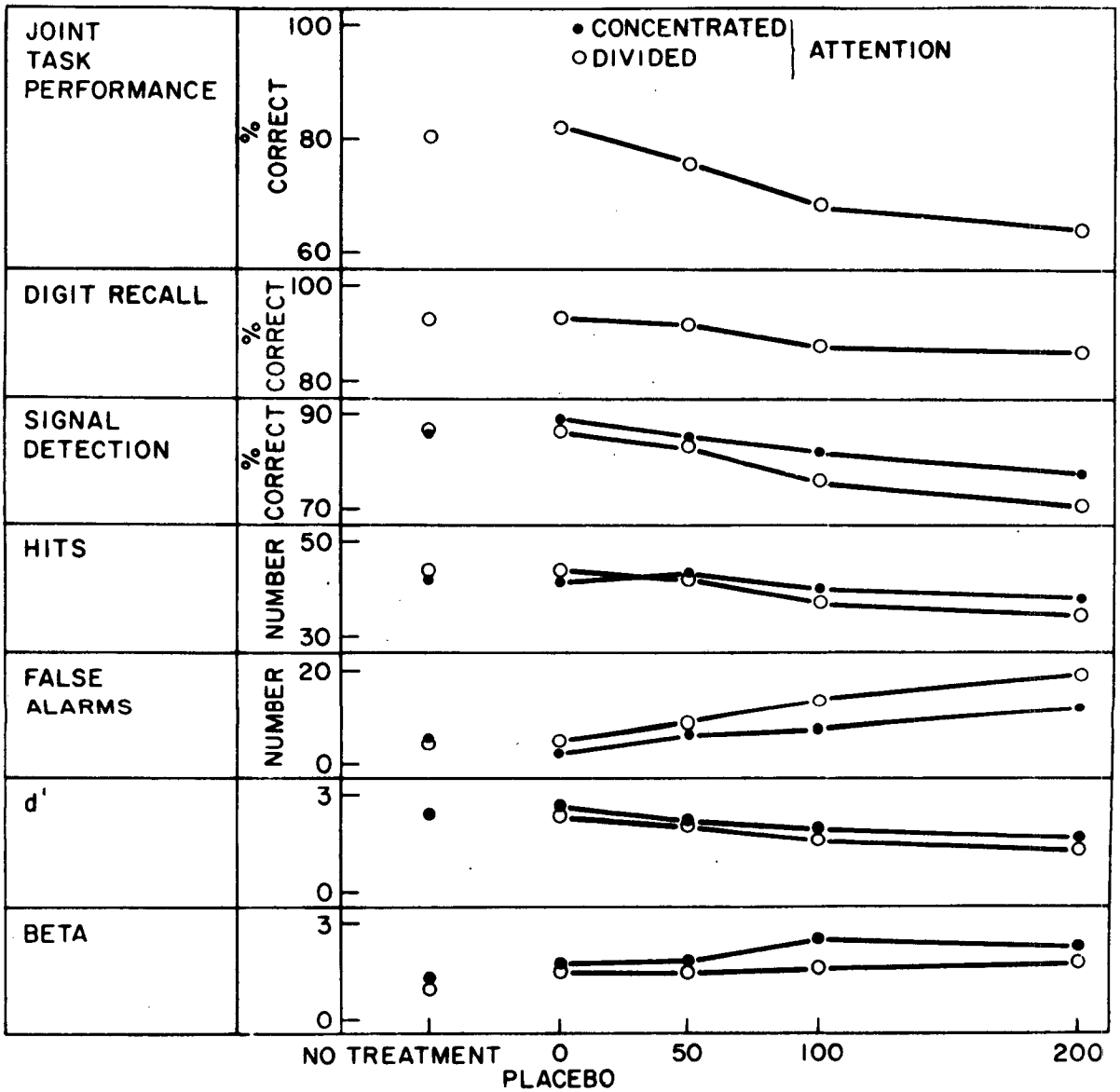

Figure 1. Marihuana (Micrograms Δ^9 THC per Kg Body Weight)

The performance data has been broken into several categories for analysis. Under the concentrated attention conditions the categories for data analysis are: percent correct on signal detection task, number of "hits" and "false alarms", and d' and beta. For the divided attention conditions there is, in addition, number of correct digit recalls and percent of trials on which both digit recall and signal detection were correct.

The terms "hits", "false alarms", and "misses" are used in analyses of the signal detection task performance. "Hit" refers to correct identification of the presence of a signal on trials where it is present. Failure to detect a signal is a "miss". "False alarm" refers to the erroneous report of a signal on trials where no signal occurred. The independent analysis of errors on trials where the signal is present and where it is absent is essential to determine whether a change in signal detection performance is due to a change in the criterion level adopted by the individual as a basis for reporting the presence of a signal (Green and Swets, 1966). The above data are utilized by the signal detection theory to generate an unbiased estimate of the subject's discrimination sensitivity which is labeled d', and a measure of the decision criterion which is labeled beta. While this measure does not reflect all the possible bias of the subject, it is certainly a suggestive measure of subjective factors in the decision process.

In contrast to the pulse rate and subjective effects data (Tables 7 and 8), the performance scores showed no differences between the no-treatment and placebo conditions (Tables 9 and 10). Since the t tests for paired comparisons between these conditions were clearly insignificant, all subsequent statistical tests (analysis of variance) were confined to comparisons of the three active treatments and the placebo.

Table 11 summarizes the results of the tests of statistical significance for the data presented in Tables 9 and 10 and Figure 1.

Table 11
Summary of Statistical Tests of Significance for Marihuana Treatments

	CONCENTRATED ATTENTION			DIVIDED ATTENTION		
	F	df	Sig. Level	F	df	Sig. Level
Joint Task Performance				6.85	3,60	.01
Digit Recall				1.84	3,60	N.S.
Signal Detection	5.48	3,60	.01	6.79	3,60	.01
Hits	3.40	3,60	.05	2.66	3,60	.05
False Alarms	4.26	3,60	.01	5.92	3,60	.01
d'	11.29	3,20	.01	10.78	3,20	.01
Beta	5.58	3,20	.01	2.85	3,20	.10

Statistical comparisons were performed on analysis of variance programs from the UCLA Health Computing Facility. (Dixon, 1969, 1970.) The measures d' and beta were examined using computer program X63 which is based on a distribution with less than usual demands for homogeneity of variance. All other scores were examined by computer program 05V which uses the standard F distribution.

The data indicate that marihuana produces a significant decrement in auditory signal detection under both attention conditions. The results differ from those found earlier for alcohol on the same task. Alcohol, at dose levels of 0.21 to 0.83 grams/Kg.B.W., produced impairment under conditions of divided attention, but not for concentrated attention (Moskowitz and DePry, 1968; Moskowitz and Shea, unpublished). The alcohol impairment appears to be related to the ability of the subject to process information from two simultaneous sources. In contrast, marihuana induced impairment occurs for single

as well as two-source information processing. A similar finding has already been reported for the visual modality (Moskowitz, Sharma and McGlothlin, 1972). The degree of impairment by marihuana is greater under the more complex demands of divided attention as shown by the divergence of the performance curves for the two attention conditions. A difference score created by subtracting the concentrated attention performance score from the divided attention performance score was found to be significant for treatment effects (For signal detection $\underline{F} = 5.48$, $\underline{df} = 3,60$, $p<.01$).

On the other hand, digit recall in the divided attention task showed only a slight and non-statistically significant effect by marihuana. This finding is in agreement with the results of earlier work which found no effect of marihuana when digit recall was the task under conditions of concentrated attention. Again, there was only a non-significant trend toward lower scores for digit recall under conditions of divided attention.

Both types of errors, "false alarms" and "misses", are significantly affected by marihuana. The drop in signal detection performance is produced by an increase in both possible errors. However, it should be noted that rate of increase of "false alarms" is almost twice as rapid as that of "misses". This result is similar to Abel (1971) who examined errors on a memory recognition task and found most errors were false recognitions of material not previously shown rather than failure to correctly identify previously presented words.

The highly significant changes in the d' scores demonstrate that the signal detection performance decline under the effects of marihuana is due, at least in part, to an effect upon perceptual discrimination sensitivity. This does not imply a marihuana effect necessarily upon sensory transducer or transmission mechanisms; the locus of the effect could well be upon central

processing of the input data. There is little evidence to suggest that peripheral visual or auditory sensory processes are affected by marihuana and, as noted at the beginning of this paper, some evidence to suggest that they are not.

There also appears to be a marihuana effect upon the criterion used to determine acceptance of a signal as evidenced by statistical significance for beta under concentrated attention conditions and marginal significance under divided attention conditions. This conclusion is somewhat reinforced by the differential changes in signal detection errors, with the greater increase in false alarms. However, the change in criterion is smaller and less significant than the change in sensitivity. Thus, it does not appear that a possible marihuana effect upon criterion is the prime reason for the performance changes.

Previous work by Jones (1971) has shown that, like most other psychoactive drugs, the frequent use of marihuana results in both behavioral and physiological tolerance. The subject sample in the present study was not selected with the intent of investigating performance as a function of prior history of marihuana use. However, it is of interest to examine the data within the limited frequency-of-use range. Table 12 compares the results for subjects using marihuana less than two times per week (N=11) with those using it two or more times per week (N=12). For the four performance measures, signal detection under concentrated and divided attention conditions and digit recall and joint task performance under divided attention conditions, there is a slight trend toward more impairment among the low-use group, but none of the differences approach statistical significance. On the other hand, there are consistently smaller changes in pulse rate after smoking among the low-use group. The high-use group does consistently rate their global level of intoxication above that for the low-use group. The results for the placebo

Table 12

Comparison of Mean Performance, Pulse Rate and Subjective Effects as a Function of Frequency of Marijuana Use

MEASURE	NO TREATMENT		MARIJUANA DOSE: mcg. THC/Kg. B.W.							
			0 PLACEBO		50		100		200	
	High Use	Low Use	High Use	Low Use	High Use	Low Use	High Use	Low Use	High Use	Low Use
Signal Detection CA	86	86	88	87	86	84	83	81	79	77
Signal Detection DA	85	88	87	84	83	82	79	73	73	71
Digit Recall DA	92	92	92	95	92	91	91	88	87	88
Joint Task DA	79	82	81	81	77	76	73	67	65	64
Change in Pulse Rate After Smoking	0	-1	16	15	29	25	43	30	46	38
Subjective Rating Global (0-100)	----	----	28	14	55	46	71	63	84	78
SDEQ Score	2	2	12	14	19	19	24	29	32	41

High use: 2 or more times a week

Low use: < 2 times a week

treatment are of particular interest; the high-use group rate their level of intoxication substantially higher than does the low-use group. However, when requested to check the specific drug effects experienced on the SDEQ, the high-use group scores about the same or slightly lower than the low-use group.

A comparison can be made of the relative impairment of auditory signal detection by alcohol and by marihuana, using the data from an unpublished study by Moskowitz and Shea. The same task and attention conditions were examined as in this study, (although only half the number of trials) and five alcohol doses were administered. The largest alcohol dose was .83 grams alcohol/Kg.B.W., which produces a mean expected peak blood alcohol level of about .09%. While this alcohol level is rather high for moderate drinkers, is is exceeded frequently by heavy drinkers. The results are shown in Figure 2.

Alcohol produced no significant decrement in signal detection performance under concentrated attention conditions. However, under division of attention conditions the highest alcohol dose produced a 17% drop in signal detection performance and a 32% drop in joint task performance. At the highest marihuana dose in this study there was a 16% change in signal detection performance and a 20% change in joint task performance under division of attention. At the same marihuana dose there was an 11% drop in signal detection performance under concentrated attention conditions.

A meaningful comparison between alcohol-induced and marihuana-induced performance deficits is not feasible for all situations involving signal detection, because it appears that the mechanisms of performance impairment are dissimilar. Alcohol does not impair signal detection per se; rather the effect appears to be upon some central information processing mechanism involved in the dual processing of information. (For further discussion of

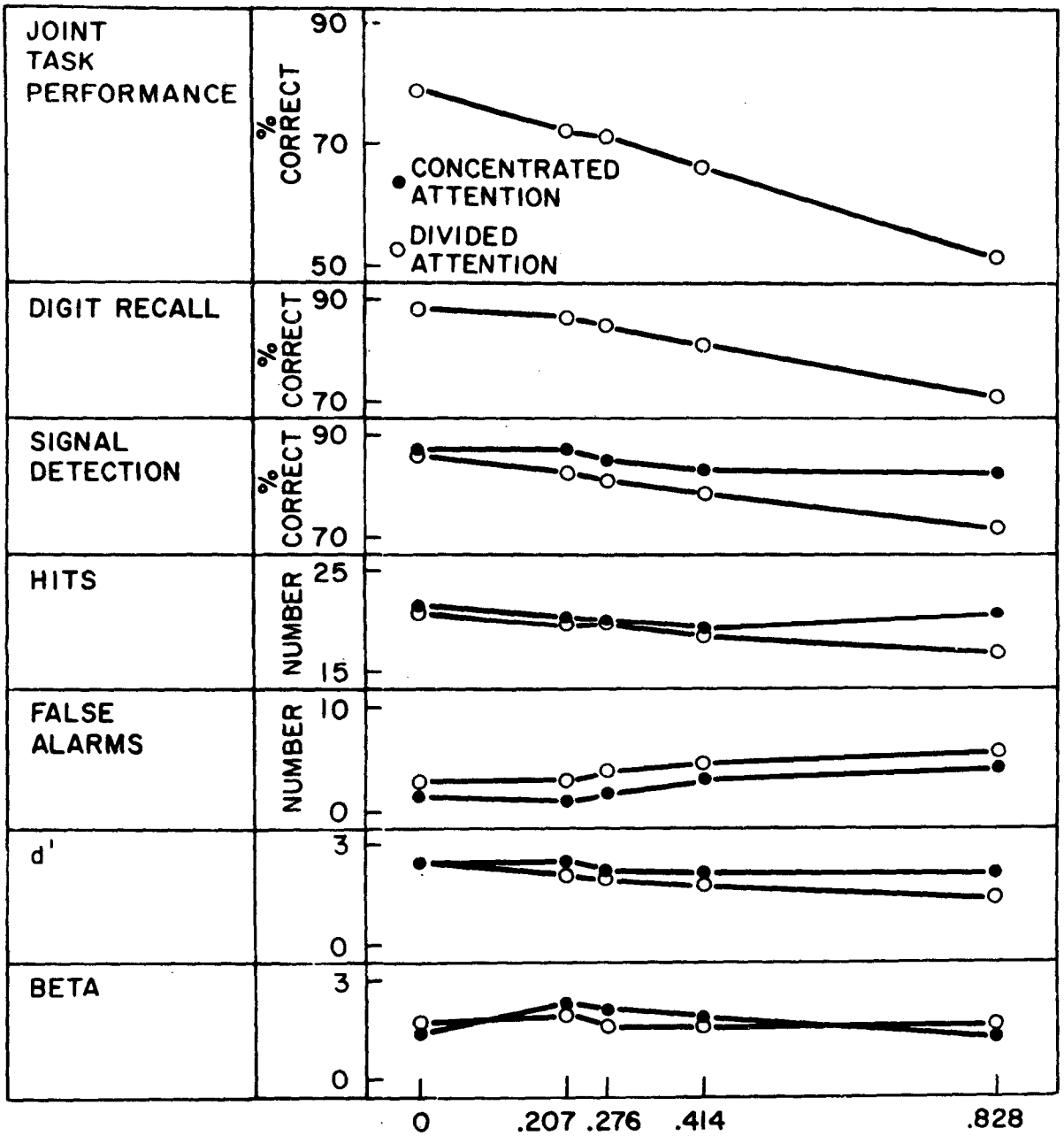

Figure 2. Grams Alcohol per Kg Body Weight.

this issue see Moskowitz and Burns, 1971; Moskowitz and Roth, 1971). The mechanism(s) involved in marihuana-induced deficits appear to be affected for simple as well as complex information processing. Thus, a marihuana deficit will appear in a situation where an alcohol deficit will not.

Many practical tasks such as automobile driving, flying, and industrial work require complex information processing of the type measured by divided attention tests. In driving there is need for time-sharing of attention between a perceptual search-and-recognition task and a tracking task. Under these conditions, it appears that the overall task performance is less affected by marihuana at 200 mg. delta-9 THC/Kg.B.W. than by .83 grams alcohol/KG.B.W. Moreover, this marihuana dose is greater than the average amount currently used in the United States. The largest alcohol dose results in a blood alcohol level just below that at which most states begin to charge a person with being under the influence of alcohol if operating a motor vehicle (0.1% alcohol). Also, the marihuana-induced impairment of digit recall is only 6% at the highest dose in comparison to 20% for alcohol at a dose of .83 grams per Kg./B.W.

Obviously, an adequate comparison of the driving hazards resulting from marihuana and alcohol use requires a much more extensive investigation than that provided by the present study. However, for the doses examined here, the impairment of performance of complex attentional tasks appear to be somewhat greater for alcohol than for marihuana.

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APPENDIX

The following are two illustrative examples of the statistical treatment of the data for this report.

Table 13 in the appendix presents the breakdown of the analysis of variance of the mean score for the 21 subjects on the average speed measure in the 4 × 4 Latin square design.

Table 14 presents the output from the computer for the paired-comparison t tests comparing the placebo with the 200 microgram delta-9 THC/Kg.B.W. dose on all 25 performance measure scores.

Table 13

Marihuana Dose Study Analysis of Variance 4 x 4 Latin Square N = 21
Average Speed During the Event

SOURCE	df	SS	MS	F	SIGNIFICANCE LEVEL
Treatment	3	33.31	11.10	1.15	Not Significant
Sequence of Treatments	3	114.19	38.06	3.94	.05
Session	3	278.88	92.96	9.63	.01
Residual	6	17.88	2.98	.31	Not Significant
Subjects	17	785.13	46.18	4.78	.05
Error	51	492.50	9.66	–	–

Analysis performed using the 05V Biomedical Computing Program, UCLA Health Sciences Computing Facility.

Table 14
Compiled Event Statistics for all Subjects Across all Events
Results of Distribution of the Individual Subject Means

	PLACEBO 21 SUBS	MARIHUANA 200 mcg delta-9 THC/Kg. B.W. 21 SUBS	DIFFERENCE 21 SUBS		t TEST	
	MEAN	MEAN	MEAN	STD DEV	t	SIG
Speed at the Beginning of the Event (MPH)	37.211	36.050	1.161	4.322	1.20	0.0
Speed at the End of the Event (MPH)	37.314	36.225	1.089	4.361	1.12	0.0
Minimum Speed During the Event (MPH)	32.630	31.379	1.252	4.419	1.27	0.0
Maximum Speed During the Event (MPH)	41.722	40.724	0.998	4.304	1.04	0.0
Speed Revs of 5 MPH Per 25 Film Frames	0.052	0.053	-0.002	0.032	-0.24	0.0
Average Speed During the Event (MPH)	37.515	36.127	1.389	4.195	1.48	0.0
Average Speed During the Event (Film Frames/Sec)	25.359	23.422	1.937	2.692	3.22	0.01
Acc. Revs of 2 Percent per 25 Film Frames	0.132	0.156	-0.024	0.071	-1.53	0.0
Acc. Revs of 5 Percent per 25 Film Frames	0.048	0.058	-0.010	0.036	-1.29	0.0
Time to 1st Complete Acc. Let-up (Secs)	1.435	1.777	-0.342	0.852	-1.80	0.0
Average Acc. Position (Percent Depressed)	5.228	4.805	0.423	1.738	1.09	0.0
Time to 1st Acc. Let-up of 3 Percent (Secs)	1.519	1.607	-0.087	0.958	-0.41	0.0
Maximum Position of Acc. (Percent Depressed)	8.547	8.231	0.316	2.150	0.66	0.0
Time From Acc. Let-up to 1st Brk Prs. (Sec)	-0.070	-0.199	0.129	0.533	1.08	0.0
Time to 1st Br. Prs. From Start of Evt. (Sec)	0.178	0.323	-0.145	0.765	-0.85	0.0
Maximum Amount of Brk Prs. (Percent of Maximum)	2.874	2.476	0.398	4.062	0.44	0.0
Average Position of the Steering Wheel (Degrees)	-18.086	-19.600	1.514	16.396	0.41	0.0
Average Rate of Chg. of Steering Wheel (Degree/Sec)	163.381	159.088	4.293	22.398	0.86	0.0
Steer Revs. of 5 Degrees per 25 Film Frames	0.445	0.417	0.028	0.273	0.47	0.0
Steer Revs of 10 Degrees per 25 Film Frames	0.235	0.236	-0.001	0.116	-0.02	0.0
Steer Revs of 15 Degrees per 25 Film Frames	0.162	0.168	-0.006	0.073	-0.39	0.0
Len. of Pth. of Car in Event (Eq. Film Frames)	317.184	320.088	-2.903	10.344	-1.26	0.0
Ratio of Eq. Film Frames to Real Film Frames	1.050	1.054	-0.004	0.038	-0.51	0.0
Average Dif. Between Steering and Steering Comp. (Degrees)	23.182	25.394	-2.213	15.064	-0.66	0.0
Maximum Dif. Between Steering and Steering Comp. (Degrees)	51.878	57.573	-5.694	17.469	-1.46	0.0