Comparison of the Effects of Marijuana and Alcohol on Simulated Driving Performance

BY ALFRED CRANCER, JR., Ph.D.,
JAMES M. DILLE, M.D.,
JACK C. DELAY, M.D.,
JEAN E. WALLACE, M.D.,
& MARTIN D. HAYKIN, M.D.

We have determined the effect of a “normal social marijuana high” on simulated driving performance among experienced marijuana smokers. We compared the degree of driving impairment due to smoking marijuana to the effect on driving of a recognized standard-that is, legally defined intoxication at the presumptive limit of 0.10 percent alcohol concentration in the blood. This study focused attention on the effect of smoking marijuana rather than on the effect of ingesting Δ^9 -tetrahydrocannabinol (Δ^9 -THC), the principal active component.

Weil *et al.* [1] have studied the clinical and psychological effects of smoking marijuana on both experienced and inexperienced subjects. They suggest, as do others,’ that experienced smokers when “high” show no significant impairment as judged by performance on selected tests; they also establish the existence of physiological changes that are useful in determining whether a subject smoking marijuana is “high.” A review of the relation of alcohol to fatal accidents[3] showed that nearly half of the drivers fatally injured in an accident had an alcohol concentration in the blood of 0.05 or more.

Crancer[4] found a driving simulator test to be a valid indicator for distinguishing driving performance; this result was

Reprinted from Science, vol. 164, May 16, 1969, pp. 851-854.

based on a five-year driving record. Further studies[5] indicated that a behind-the-wheel road test is not significantly correlated to driving performance. We therefore chose the simulator test, which presents a programmed series of emergency situations that are impractical and dangerous in actual road tests.

Subjects were required to be (i) experienced marijuana smokers who had been smoking marijuana at least twice a month for the past six months, (ii) licensed as *a* motor vehicle operator, (iii) engaged in a generally accepted educational or vocational pursuit, and (iv) familiar with the effects of alcohol. The subjects were given (i) a physical examination to exclude persons currently in poor health or under medication, and (ii) a written personality inventory (Minnesota Multi-phasic Personality Inventory) to exclude persons showing a combination of psychological stress and inflexible defense patterns. Seven of the subjects were females and twenty-nine were males (mean age, 22.9).

We compared the effects of a marijuana "high," alcohol intoxication, and no treatment on simulated driving performance over a four and a half hour period. We used *a* Latin-square analysis of variance design[6] to account for the effects of treatments, subjects, day, and the order in which the treat*ments* were given. 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 thirty-six subjects was determined to be sufficient in size to meet the demands of this experimental design.

Three treatments were given to each subject. In treatment M (normal social marijuana "high"), the experimental subject stated that he experienced the physical and psychological effects of smoking marijuana in a social environment comparable to his previous experiences. This subjective evaluation of "high" was confirmed by requiring a minimum consumption of marijuana established with a separate test group, and by identifying an increase in pulse rate.'

In treatment M, the subjects smoked two marijuana' cigarettes of approximately equal weight and totaling 1.7 g. They completed smoking in about thirty minutes and were given their first simulator test thirty minutes later.

Some confirmation that the amount of marijuana smoked was sufficient to produce a "high" is found in Weil's[1] study.

His subjects smoked about 0.5 g of marijuana of 0.9 percent Δ^9 -THC.

In treatment A, subjects consumed two drinks containing equal amounts of 95 percent alcohol mixed in orange or tomato juice. Dosage was regulated according to subject's weight with the intended result of 0.10 blood alcohol concentration as determined by a Breathalyzer reading.' Thus, a subject weighing 120 pounds received 84 ml of 95 percent laboratory alcohol equally divided between two drinks. This was equivalent to about six ounces of 86 proof liquor. The dosage was increased 14 ml or one-half ounce for each additional fifteen pounds of body weight. A Breathalyzer reading was obtained for each subject about one hour after drinking began; most subjects completed drinking in thirty minutes.

Treatment C consisted of waiting in the lounge with no treatment for the same period of time required for treatments M and A. The experimental subject stated that his physiological and psychological condition were normal. Subjects were requested to refrain from all drug or alcohol use during the time they were participating in the experiment.

A driver-training simulator was specially modified to obtain data on the effect of the treatments. The car unit was a console mockup of a recent model containing all the control and instrument equipment relevant to the driving task. The car unit faced a six by eighteen 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 and 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 zero to 405 errors per test. Errors were accumulated as follows:

1. *Speedometer errors.* Speedometer readings outside the range of 15 to 35 mile/hour for city portion of film and 45 to 65 mile/hour for freeways. The speed of the filmed presen-

tation 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.

2. Steering errors. Steering wheel in other than the appropriate position.

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

4. ***Accelerator errors.*** Acceleration when the appropriate response is to declerate, or deceleration when it is appropriate to accelerate.

5. Signal errors. Use of turn signal at an inappropriate time or position.

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

Two rooms were used for the experiment. The lounge, designed to provide a familiar and comfortable environment for the subjects, was approximately twelve 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, and contemporary rock music was played. Snacks, soft drinks, ashtrays, wastebaskets, and a supply of cigarettes were readily available. Subjects remained in this room except during simulator tests.

The driving simulator was located in a larger room about fifty feet from the lounge. The simulator room was approximately twenty by thirty feet and was kept in almost total darkness.

Each subject took three preliminary tests on the driving simulator to familiarize himself 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. On day 1, six subjects took a final test on the driving simulator to assure recent familiarity with the equipment. A "normal" pulse rate was recorded, and each was given two marijuana cigarettes of approximately 0.9 g each. Subjects smoked the marijuana in the lounge to become acquainted with the surroundings and other test subjects, and with the potency of the marijuana. 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 started smoking.

Three of the subjects were scheduled for testing in the early evening of 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 requirement of a Latin-square design. Procedure for each evening was identical except for the specific treatment.

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

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

The three simulator tests taken after each treatment establish 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

TABLE 1

Analysis of variance of total driving simulator error scores for three treatments; marijuana (M), control (C), and alcohol (A).

Source of variation	Sum of squares	Degrees of freedom	Mean square	Mean square ratios
Treatments	2,595.1	2	1,297.5	6.7'
M versus C	(11.7)	(1)	11.7	0.1
A versus M and C	(2,583.4)	(1)	2,583.4	13.3†
Days	738.5	2	369.3	1.9
Subjects	40,872.5	24	1,703 .0	9.7†
Squares	13.708.5	11	1,247.2	6.4†
Pooled error	13,253.8	68	194.9	
Total	71,168.4	107		

* $P < .05$. † $P < .01$.

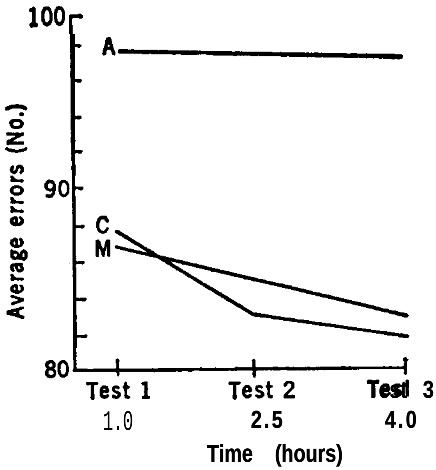
of variance for period 1 scores; results comparable to these were obtained for scores in periods 2 and 3.

The simulated driving scores for subjects experiencing a normal social marijuana "high" and the same subjects under control conditions are not significantly different (Table 1). However, there are significantly more errors ($P<.01$) for intoxicated than for control subjects (difference of 15.4 percent). This finding is consistent with the mean error scores of the three treatments: control, 84.46 errors; marijuana, 84.49 errors; and alcohol, 97.44 errors.

The time response curves for "high" and control treatments are comparable (Figure 1). In contrast, the curve for

FIGURE 1

Display of the effect of each treatment on simulator error scores over a four-hour period. Alcohol (A), marijuana (M), and control (C).



alcohol shows more total errors ($P<.01$). These higher error scores for alcohol persist across all three time periods with little evidence of the improvement shown under the other two treatments.

A separate Latin-square analysis of variance was completed for each test variable to supplement the analysis of total errors (Table 2). In comparison of intoxicated and control subjects, significant differences ($P<.05$) were found for accelerator errors in periods 1 and 2, for signal errors in periods 1, 2, and 3, for braking errors in periods 2 and 3, and for speedometer errors in period 1. In the comparison of mari-

TABLE 2

Significant treatment differences from Latin-square analysis of variance ($P < .05$). Accelerator, signal, and total errors are significantly correlated with driving performance for normal drivers. No correlation was found for brake, speedometer, and steering errors; A > C, M > C indicate that error scores for alcohol (A) or marijuana (M) treatment are greater than control (C).

Simulator test	Test variable errors					
	Accelerator	Signal	Total	Brake	Speedometer	Steering
Period 1	A > C	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

juana smokers and controls, 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 are Latin squares, subjects, and days. In all of the analyses, the effect of subjects and Latin squares (representing groups of subjects) were significant ($P < .05$). In contrast, the effect of days was not significant, thus indicating that no significant amount of learning was associated with repeated exposure to the test material.

For normal drivers, Crancer[4] found a significant correlation ($P < .05$) between the 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.

It may not be valid to assume the same relationship for persons under the influence of alcohol or marijuana. However, we feel that, because the simulator task is a less complex but related task, 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 finding significantly more accelerator, signal, and total errors by intoxicated subjects implies a deterioration in actual driving performance.

Relating speedometer errors to actual driving performance is highly speculative because Crancer[4] 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 intoxicated or "high" subjects probably indicates that the subjects 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 marijuana 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.

Weil *et al.*[1] emphasize 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 under all treatments.

Traditional methods for controlling potential subject bias by using placebos to disguise the form or effect of the marijuana treatment were not applicable. This is confirmed by Weil ***et al.***' ; they showed that inexperienced subjects correctly appraised the presence or absence of a placebo in twenty-one of twenty-seven trials.

The nature of selection probably resulted in subjects who preferred marijuana to alcohol and, therefore, had a set to perform better with marijuana. The main safeguard against bias was that subjects were not told how well they did on any of their driving tests, nor were they acquainted with the specific methods used to determine errors. Thus, it would have been very difficult intentionally and effectively to 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 before each treatment. We found no significant difference in the mean error scores preceding the treatments of marijuana, 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 marijuana did not influence the results of this experiment.

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

Four additional subjects who had never smoked marijuana before were pretested to obtain control scores, then given marijuana 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 marijuana dosage or inexperience with the drug.

A significant difference ($P<.01$) was found between the pulse rates before and after the marijuana treatment. Similar results were reported' for both experienced and inexperienced marijuana subjects. We found no significant difference in pulse rates before and after drinking.

Thus, when subjects experienced a social marijuana "high," they accumulated significantly more speedometer errors on the simulator than under control conditions, but 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. Furthermore, impairment in simulated driving performance apparently is not a function of increased marijuana dosage or inexperience with the drug.

REFERENCES AND NOTES

1. A. T. Weil, N. E. Zinberg, J. M. Nelsen, Science 162, 1234 (1968).

2. Mayor's Committee on Marihuana, ***The Marihuana Problem in the City of New York*** (1944).

3. W. J. Haddon and V. A. Braddess, ***J. Amer. Med. Ass.*** 169, No.

14, 127 (1959); J. R. McCarroll and W. J. Haddon, *J.* Chronic ***Dis.*** 15, 811 (1962); J. H. W. Birrell, ***Med.*** *J. Aust.* 2, 949 (1965); R. A. Neilson, ***Alcohol Involvement in Fatal Motor Vehicle Accidents*** in *Twenty-Seven* ***California Counties in 1964,*** (California Traffic Safety Foundation, San Francisco, 1965).

4. A. Crancer, ***Predicting Driving*** Performance ***with a Driver Simulator Test*** (Washington Department of Motor Vehicles, Olympia, 1968).

5. J. E. Wallace and A. Crancer, ***Licensing Examinations and*** Their ***Relation to Subsequent Driving*** Record (Washington Department of Motor Vehicles, Olympia, 1968).

6. A. E. Edwards, ***Experimental Design*** in ***Psychological Research*** (Holt, Rinehart &Winston, New York, 1968), pp. 173-174.

7. The marijuana was an assayed batch (1.312 percent Δ^9-THC) from NIH through the cooperation of Dr. J. A. Scigliano.

8. L. A. Greenberg, ***Quart. J. Studies Alcohol 29, 252 (1968).***