

Effects of Marihuana on Reaction Time and Short-Term Memory in Human Volunteers¹

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ROSSI, A. M., J. C. KUEHNLE AND J. H. MENDELSON. *Effects of marihuana on reaction time and short-term memory in human volunteers*. PHARMAC. BIOCHEM. BEHAV. 6(1) 73–77, 1977. — Twenty-seven adult male marihuana smokers volunteered to participate in a hospital research ward study for a 31-day period. Following five days of baseline acclimatization, subjects could purchase and smoke marihuana cigarettes on a free choice basis for a period of 21 consecutive days. The marihuana smoking period was followed by a concluding five-day baseline. Measurements of simple reaction time, choice reaction time and short-term memory were carried out during the entire study. Analysis of variance revealed no statistically significant differences between control and marihuana performance; however, a correlational analysis showed that individual subject performances on all three tasks were significantly correlated from test session to test session during control conditions but not during marihuana smoking conditions. Findings are discussed in relation to attentional and motivational factors associated with performance on the three tasks.

Simple reaction time Choice reaction time Short-term memory Marihuana

ONE of the most frequently cited effects of marihuana is its apparent interference with short-term memory. Early attempts to document this effect with controlled research led to inconsistent results. Some investigators found such an effect [11, 18, 22, 23, 28] and others did not [5, 14, 29, 31]. The inconsistency was attributed to variations in set and setting and to different measurement procedures employed from study to study. However, recent studies in this area were based on a systematic analysis of the processes involved in short-term memory, and these studies have yielded more consistent results. In brief, these latter studies suggest that it is the information acquisition and storage phases of short-term memory that are most susceptible to marihuana effects, the phases that are heavily dependent on attention [1, 2, 3, 9, 10].

The suggestion that marihuana-related deficits in short-term memory are mediated through the drug's interference with attentional processes appears to conflict with the results of studies which indicate that marihuana does not directly interfere with the ability to sustain attention [16, 17, 21, 25, 30, 32]. The resolution of this apparent conflict may lie in the findings of still other studies which indicate that subjects, when motivated, can volitionally control some of the effects of the drug well enough to perform adequately on experimental tasks [6, 7, 26, 27, 28].

One hypothesis that may be drawn from an integration of the findings from these three areas of marihuana research is that subjects' marihuana-related performance on a short-term memory task will vary according to the degree of attention they devote to experimental tasks. The present study provides results bearing on that hypothesis.

METHOD

Subjects

A total of 28 male subjects were recruited by newspaper advertisements and employed in seven separate but identically designed studies with four different subjects in each study. All subjects were fully informed about the nature and course of the study and all provided informed consent for their participation. One subject terminated his participation before the conclusion of the study. Of the remaining 27 subjects, 12 were defined as casual users and 15 as heavy users. The casual users had at least a one-year history of marihuana use and were currently averaging eight smoking sessions per month. The heavy users had a minimum of a two-year history of marihuana use and were averaging 33 smoking sessions per month. The subjects employed in each separate study were either all casual or all heavy users. The average age of subjects was 23.6 for casual users and 23.2

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for the heavy users. Most subjects had used or experimented with other psychotropic drugs at one time or another, but none admitted to regular use of drugs other than alcohol and marihuana at the time of their recruitment.

Setting

Subjects lived on a hospital research ward for 31 days, under living conditions that were made as comfortable as possible consistent with security and experimental requirements. The ward area included individual bedrooms for subjects, facilities for providing snacks and preparing meals (food carts were brought to the ward from a central hospital kitchen), and a dayroom with TV, hi-fi, reading materials, and game materials. Twice a day, for a total of two and one-half hours, subjects had the opportunity to leave the ward for either a supervised walk around the hospital grounds or use of the hospital's patient recreation rooms. Movies were shown in the ward dayroom several nights a week. Visitors and use of the telephone were not permitted.

Marihuana

The marihuana used in this research was obtained from the National Institute of Mental Health in a lot standard dosage form. The cigarettes were machine-rolled to ensure maximal standardization in dosage and draw characteristics. Each cigarette contained approximately 1 g marihuana with a delta-9 THC content of 1.8 to 2.3 percent and less than 0.1 percent delta-8 THC, 0.1 percent cannabitol, and 0.1 percent cannabidiol (as assayed by the NIMH).

Marihuana Administration

Each of the seven 31-day studies was divided into three periods: a five-day predrug period, in which subjects did not have access to marihuana; a 21-day drug period, from the sixth to the twenty-sixth day when subjects were permitted to purchase and smoke marihuana on a free-choice basis; and a five-day postdrug period without access to marihuana. Throughout each study, subjects had the unrestricted opportunity of performing an FI 1 sec operant task (button-pressing) which accumulated points on an electronic counter. These points could be used to purchase marihuana during the 21-day drug period or exchanged for money at the conclusion of the study. The purchase price of a marihuana cigarette was 1,800 points which required approximately 30 min to accumulate on the operant task and had a monetary exchange value of 50 cents.

Subjects were permitted to purchase and smoke marihuana cigarettes whenever they chose during the drug period, with two conditions: (1) all smoking of marihuana was to be done under the observation of a staff member; (2) the unsmoked portion of the cigarette was to be returned to the staff upon completion of smoking. These conditions were established both to ensure security and to permit accurate recording of observations relating to smoking behavior. Heavy user subjects smoked an average of four to six marihuana cigarettes daily, and casual user subjects smoked an average of two to three marihuana cigarettes daily during the drug period.

A number of biological, behavioral, and social assessments were carried out during the study under the

supervision of a multidisciplinary research staff. The results reported in this paper are limited to assessments of simple reaction time, choice reaction time, and short-term memory. Other results are reported elsewhere [4, 19, 20].

Tasks

A Discriminate Stimulus Response (DSR) apparatus was used for stimulus presentation and response recording for all three tasks. This apparatus consists of a visual display screen, four response keys, capacity for programmed display of series of primary digits at timed intervals, and automatic recording of both response times and correct responses. The DSR was used to carry out the following assessments which were always conducted in the order described:

1. *Simple reaction time.* Subjects were instructed to press response key 1, 2, 3, or 4 as quickly as possible when the corresponding digit was visually displayed. The stimulus presentation during each testing session consisted of displaying Digit 1 ten times, Digit 2 ten times, Digit 3 ten times and Digit 4 ten times, always in that order. Digits were displayed 1 sec with 1 sec intervals between displays. Subjects were informed of this invariant schedule for stimulus presentation.

This task was included on the assumption that after several repeated trials, minimal attention would be required for successful performance.

2. *Choice reaction time.* Subjects were instructed to press response key 1, 2, 3, or 4 as quickly as possible when the corresponding digit was visually displayed, and to make no response when Digits 5–9 were displayed. During each trial Digits 1–9 were displayed in random order with five displays of each digit. Digit display times and interdisplay times were both 1 sec.

This task was included on the assumption that a moderate degree of attention would be required for successful performance even after repeated trials. It was further assumed that the scheduling of more no response stimuli (Digits 5–9) than response stimuli (Digits 1–4) would make it more difficult to maintain attention to the task.

3. *Short-term memory.* Subjects were instructed to press response key 1, 2, 3, or 4 as quickly as possible when the corresponding digit was visually displayed but the effective stimulus would be the digit displayed two steps prior to the digit currently being displayed. Thus, subjects were required to retain the effective stimulus in memory before responding. Digits 1–4 were displayed in random order with ten displays of each digit occurring during each trial. Digits were displayed for 2 sec with a 1 sec interval between displays. At the completion of these trials the process was repeated with the exception that subjects were instructed that the effective stimulus would be the digit displayed three steps prior to the digit currently being displayed.

The three tasks included in this study were purposely designed to require similar psychomotor processes for successful performance so that variations in performance between tasks, if they occurred, could be more reasonably related to cognitive rather than psychomotor processes.

All subjects performed at these tasks daily beginning approximately 10 a.m. In addition, during the 21-day drug period one subject a day performed at the tasks beginning approximately 30 min after smoking marihuana. Subjects were selected for the later assessments on a rotating basis.

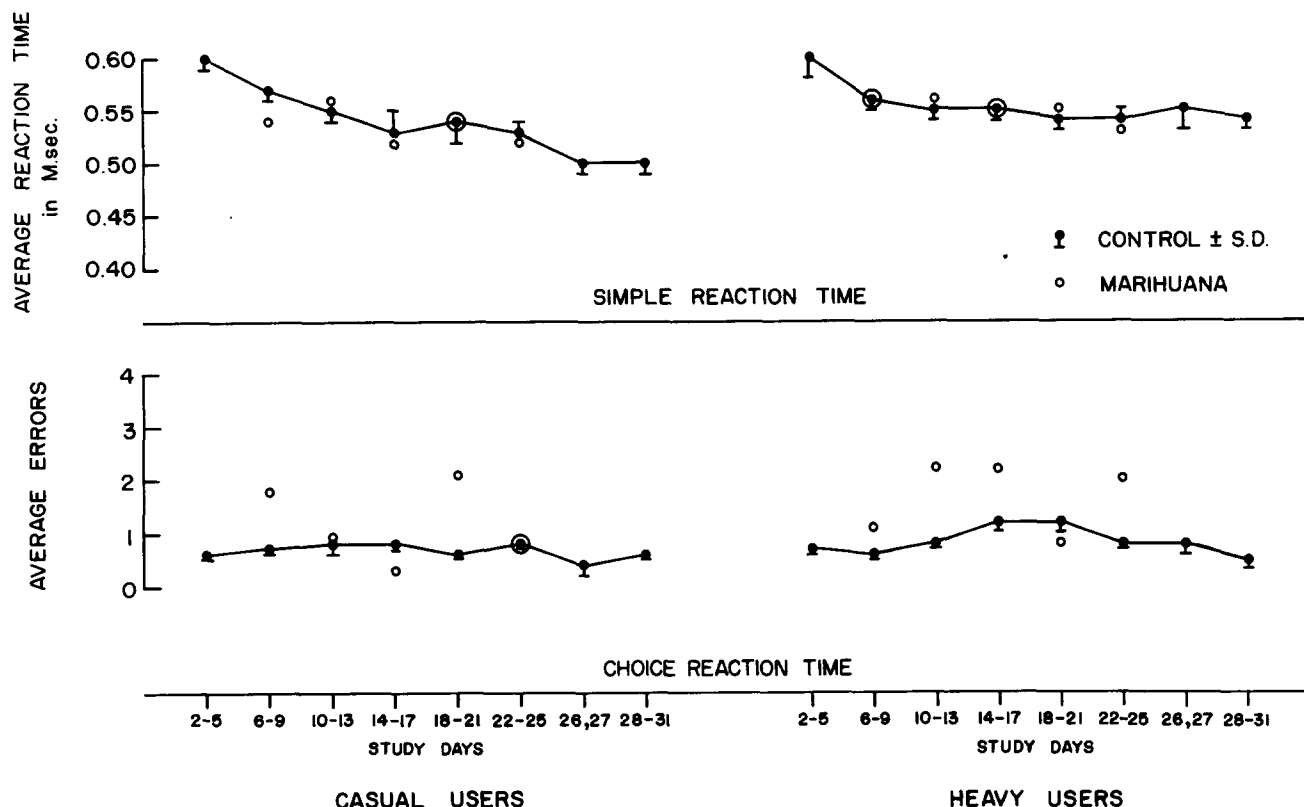


FIG. 1. Four-day means and standard deviations of marihuana and control performances of 15 heavy and 12 casual marihuana users on Simple Reaction Time and Choice Reaction Time tasks administered over a 31-day period. Performance results for the first day were not recorded because assessment sessions were devoted to acquainting subjects with testing procedures.

RESULTS

Two measures of performance were recorded for each task: reaction time in msec and errors of either omission (failure to press correct response key in the allotted response time) or commission (responding to a no response stimulus). Errors rarely occurred on the simple reaction time task so only the reaction time scores for this task were used in the data analysis. On the other hand, errors on the choice reaction time and short-term memory tasks occurred frequently enough to seriously distort reaction time scores so only the error scores for these tasks were used in the data analyses. Average performance scores are presented in Figs. 1 and 2.

The results were first analyzed for evidence of differences in task performance between marihuana and control conditions and between heavy and casual users. The control condition consisted of the scheduled daily testing sessions which occurred on the same days subjects also completed a special assessment 30 min after smoking marihuana. Complete control and marihuana assessment data were not obtained from three heavy user subjects because of equipment failure or other problems. Therefore, the data analyses were based on 12 heavy user subjects and 12 casual user subjects. Data obtained in assessments of simple reaction time, choice reaction time, and two-step and three-step short-term memory were analyzed separately with repeat measure ANOVAs. The results of these analyses disclosed no statistically significant differences in performance on any of the tasks attributable to conditions

(marihuana and control), groups (heavy and casual users), or main interaction (groups \times conditions). The results of the ANOVA employed in analyzing the short-term memory data also disclosed no statistically significant different main or interaction effects between the two-step and three-step delay conditions. Therefore, only the data obtained during the three-step delay condition were used in future analyses of performance on the short-term memory task.

In the second procedure used to analyze the results, correlations were computed between performance scores on the three tasks across testing sessions. These correlations were computed separately for each subject and for the control and marihuana testing sessions. In order to control for relationships in task performances due to practice effects, partial correlations were computed with practice effects (i.e., study day) partialled out. The partial correlation coefficients obtained for each subject were transformed into Z scores, averaged across subjects within each group (heavy users and casual users) for each condition (marihuana and control), and tested for statistical significance by *t*-test [13]. The average Z scores were retransformed into average correlation coefficients and are presented in Table 1. Performance scores on all three tasks were significantly intercorrelated across the control testing sessions, but only the performance scores on the short-term memory and choice reaction time tasks were significantly correlated across the marihuana testing sessions. This pattern was found in the scores obtained from both the casual and heavy user subjects.

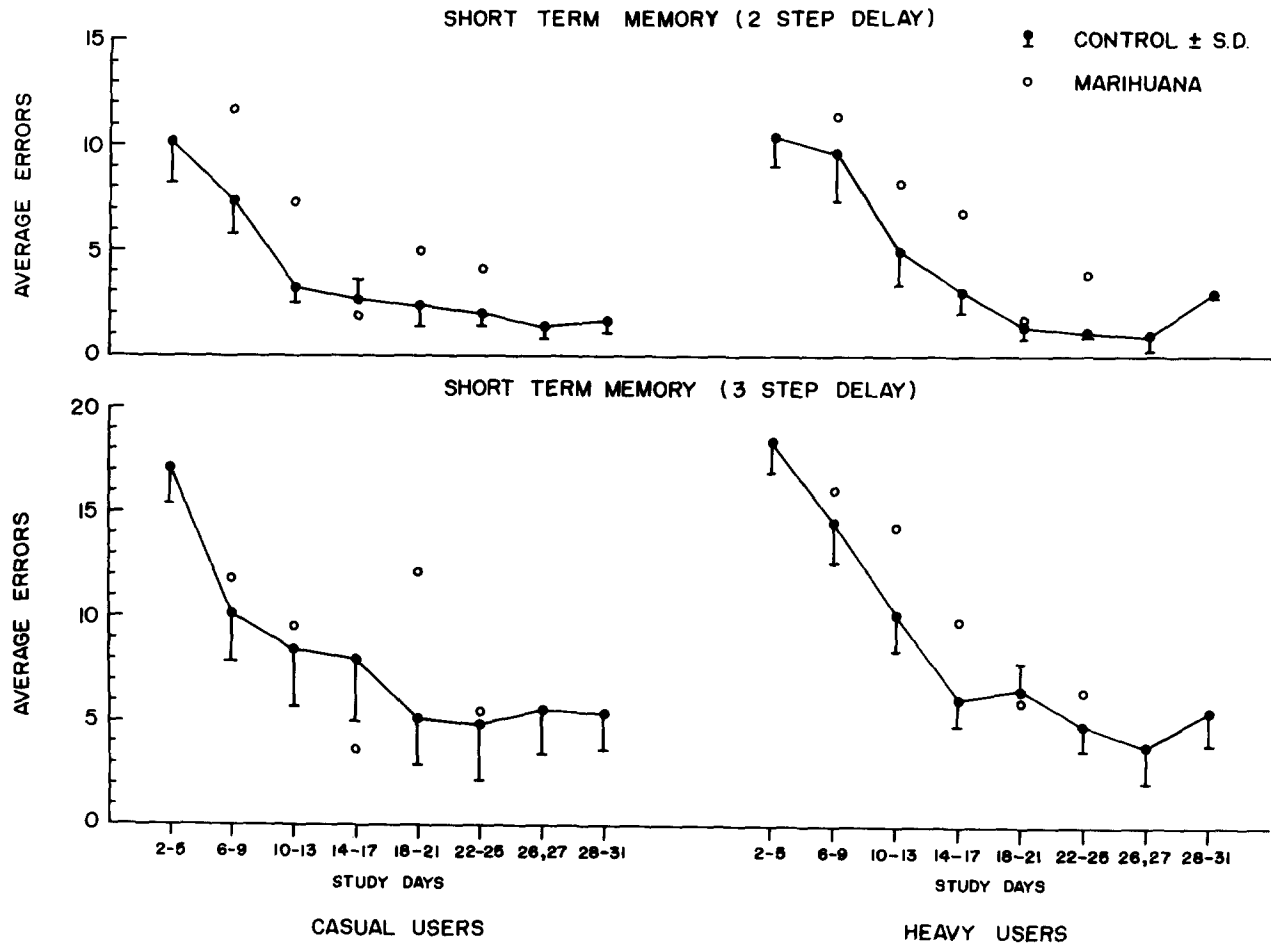


FIG. 2. Four-day means and standard deviations of marihuana and control performances of 15 heavy and 12 casual marihuana users on Short-Term Memory tasks administered over a 31-day period. For further details, see legend to Fig. 1.

TABLE 1

AVERAGE CORRELATIONS BETWEEN PERFORMANCE SCORES ON TASKS ASSESSING SHORT-TERM MEMORY (STM), CHOICE REACTION TIME (CRT) AND SIMPLE REACTION TIME (SRT) OBTAINED UNDER CONTROL AND MARIHUANA CONDITIONS FROM CASUAL USERS (N = 12) AND HEAVY USERS (N = 12)

	STM x CRT	Control STM x CRT	CRT x SRT	STM x CRT	Marihuana STM x SRT	CRT x SRT
Casual Users	0.31*	0.35*	0.52*	0.70*	0.13	0.36
Heavy Users	0.37†	0.31‡	0.35*	0.48*	0.22	0.25
Casual & Heavy Users	0.36*	0.35*	0.47*	0.69*	0.18	0.32

* $p < 0.001$.

† $p < 0.01$.

‡ $p < 0.05$.

DISCUSSION

The results of the analysis of variance employed in the present study disclosed no statistically significant differences between task performance under control and mari-

huana conditions. However, the failure to find significant differences appeared to be at least partially related to large daily fluctuations in the marihuana related performance (Figs. 1 and 2). The findings of large variations in marihuana related assessments has been reported so fre-

quently [7, 8, 12, 23, 25, 31] that inconsistent performance perhaps may be one of the few reliable effects that can be attributed to marihuana use.

A correlational analysis of individual task performances across testing sessions was carried out to determine whether the variations in individual performance from testing session to testing session were entirely random. The results of this analysis disclosed significant correlations among performance scores on all three tasks across the control testing sessions. This finding indicates that the scores varied in common from session to session for individual subjects. This common variation can be attributed to fluctuations in general test-taking factors (fatigue, negativism, etc.), which could be expected to affect performance on all three tasks equally for a particular subject during any particular testing session. During the marihuana testing sessions only the performance scores on the short-term memory and choice reaction time tasks were significantly correlated (Table 1). The fact that these performance scores were significantly correlated indicates that the variations found in marihuana

related performances on these tasks were not entirely random. Further, the fact that performance scores on the simple reaction time task were not significantly correlated with performance scores on either of the other two tasks makes it unlikely that the covariation in marihuana related performances on the short-term memory and choice reaction time tasks was due solely to the influence of general test-taking factors. Since successful performance on the latter two tasks required greater degrees of attention than that required by the simple reaction time task, a tenable inference is that marihuana related performances on the short-term memory and choice reaction time tasks covaried as a function of the subjects' ability or motivation to sustain attention to the laboratory tasks during any particular testing session. Although this inference is drawn from an analysis of intercorrelations of performances on only three tasks, it is strengthened by the fact that similar results were obtained in separate analyses of results obtained from both casual and heavy users.

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