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ABSTRACT

Investigating the effects of marijuana on human psychological functioning, this study differs from previous research in two ways: 1) it is concerned with relatively complex cognitive processes; 2) it has a theoretical rationale. The general hypothesis of the study states that marijuana will impair its user's ability to form and use abstract concepts. Twelve adult, male, experienced volunteer users of marijuana served as subjects for the study. To require the subjects to form and use abstract concepts in a variety of ways, the study administered the following tests: letter series, word grouping, conceptual clustering memory, closure speed, embedded figures, size-weight illusion, water-jar, hidden word, and anagram. Of the seven tests, results partially or strongly supported five, failed to support one, and rejected one. In general, the study demonstrated drug-induced impairments with dosage level constituting an important factor in determining the results. (Author/LAA)

THE EFFECTS OF MARIJUANA ON HUMAN COGNITION

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INTRODUCTION

The present investigation is an attempt to add to our knowledge of the effects of marijuana on human psychological functioning. This study differs from previous research chiefly in two ways: 1) It is concerned with relatively complex cognitive processes. Most previous research has had to do with sensory acuity, perceptual-motor skills, or relatively simple cognitive functions (e.g., short term memory, digit symbol substitution, simple arithmetical manipulations, etc.), 2) It has a theoretical rationale. This has not been the case for most previous marijuana research. The tests of marijuana effects used in most previous studies seem to have been chosen either because they are standard tests for drug effects (e.g., reaction time), they are relevant to descriptions by marijuana users of their subjective experience (e.g., auditory acuity), they are simple and convenient, or because they had been used in other research studies.

The general hypothesis of this study is that marijuana will impair its user's ability and/or tendency to form and use abstract concepts, i.e., to conceptually organize his world. This hypothesis was suggested by Aldous Huxley in his attempt to explain his own experiences with mescaline, which he describes in The Doors of Perception. Huxley asserts that man's perception of his world is influenced by his tendency to conceptually organize his sensory data, and that, if a person can avoid such conceptualization, he will perceive reality differently.

This idea is not original with Huxley. He gives credit for it to the French philosopher, Henri Bergson:

> Reflecting on my experience, I find myself agreeing with the eminent Cambridge philosopher, Dr. C. D. Broad, "that we should do well to consider much more seriously than we have hitherto been inclined to do the type of theory which Bergson put forward in connection with memory and sense perception. The suggestion is that the function of the brain and nervous system and sense organs is in the main eliminative and not productive. Each person is at the moment capable of remembering all that has ever happened to him and of perceiving everything that is happening everywhere in the universe. The function of the brain and nervous system is to protect us from being overwhelmed and confused by this mass of largely useless and irrelevant knowledge, by shutting out most of what we should otherwise perceive or remember at any moment, and leaving only that very small and special selection which is likely to be practically useful." According to such a theory, each one of us is potentially Mind at Large. But in so far as we are animals, our business is at all costs to survive. To make biological survival possible, Mind at Large has to be funneled through the reducing valve of the brain and nervous system. What comes out at the other end is a measly trickle of the kind of consciousness which will help us to stay alive on the surface of this particular planet. To formulate and express the contents of this reduced awareness, man has invented and endlessly elaborated those symbol-systems and implicit philosophies which we call languages. Every individual is at once the beneficiary and the victim of the linguistic tradition into which he has been born--the beneficiary inasmuch as language gives access to the accumulated records of other people's experience, the victim in so far as it confirms him in the belief that reduced awareness is the only awareness and as it bedevils his sense of reality, so that he is all too apt to take his concepts for data, his words for actual things. That which, in the language of religion, is called "this world" is the universe of reduced awareness, expressed, and, as it were, petrified by language /p. 22-24/.

Huxley goes on to suggest that perhaps hallucinogenic drugs affect perception of reality by decreasing one's tendency to conceptually organize his sensory data.

The assertion presented by Huxley is implicit in Bergson's book, An Introduction to Metaphysics, (1912). In it Bergson makes a distinction between relative and absolute knowledge. Relative

knowlege "depends on the pont of view at which we are placed and on the symbols by which we express ourselves /p.17." Absolute knowledge "neither depends on a point of view nor relies on any symbol /p.17." Bergson gives, as an example, his ability to know a character in a novel:

> All the traits which describe him, and which can make him known to me only by so many comparisons with persons or things I know already, are signs by which he is expressed more or less symbolically. Symbols and points of view, therefore, place me outside him; they give me only what he has in common with others, and not what belongs to him and to him alone. But that which is properly himself, that which constitutes his essence, cannot be perceived from without, being internal by definition, nor be expressed by symbols, being incomensurable with everything else. Description, history, and analysis leave me here in the relative. Coincidence with the person himself would alone give me the absolute. /p. 4-5/.

Bergson labels the act of obtaining absolute knowledge 'Intuition', and the act of obtaining relative knowledge 'analysis':

> . . . an absolute could only be given in an intuition, whilst everything else falls within the province of analysis. By intuition is meant the kind of intellectual sympathy by which one places oneself within an object in order to coincide with what is unique in it and consequently inexpressible. Analysis, on the contrary, is the operation which reduces the object to elements already known, that is, to elements common both to it and other objects. To analyze, therefore, is to express a thing as a function of something other than itself. All analysis is thus a translation, a development into symbols . . . /p. 7/.

Bergson summarizes his ideas about intuition and analysis as follows:

> Just in so far as abstract ideas can render service to analysis, that is, to the scientific study of the object in its relations to other objects, so far are they incapable of replacing inuition, that is, the metaphysical investigation of what is essential and unique in the object. For on the one hand these concepts, laid side by side, never actually give us more than an artificial reconstruction of the object, of which they can only symbolize certain general, and, in a way, impersonal aspects; it is therefore useless to

> believe that with them we can seize a reality of which they present to us the shadow alone /p. 18/.

Bergson has defined metaphysics as "the science which claims to dispense with symbols /p.9/." His position is, essentially, that metaphysical truths can only be obtained by intuitive vision which goes beyond the distortions of conceptual thought.

Huxley (1954) summarizes his own position as follows:

> We can never dispense with language and the other symbol systems; for it is by means of them, and only by their means, that we have raised ourselves above the brutes, to the level of human beings. But we can easily become the victims as well as the beneficiaries of these systems. We must learn how to handle words effectively; but at the same time we must preserve and, if necessary, intensify our ability to look at the world directly and not through that half opaque medium of concepts, which distorts every given fact into the all too familiar likeness of some generic label or explanatory abstraction /p. 74/.

There are a number of reasons that make this theoretical framework suitable as a basis for a study of marijuana. First, of course, is the fact that Huxley found it compelling in accounting for his own drug experience. Second, it accounts, at least intuitively, for a number of the most commonly reported effects of marijuana. For example, marijuana users often report that while under the influence of marijuana they perceive objects as if seeing them for the first time. According to the theoretical framework underlying this study, one views an object in terms of the conceptual categories in which he places it. If one views a chair, for example, he does not simply experience the pattern of stimulation presented to his retina, he immediately categorizes the pattern in terms of familiar concepts: 'separate object,' 'furniture,' 'something to sit on,' 'chair,' etc. This categorization greatly influences the

phenomenal awareness elicited by the pattern of stimulation. The concept dominates the percept.

That people do, in fact, perceive this way can be clearly seen in the phenomenon of perceptual constancy. A familiar object looks the same, phenomenally, when seen from the front as when seen from the side, yet the two patterns of stimulation presented to the retina may be significantly different. But the concepts which describe the object do not change.

If marijuana does allow one to escape this dependence upon categorization, to view the world in terms of percepts rather than concepts, then viewing an object while under the influence of marijuana is, in a very real sense, seeing it for the first time. Huxley describes this sort of experience in The Doors of Perception:

> At any other time I would have seen a chair barred with alternate light and shade. Today the percept had swallowed up the concept. I was so completely absorbed in looking, so thunderstruck by what I actually saw, that I could not be aware of anything else. Garden, furniture, laths, sunlight, mere verbalizations, for utilitarian or scientific purposes, after the event. The event was this succession of azure furnace doors separated by gulfs of unfathomable gentian /p. 53/.

A similar experience can be gotten without drugs. If one repeats a word over and over it eventually loses its conceptual identity (i.e., 'word with a particular meaning') and becomes simply a pattern of sounds. And, indeed, one often does feel that he is hearing the word as if for the first time, sometimes to the point of not being sure if it is a real word at all.

This theoretical framework could also account for the paradoxical fact that heightened sensory acuity is almost universally reported by marijuana users, although research has found no evidence of it.

If one sees a chair as simply a pattern of sensory stimulation, rather than immediately categorizing it as a 'chair,' one will be more aware of the simple sensory qualities of the pattern of sensation. Color, texture, shape, etc., will stand out rather than being subordinate to the concept 'chair.' The observer may, quite reasonably, say that his senses are heightened. But, of course, he will exhibit no change in measurable sensory acuity, since the change is not in his capacity to discriminate sensations, but in his 'awareness' of those sensations available to him.

Another experience commonly reported to occur under the influence of marijuana is noticing new details and seeing new relationships. Such experiences could be reasonably expected to result from a decrease in the tendency to quickly categorize sensory input, since such categorization generally fits new sensory input into already familiar concepts, thereby interfering with the discovery of new details and relationships.

Lastly, marijuana users commonly report difficulty in expressing themselves while high. Words are expressions of concepts. Linguistic expression requires conceptual organization of whatever is to be expressed. If such conceptual organization becomes more difficult, then it is to be expected that linguistic self expression would also become more difficult.

METHODS

Subjects

The Ss were 12 adult, male, experienced volunteer users of marijuana. The approximate number of times each had used marijuana in the year preceding the experiment, according to the Ss' own estimates, ranged from 3 to 500.

All Ss were respondents to word of mouth advertising about the project. Each S was paid $20 for his participation in the study. The mean age was 25.8 with a range of 21 to 33 years. Of the 12 Ss, 10 were university students and 2 were employed. All Ss agreed to abstain from use of drugs for at least 24 hours prior to each experimental session.

Tests

The tests used were chosen to require the Ss to form and use abstract concepts in a variety of ways. They included the following:

1. The Letter Series Test

   This test was taken from the Science Research Associates Primary Mental Abilities Test, Revised, 1962. In each problem of this test, the S was presented with an ordered series of letters. His task was to abstract the pattern underlying the series in order to figure out which letter comes next, e.g., abababab?. Scores were recorded for both time and number correct. Ss were allowed a maximum of 120 seconds for each problem.

2. The Word Grouping Test

   This test was also taken from the Science Research Associates Primary Mental Abilities Test, Revised, 1962. In each problem, the S was presented with a group of five words, four of which belonged to the same conceptual category. He had to abstract the conceptual category in order to determine which word did not belong with the other four. Scores were recorded for both time and number correct.

3. The Conceptual Clustering Memory Test

   In this test, the S was presented with a list of 24 words, one at a time which he read within 2 minutes. When he finished he

was instructed to recall, and write down, as many of the words as he could, in whatever order they came to him. Each list consisted of six words from each of four conceptual categories, arranged in random order. The Ss score was determined by the degree to which he recalled words from the same conceptual categories in adjacent positions. Bousfield (1953) has shown that Ss who are presented with this kind of task tend to recall members of the same conceptual category in adjacent positions with greater than chance frequency.

This test measures a S's tendency to organize the list of words according to the categories implicit in it, i.e., his tendency to use the abstract concepts (categories) available to him. Bousfield (1953) states that, "The theoretical significance of this undertaking derives in part from the assumption that clustering is a consequence of organization in thinking and recall. If clustering can be quantified, we are provided with a means for obtaining additional information on the nature of organization as it operates in the higher mental processes (p. 229)."

The measure of conceptual clustering used in this study is the ratio of repetition (RR). The RR was first used by Bousfield (1953), and has since become one of the most commonly used indices of clustering. The RR=S/N-1, where S is the number of sequences in the list of remembered words and N is the number of words remembered. A sequence occurs any time that two words from the same conceptual category are recalled in adjacent positions. The RR is said to be independent of the number of

words actually recalled (Dalrymple-Alford, 1970). According to the general hypothesis of this study, the mean RR should be smaller in the marijuana than in the placebo conditions. The number of words recalled from the list was also recorded as a rough measure of short-term memory.

4. The Closure Speed Test

This test was adapted from the Closure Speed Test (1956), published by the Industrial Relations Center of the University of Chicago, and the Gestalt Completion Test (1962), published by the Educational Testing Service, Princeton, N.J.

The S was presented with a series of pictures with parts missing. His task was to identify the pictures as quickly and as accurately as possible. He was given two minutes to identify as many pictures as he could.

This is a test of the S's concept formation at the perceptual level with ambiguous material. The Closure Speed Test Administration Manual, Revised (1966) describes it as, "... the ability to perceive an apparently disorganized or unrelated group of parts as a meaningful whole, i.e., the capacity to construct a whole picture from incomplete or limited material. This basic perceptual capacity may manifest itself at a more general level as the conceptual ability to group and unify a complex situation (p. 1)." According to the general hypothesis of this study, performance on the Closure Speed Test should be impaired by marijuana.

5. The Embedded Figures Test

This was an adaptation of the Embedded Figures Test developed by Witkin (1950) and published in 1969 by the Consulting Psychologists Press, Inc. In each item of this test the S was shown a complex design and required to find, as quickly as possible, a simple figure which was embedded within it. He was allowed a maximum of three minutes on each item. His score was the total amount of time taken to solve all the items, with failures scored as 180 seconds.

The Embedded Figures Test was designed to reflect the manner in which a person perceives an object in relation to its surroundings, or a part within a larger whole. A person whose perception of the part is strongly influenced by the surrounding field is called 'field dependent' and should do poorly on this test. A person whose perception of the part is not strongly infleunced by the surrounding whole is called 'field independent' and should do well on this test. The Embedded Figures Test required the S to overcome his tendency to organize the complex designs presented to him in terms of familiar concepts: rectangles, triangles, straight lines, colors, etc., since the simple figure was hidden by this most obvious and 'natural' organization of the complex design. Witkin's instructions for the Embedded Figures Test require that the S describe, aloud, the complex figure, apparently in order to strengthen his conceptual organization of it, before he tries to find the simple figure within it.

If marijuana decreases concept formation skills at the perceptual level, users should more readily find the simple figure in the complex design and thus improve performance on the test, unless visual perceptual skills themselves are impaired.

6. The Size-Weight Illusion Test

In this test the S was presented with a series of 29 small volume cylindrical weights, arranged in a semi-circle before him. The cylinders were ordered according to weight. He was then given three larger cylinders, one at a time, and instructed to place each one in the series of small cylinders, in accordance with its weight, so that the small cylinder to its left seemed lighter than it and the small cylinder to its right seemed heavier than it. He was scored according to how far away from its true position he placed each large weight, without regard to direction. The score recorded for each S is a total of three such absolute deviation scores, one for each large weight placed.

Research has shown that Ss who are presented with this kind of task will almost invariably underestimate the weight of the large cylinders relative to that of the small ones (Werber and King, 1962). This test can be interpreted as follows: The size-weight illusion (SWI) results because people tend to confuse weight with density. For example, the question, "Which is heavier, a pound of lead or a pound of feathers? is often answered, "Lead," because it is denser than feathers." This is a confusion of concepts. Most people have a tendency to analyze the sensation of weight according

to the rules for the concept of density. Although this explanation of the SWI is not universally accepted, it is consistent with current thinking about the phenomenon (Nyssen and Bourdon, 1956; Werber and King, 1962). If, as hypothesized, a person under the influ of marijuana is less likely to generate a conceptual organization of the sensory data available to him, then he should be less subject to this sort of confusion and less subject to the SWI.

Ss were also asked to place in the series of small weights two cylindrical weights of the same size as those in the series. This procedure does not relate to the general hypothesis of this study, but was included as an easily obtainable measure of simple weight judging ability. The scoring procedure was the same as for the large weights.

7. The Water-Jar, Hidden Word, and Anagram Tests

These were included as tests of stereotypy or perseveration in solutions of problems. The Water-Jar Test was developed by Luchins (1942). The S was presented with a series of problems of the following form: Given three jars, one holding 21 quarts, one 127 quarts, and one 3 quarts, and an unlimited supply of water, obtain 100 quarts of water. The first few problems are all solvable by the same formula: B(127) - A(21) - 2C(6) = the correct answer (100). These problems establish a problem-solving set to use this formula. They are followed by a series of critical problems, which may be solved by this formula or a more direct method. For example, A=23 quarts, B=49 quarts, C=3 quarts, obtain 20 quarts: B(49) - A(23) -2C(6) = 20, or

A(23) - C(3) = 20.

The Hidden Word Test was also developed by Luchins (1942). It is structured similarly to the Water-Jar Test, differing only in the nature of the problems solved. In the Hidden Word Test, the S's task was to find a word in a string of letters, without changing the order of the letters. The training problems establish the set of using alternate letters in the list, beginning with the first letter, to find an animal name, e.g., MSAVRAE (solution: MARE). The critical problems can be solved this way, but they also include a more direct solution, a series of consecutive letters which form a word, e.g., TSINGREVR (set solution: TIGER; direct solution: SING).

The Anagram Test was developed by Rees and Israel (1934-35). It consists of a series of 30 anagrams. The first 15 (training) anagrams are solvable only by a particular rearrangement of the letter order. The second 15 (critical) anagrams are solvable by this pattern, but also include other solutions.

It was assumed that the less rigid a S was, the more direct (or non-pattern) solutions he would use in the critical problems. The rigidity measured by these tests might be interpreted as a rigidity of conceptualization. The rigid S puts the initial problems in the category of being solvable by a certain method and he is unable to overcome that categorization with the critical problems. If it is true that marijuana lessens its user's ability to generate concepts, even rigid ones might not be applied and his rigidity as measured by these tests might be reduced. However, the overall performance on the tests

also should be reduced.

For purposes of analysis, these three tests were treated as parallel forms of the same test. They are, of course, not really parallel forms of the same test. But, in view of the fact that, for obvious reasons, none of these tests could be given more than once to each S, and given the constraints of the experimental design (each S tested three times), this treatment was felt to be the best solution.

The score recorded for each of the tests was the ratio of the number of direct solutions to the total number of solutions of the critical problems. This variable was used, rather than simply the number of direct solutions, to make the tests comparable and to control for differences among dosage levels in the total number of critical problems solved.

Experimental Design

The experimental design used in this study is a three by three Greco-Latin Square, replicated four times. Each S was randomly assigned a number from 1 to 12 to determine his place in the design. The order in which the seven tests were administered was separately randomized for each S, subject to the restriction that each test appear approximately the same number of times in each sequential position. Each S experienced the same order of test administration in all three experimental sessions, but a different parallel form of each test in each session.

Procedures

The Marijuana

Both the active and placebo marijuana were obtained from the National Institute of Mental Health for use in this study. The two

active grades of marijuana contained 1.5% Δ^9-THC (low dose) and 2.9% Δ^9-THC (high dose). The placebo material consisted of marijuana from which all of the Δ^9-THC had been extracted without significant alteration of taste, smell and texture of the material.

Ss smoked the marijuana in cigarettes prepared by the staff pharmicist at the Lafayette Clinic in Detroit, Michigan.

Dosage Levels

Prior to the three experimental sessions of this study, each S participated in an experimental session at which his individual dosage level was set. During this session, the S was instructed to smoke as much 2.9% Δ^9-THC marijuana as he could, to a maximum of four 300 mg cigarettes. The S was encouraged to continue smoking until he actually refused to smoke anymore, generally because he felt "too high" in spite of moderate urging by the experimenter. Both the S and the experimenter knew prior to the beginning of this session that active marijuana was being used.

In the following three session, each S smoked the same number of cigarettes and/or fractions thereof that he had smoked during the first session. For different sessions he smoked only one grade of material, either the "high dose" (2.9% Δ^9-THC), "low dose" (1.5% Δ^9-THC), or placebo (0% Δ^9-THC). After each session the cigarette butts were weighed to determine precisely how much the S had smoked during that session.

The Experimental Sessions

The sequence of events for each of the three experimental sessions was as follows:

Approx. time		Activity
1.	20 min.	Pre-smoking neuropsychological tests
2.	20-40 min.	Smoking
3.	20 min.	Post-smoking neuropsychological tests
4.	40-60 min.	Cognitive tests
5.	20 min.	Final neuropsychological tests

The results of the neuropsychological tests are not reported in this paper.

The experimental sessions were held in three isolated sound quieted testing rooms in the research wing of the Lafayette Clinic. The smoking took place in one room, the neuropsychological tests in another, and the cognitive tests in the third.

During each session the S's pulse was taken on at least 6 occasions. Ss were tested one at a time. During the administration of the cognitive tests, the experimenter sat next to the S at a small table and timed the S's performance, where appropriate, with a stop watch. The S's smoking was supervised by the experimenters who sat in the same room, lightly conversing with the S while observing. Ss were asked, immediately after smoking, to judge whether the marijuana they had smoked that evening was 'strong,' 'medium,' or 'weak.' The Ss knew that they would be smoking three different strengths of marijuana during the three experimental sessions. They did not know the Δ^9-THC content of the three strengths (although most of them seemed to assume that one would be placebo) or the strength used in any particular session. At the conclusion of the last experimental session, each S was given a short questionnaire to fill out the following day and return by mail. The questionnaire asked Ss to compare the three experimental sessions with regard to the strength of marijuana they smoked, their performance on

the cognitive tests, their motivation to do well, and the time pressure they felt on those cognitive tests which were timed.

The three experimental sessions were generally held at one week intervals, although a few were separated by two or three weeks. Generally, two Ss were run each Tuesday and Thursday evening, beginning about 6:30 P.M. The second S began his pre-smoking neuropsychology segment when the first S began his cognitive test segment.

Analysis of Data

The design allowed repeated measures for each measure over the three sessions and dosages. Only the dosage data is reported, as no order effects were noted.

RESULTS

Subjective Effects of Marijuana Smoking

The amount of marijuana smoked by each subject varied from only slightly over 1 to all 4 300 mg cigarettes and is given in Table I for each S and session.

Each S was asked to estimate at three different times (just after smoking, just before testing, and just after testing) his subjective "high" on a 0 to 10 scale with 10 being the greatest "high" he ever experienced. The mean high $\pm$ S.D. for all 12 subjects was as follows:

	0.0%	1.5%	2.9%
After smoking	2.2 $\pm$ 1.9	6.3 $\pm$ 2.5	8.8 $\pm$ 1.3
Before testing	1.5 $\pm$ 1.3	6.7 $\pm$ 2.4	8.6 $\pm$ 2.0
After testing	0.5 $\pm$ 0.8	5.0 $\pm$ 2.4	7.2 $\pm$ 2.7

It can be seen that there was a dose related increase in the mean subjective "high." Furthermore, over the one hour period of testing the subjective "high" dissipated more rapidly for the placebo than active marijuana.

Especially with the most potent marijuana some Ss were quite giddy and frivolous when not concentrating on the tests. One vomited, but felt well enough to complete the test series.

Letter Series Test

The prediction concerning the Letter Series Test was basically supported by the data. Marijuana led to a dose related impairment in both time and error scores although only the difference in error scores between the placebo and high dose conditions was statistically significant ($P < .025$). The mean ± S.D. for the time scores (in seconds) were: placebo 162.4 ± 68.5, low dose 210.0 ± 118.1, and high dose 224.4 ± 83.8 seconds. The mean ± S.D. for the number right was: placebo 7.6 ± 1.3, low dose 6.6 ± 2.3, and high dose 5.8 ± 2.1.

Word Grouping Test

The prediction concerning the Word Grouping Test was only partially supported by the data. Marijuana had a dose related effect in the predicted direction on time scores. Newman-Keuls tests showed that the differences between placebo and high dose conditions ($P < .01$) and between low dose and high dose conditions ($P < .05$) were both statistically significant while the difference between placebo and low dose conditions was not. The means ± S.D. for the time score were: placebo 115.0 ± 36.1, low dose 139.5 ± 64.2, and high dose 173.3 ± 61.3 seconds.

There were only slight differences among the three conditions with regard to number right. The differences were not dose-related, nor were they statistically significant. The means ± S.D. for the number right were placebo 8.3 ± 1.2, low dose 7.7 ± 2.2, and high dose 8.0 ± 0.9.

Conceptual Clustering Memory Test

The prediction concerning the Conceptual Clustering Memory Test was strongly supported by the data. Marijuana had a dose related effect on the ratio of repetition in the predicted direction. Newman-Keuls tests show that the differences between placebo and high dose conditions ($P < .01$) and between placebo and low dose conditions ($P < .01$) were both statistically significant, but that the difference between high dose and low dose conditions was not. The means ± S.D. for the ratio of repetition were: placebo .53 ± .12, low dose .35 ± .17, and high dose .29 ± .12.

Closure Speed Test

The prediction concerning performance on the Closure Speed Test was partially supported by the data. Ss correctly identified significantly ($P < .01$) fewer Closure Speed pictures in the high dose condition than in the placebo condition but showed no difference between the low dose and placebo conditions. This same pattern held in the number of items attempted by Ss. Ss were correct on 87% of the items attempted in the placebo and low dose conditions, but on only 74% of the items attempted in the high dose condition. The means ± S.D. for the number right were: placebo 10.3 ± 1.6, low dose 10.3 ± 1.8, and high dose 7.2 ± 3.6. The means ± S.D. for the number attempted were: placebo 11.8 ± 2.1, low dose 11.8 ± 2.0, and high dose 9.8 ± 3.1.

Embedded Figures Test

Marijuana did have a dose related effect on Ss' Embedded Figures Test performance in a direction suggesting that the perceptual impairment overcame any "beneficial" effects of conceptual simplification. Marijuana impaired rather than improved Ss' performance. Newman-Keuls

tests show that only the difference between high dose and placebo conditions was significant ($P < .05$). The means ± S.D. for the time scores were: placebo 225.9 ± 216.9, low dose 339.9 ± 268.9, and high dose 412.7 ± 361.7.

The Size-Weight Illusion Test

The prediction concerning performance on the Size-Weight Illusion Test is only minimally supported by the data. Marijuana did have a dose related effect on the magnitude of the SWI, and the effect was in the predicted direction, but it was not statistically significant. Means ± S.D. of the sum of absolute deviations were: placebo 48.8 ± 6.1, low dose 45.0 ± 10.9, and high dose 42.5 ± 14.2.

The Water-Jar, Hidden Word, and Anagram Tests

The prediction concerning performance on the Water-Jar, Hidden Word, and Anagram Tests is not supported by the data. The differences among dosage levels are neither dose related nor statistically significant, and they are in the direction opposite that predicted. The means ± S.D. of the ratio of the direct critical/total critical solutions were: placebo .48 ± .34, low dose .29 ± .28, and high dose .32 ± .32.

Variability of Performance

Clark et al. (1970) concluded that "... in the dose given the principal effect of marijuana on reaction time occurs through sporadic impairment of the subject's capacity to maintain response set (p. 197)." If this sporadic impairment in response set is a general effect of marijuana intoxication, and not specific to reaction time tests like those used by Clark and his associates, then it should be reflected in the variability within a S's scores on a series of similar test items, such as those which make up the Letter Series Test and the Embedded Figures

Test. Since the items in these tests were timed individually, it was possible to compute a standard deviation for each S on each test which would reflect such variability. The means ± S.D. of the standard deviations for the Letter Series test were: placebo 11.4 ± 7.3, low dose 15.7 ± 10.9, and high dose 15.4 ± 8.4. The means ± S.D. of the standard deviations for the Embedded Figures Tests were: placebo 28.2 ± 24.2, low dose 41.1 ± 24.8, and high dose 40.4 ± 21.5. The pattern of results is similar for both tests. Mean S.D.s are considerably higher in the marijuana conditions than in the placebo condition but the differences are not statistically significant and there is almost no difference between low dose and high dose conditions. Although these results do not definitely support the findings of Clark and his associates, they are moderately consistent with them.

Short Term Memory

One of the most commonly reported effects of marijuana intoxication is impairment of short term memory. Two measures of short term memory were recorded as part of this study: the number of words recalled in the Conceptual Clustering Memory Test and the number of reviews (requests to see the simple figure again) in the Embedded Figures Test.

Marijuana clearly had a detrimental, dose related effect on the number of words recalled in the Conceptual Clustering Memory Test. Newman-Keuls tests show that the differences between high dose and placebo conditions ($P < .01$) and between low dose and placebo conditions ($P < .01$) are both significant, although the difference between high dose and low dose conditions is not. The mean ± S.D. number of words recalled in each dosage condition was: placebo 13.4 ± 3.4, low dose 9.8 ± 3.5, and high dose 8.5 ± 3.4.

The effect of marijuana on number of reviews in the Embedded Figures Test is unclear. The mean number of reviews is higher in both marijuana conditions than in the placebo condition but it is higher in the low dose than in the high dose condition and the difference between the high dose and placebo conditions is relatively small. None of the differences are statistically significant. The mean ± S.D. number of reviews in each dosage condition was: placebo 1.5 ± 1.8, low dose 2.8 ± 3.5, and high dose 1.8 ± 1.4. One might speculate, in accordance with the general hypothesis of this study, that remembering a list of words is more dependent on conceptual organization than is remembering an abstract figure.

Weight Judging Ability

Sensory acuity has generally been found to be unaffected by marijuana. Results of that part of the SWI test which measured simple weight judging ability support this finding. Marijuana had no significant nor dose related effect on weight judging ability. The means ± S.D. for the sum of absolute deviations in placing the small cylinders in the SWI test were: placebo 6.3 ± 2.5, low dose 5.9 ± 4.0, and high dose 7.2 ± 5.6.

Ss' Estimates of Their Own Performance

Each S was asked to rate each test (except the Water-Jar, Hidden Word, and Anagram Tests) with regard to the experimental session in which he felt he did best and worst on that test. Thus, there was a total of 60 test performances to be rated 'best' and 'worst' (10 Ss, 6 tests each). The results are as follows:

	Best	Worst	Don't Know
High dose	5	37	
Low dose	14	4	13
Placebo	28	6	

Subtracting the 13 'don't know' responses there are 47 'bests' and 'worsts' distributed among the three dosage levels. It is clear that Ss generally felt they did worst in the high dose condition and best in the placebo condition. These ratings are consistent with Ss' actual performance, and contradict the notion that marijuana leads one to greatly overestimate his capabilities.

DISCUSSION

Of the seven tests of concept formation, it is obvious that the Embedded Figures Test and the Size-Weight Illusion Tests involve complex perceptual skills to a greater degree than the others. If marijuana were to impair perceptual skills then the expected improvement in performance on these two tests would be attenuated. Of the seven test-specific predictions derived from the general hypothesis of this study, five were either strongly or partially supported by the data (tests 1, 2, 3, 4, and 6), and one was not supported (test 7), and one was rejected, i.e., its opposite was supported (test 5). In general, drug induced impairments were demonstrated. Future research testing the hypothesis of this study should pay special attention to the possibility of drug induced improvements in performance on tests such as Witkin's Embedded Figures and the SWI, which require for good performance that the S overcome dependence on conceptual organization. At least one study, Harman et al. (1966), found that Ss performed significantly better on the Embedded Figures Test when under the influence of LSD-25.

In order to make a realistic interpretation of the results of this study, one must take into account two methodological considerations. To begin with, dosage levels were determined subjectively. Ss did not

all smoke the same quantity of marijuana, nor were the amounts they smoked based on their respective body weights. Each S's dose was individually determined according to his point of refusal during the initial session. Thus, any implications concerning the effects of marijuana drawn from this study cannot include an objective specification of the amount of marijuana which is likely to produce that effect.

There were three reasons for this departure from the traditional objective specification of dosage level. The first was purely practical. It has been the authors' experience that marijuana users have highly individual styles of smoking. They vary considerably with regard to length of time between inhalations, amount of smoke taken in during a single inhalation, and amount of time that the smoke from a single inhalation is held in the lungs. Efforts to make different Ss conform to the same style have been generally unsuccessful. Thus, it appeared that it would be very difficult to attempt to standardize dosage by setting a fixed quantity of marijuana for each S to smoke.

The second reason was more theoretical. If one conceives of a marijuana study as an investigation of the effects of a drug on an organism, then one would certainly want to objectively standardize the amount of the drug consumed by each S. But if one conceives of a marijuana study as an attempt to analyze the marijuana experience as a subjective one, then it is the 'intensity' of the experience which should be standardized. In view of the folklore that the intensity of the marijuana experience is not invariably related to the amount smoked (e.g., experienced smokers are said to need less than new smokers to achieve the same subjective effects) it makes a good deal of sense to use a subjective endpoint in determining dosage. This study was, in fact, conceived of as an attempt

to analyze the subjective marijuana experience at three different levels of Δ^9-THC content.

The third reason had to do with the potential implications of the study. Insofar as one wishes to draw implications from a laboratory study for a real world situation, it is desirable to reproduce, as closely as possible, the real world situation in the laboratory. In the real world, marijuana users generally dose themselves subjectively; they keep smoking until they don't want anymore. Thus, it makes sense to use a similar procedure in the laboratory.

Of the seven variables which showed statistically significant differences with respect to dosage level, five of them showed significant differences between the high dose and placebo conditions, but not between the low dose and placebo conditions. Thus dosage level was certainly an important factor in determining the pattern of results obtained in this study. With regard to the implications of this study for the real world, it should be noted that the high dose is probably more than most of the Ss would normally smoke. In fact, the importance of dosage level may have been underestimated. There are some indications (casual discussions with Ss, etc.) that a few of the Ss felt significant anxiety during the first (dosage setting) session, and attempted to modify their smoking techniques in the later sessions so as to decrease their dosage. Thus, the difference between the low and high doses of these Ss may have been less than intended.

These results clearly indicate that the pattern of marijuana effects demonstrated in a research study may substantially depend upon the dosage level used in the study. The importance of dosage level may help explain the general inconsistency of the findings of marijuana research to date. Various studies have used different dosage levels, thus it is

not surprising that they have obtained different results. Even within the present study, the pattern of results one sees by looking only at low dose-placebo comparisons is considerably different than the pattern of results one sees by looking only at high dose-placebo comparisons.

An important methodological consideration has to do with the attempt to make the study double-blind. This was not very successful. Results of the post-study questionnaire indicate that Ss were generally aware of which dose was received in each session. Only one S erred in guessing the doses of marijuana he received. He confused the "strongest" and "medium" doses, but guessed the "weakest" dose correctly. In addition, the experimenter could almost always tell whether a S had received placebo or active marijuana, either by the Ss behavior or simply by his unsolicited statements that he was or was not 'stoned.' Discriminations by the experimenter between low dose and high dose conditions could occasionally be made but much less frequently and with less certainty. These results conflict with the report of Jones and Stone (1970) that Ss could not distinguish active marijuana from placebo, and support Weil's (1969) contention that it is impossible to do truly double blind research on marijuana, using experienced Ss.

In view of the fact that Ss could distinguish among different dosage levels on the basis of subjective effects and the experimenter could distinguish among different dosage levels on the basis of the S's post-drug behavior, there is no reason to expect that this problem would be eliminated by using oral rather than smoked doses of marijuana.

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TABLE I

AMOUNT OF MARIJUANA SMOKED BY EACH S IN EACH SESSION (IN MG)

S No.	1st Session	2nd Session	3rd Session	Sum	Mean
1	591.8	587.8	595.0	1774.6	591.5
2	787.5	640.8	587.1	2015.4	671.8
3	815.5	964.0	1011.9	2791.4	671.8
4	566.6	562.0	596.9	1725.5	575.2
55	492.5	476.6	337.3	1306.4	435.5
6	586.1	685.6	660.3	1932.0	644.0
7	1111.4	1042.8	1055.9	3210.1	1070.0
8	881.5	848.8	875.0	2605.3	868.4
9	408.8	399.4	507.3	1315.5	438.5
10	849.8	833.0	874.6	2557.4	852.5
11	393.4	259.3	276.2	928.9	309.6
12	1000.0	1026.6	928.0	2954.6	984.9