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Marihuana and Memory: Acquisition or Retrieval?

Abstract. *Two experiments were conducted to determine the means by which marihuana affects human memory. The results of these studies indicated that marihuana did not affect retrieval of information in memory when the method of free recall was used, but did affect recognition processes such that subjects were less able to discriminate between items that had been presented previously and items that had not appeared a short time before. With respect to initial learning, marihuana was shown to affect acquisition processes involved in the storage of information.*

Marihuana has been shown to have deleterious effects on human memory (*1*). The actual process by which this occurs, however, has not as yet been determined. For instance, marihuana may interfere with either acquisition of information, or storage of acquired information, or retrieval of stored material, or any combination of these processes. An earlier study (*2*) failed to detect any effect of marihuana on retrieval, thereby suggesting that acquisition or storage processes were being affected. The following studies were designed to investigate this possibility.

The first of the present studies constitutes a replication and extension of work by Abel (*2*) wherein marihuana was found to have no significant effect on the retrieval of information already present in memory. Forty-nine adult males and females served as either marihuana, placebo, or control subjects. Assignment of subjects was similar to that previously described (*2*), the only provision being that subjects that had not used marihuana previously were placed in either the control or the placebo condition. Subjects that were familiar with the effects of marihuana were allocated to any of the three test conditions.

The design of the study was similar to that used by Cohen (*3*). Eighteen ten-item lists of words were read aloud at a rate of approximately 1.5 seconds per word. One minute was allowed for spoken free recall of a list immediately after its presentation. After completion of the initial free recall of the last list, the subject was presented with a list containing 60 words, 30 of which had appeared on the first three lists of the prior test, along with 30 new items, or "lures." The subject was asked to circle all those he thought were on the prior lists, and for each item circled he was to indicate how confident he felt about the accuracy of his response, using a 5-point scale similar to that used by Murdock (*4*). This task lasted approximately 8 to 10 minutes, and will be referred to as the immediate recognition test.

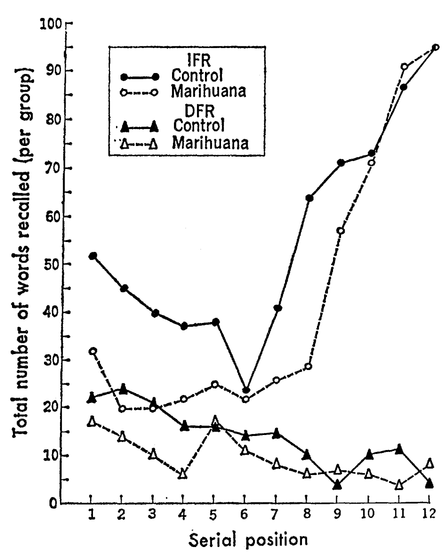

Fig. 1. Free recall as a function of serial position; *IFR*, initial free recall; *DFR*, delayed free recall.

Upon completing the task, subjects in the marihuana group were allowed to smoke one marihuana cigarette, the tetrahydrocannabinol content of which had not been determined. Subjects in the placebo group were given a cigarette containing ordinary tobacco, but were told that it had been dipped in tetrahydrocannabinol, the active ingredient in marihuana, and that as a result it would "taste and smell like tobacco, but the psychological effect will be like that of smoking marihuana." The smoking period lasted approximately 5 to 10 minutes. Control subjects were left undisturbed during this period.

Immediately after the smoking period, the experimenter made a pretense of testing "concept formation" and administered the Block Design Test and the Picture Arrangement Test —two subtests of the Wechsler-Bellevue Intelligence Test (*5*). These tests were conducted for purposes of occupying the subjects with some distracting task in the time period between the end of the initial free recall test and the start of the next phase of the study. Twenty-five minutes after the initial free recall test, subjects in the marihuana and placebo conditions were given a 10-point rating scale and were asked to rate how "high" they felt at that moment (1, not high at all; 3, slightly high; 5, moderately high; 8, very high; 10, extremely high). The subjects were then given 5 minutes to write out as many words as they could remember from the prior lists (this task being delayed free recall). After this, a second recognition task was administered (delayed recognition). The test lists in this second recognition test contained 300 items, 150 items from the last 15 lists and 150 lures, none of which had been used in the first recognition test.

Only marihuana subjects who rated themselves at 5 or more were included in the analysis of the data. The marihuana subjects were then matched by inspection with an equal number of subjects in the control and placebo groups on the basis of their scores on the initial free recall test ($N = 13$ for each group). The words used in the initial free recall and recognition tests were selected from the lists in Thorndike and Lorge (*6*). One-third were high-frequency words (A and AA), one-third were of low frequency (five or fewer occurrences per million), and the remaining third were of moderate frequency (20 to 30 per million). All words in a list were of the same word frequency.

The results are presented in Table 1. An analysis of variance (*7*) indicated that the differences between the three groups on the initial free recall test were not significant. The measures for the recognition test are taken from signal detection theory (*8*). Briefly, "hits" refer to the number of items correctly identified as being on the lists previously read. "False alarms" refer to the number of lure items incorrectly identified as bein on the lists. The index, d′, is a measure of the subject's ability to discriminate between the correct and the incorrect items. It is based on the notion that the memory trace of a list item is similar to a signal which must be differentiated from background noise. This measure is assumed to be independent of any motivational bias. This latter factor is represented by β, which is an index of how cautious the subject is in making his decision.

The differences between groups were not significant for any of these measures in the immediate recognition task. Although not presented in Table 1, words of high frequency were correctly recalled and recognized significantly more often than words of lower frequency, but this factor did not interact with any of the treatment factors.

There were also no significant differences between the groups in the delayed free recall task, although there was a slight trend in the direction of poorer recall under the marihuana condition. The analysis of the data, however, indicates that marihuana does not significantly interfere with the retrieval of information already present in the memory. On the other hand, recognition processes were significantly influenced by marihuana. While the number of items correctly identified was the same for all groups, subjects who had smoked marihuana were prone to accept more incorrect items as well. This latter difference is reflected in their lower sensitivity (d′) and criterion (β) indices. These findings are similar to those previously reported (*2*) and indicate that under the influence of marihuana there is (i) a decrease in the ability of an individual to discriminate between items that were on a prior learning list and those that were not, and (ii) a tendency for individuals to be less cautious in reporting signals that may or may not have been presented in a prior learning list.

Table 1. Effects of marihuana in retrieval mechanisms in free recall and recognition (mean number of words per subject).

Item	Treatments: Control	Placebo	Marihuana
Initial free recall			
	106.5	100.8	106.1
Immediate recognition			
Hits	6.1	6.1	5.9
False alarms	2.0	2.5	2.0
d′	1.8	1.6	1.5
β	2.0	2.2	1.8
Delayed free recall			
	11.9	9.9	8.0
Delayed recognition			
Hits	67.5	59.2	59.4
False alarms	19.5	16.2	26.8*
d′	1.2	1.2	0.8*
β	2.4	3.0	1.8*

* $P < .05$.

Having eliminated the possibility that retrieval processes are influenced by marihuana, I designed the following experiment to study the effects of maıihuana on acquisition and storage.

The subjects were ten adult males and females, all of whom were familiar with the effects of marihuana. Each subject was tested twice. In the first session, one-half the subjects served as controls; the other half smoked marihuana prior to being tested. Approximately 1 week later, the roles were reversed, so that those that had been controls before were now given marihuana, and vice versa.

The procedure used by Caldwell *et al.* (*9*) was followed in allowing subjects to smoke as much marihuana as they wished in order to attain their own subjective "high." The experiment began 5 minutes after a subject had finished smoking the marihuana. As in the previous study, subjects were asked to rate how "high" they felt; all subjects rated themselves at either 7 or more on the 10-point scale. The test material consisted of ten lists of 12 words each. Two different sets of 10 word lists were employed so that subjects were not tested twice with the same material. The words were all of moderate frequency, and the rate of presentation was the same as that used in the first study. After the last list had been tested, subjects were given 5 minutes to write down as many of the words as they could recall from the test lists just presented.

All ten subjects remembered fewer words in the marihuana condition in initial free recall ($P < .001$, binomial test). The mean total words recalled per subject were 66.7 and 50.9 for the control and the marihuana conditions, respectively. This is a difference of 13.17 percentage points based on the total 120 words. In the delayed free recall test, eight subjects out of ten did worse in the marihuana condition, one subject did better, and for the remaining subject there were no differences between conditions in total words recalled. If this latter subject is eliminated from the analysis, this result is also highly significant by the binomial test ($P < .02$). The mean numbers of words recalled per subject in delayed free recognition were 16.7 and 11.4 for control and marihuana conditions, respectively. This represents a difference of 4.42 percent.

These results demonstrate that marihuana interferes with learning processes. The nature of the effect on memory is depicted in Fig. 1, which shows the number of words correctly recalled for each serial position in the list. These data can be readily interpreted in terms of the model of human memory described by Shiffrin and Atkinson (*10*). Applying this model to the initial free recall curves in Fig. 1, items in serial positions 10 to 12 may be assumed to be recalled from the sensory register component of memory. This is the store which receives information from the sense organs, and from which information is subject to rapid decay. Inspection of the curves for the marihuana and control conditions indicates that there are virtually no differences in this part of the curve, indicating that subjects are receiving information equally as well in each condition. Items in serial positions 6 to 9 represent information recalled from the short-term store, which temporarily holds information that has entered it from the sensory register. Forgetting from the short-term store occurs via spontaneous decay. To prevent such decay, the subject must rehearse the information he wishes to retain so that it remains in the short-term store long enough to be transferred to the long-term store, which holds information permanently.

It can be seen from Fig. 1 that according to the model just described, there are more items recalled from both the short-term store (items 6 to 9) and the long-term store (items 1 to 5) for subjects in the control condition than in the marihuana condition.

This means that information is probably being rehearsed to a greater extent in the control condition and, as a result, more information is entering the long-term store. The fact that more information enters the long-term store under control conditions is confirmed by the greater number of items that are recalled in delayed free recall in the control condition as compared with the marihuana condition.

Finally, for items to be rehearsed, subjects must fix their attention on retaining information after it has been presented. Upon being interviewed after the experiment, many of the subjects stated that after smoking marihuana they were simply unable to concentrate on the task long enough for them to perform to their best ability. This inability to concentrate is thus the most likely reason memory is adversely affected by marihuana. In not being able to concentrate, subjects cannot rehearse. As a result, information cannot be transferred to permanent memory.

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Retrieval Failure or Selective Attention?

To specify whether forgetting is primarily a result of memory trace degradation or a memory search failure at the time of retrieval, Shiffrin (*1*) employed a procedure termed delayed free recall (DFR) in which subjects were presented a series of different word lists. Upon the completion of presentation of any one list, the subjects were required to recall the words of the immediately preceding list. In this way, Shiffrin was able to manipulate independently both the length of the list to be recalled and the length of the "interpolated" list intervening between presentation and recall. Shiffrin reasoned that if forgetting is a result of memory trace degradation, then recall should be influenced by the length of the interpolated list (that is, long interpolated lists should produce more forgetting than short interpolated lists). However, if forgetting is the result of memory search failure, then length of the list to be recalled should be the effective determinant in forgetting (that is, words from long lists should be more difficult to remember than words from short lists).

Shiffrin reported three separate experiments in which subjects practiced 20 successive lists. Some lists were short (five words) and some lists were long (20 words). In all experiments, Shiffrin found relatively more forgetting of words from long than from short lists, but no effect on forgetting attributable to length of interpolated list. Shiffrin interpreted these findings as favoring a theory of forgetting in which retrieval factors are more important than memory trace degradation.

In light of the theoretical significance that such an interpretation carries for human memory, a closer examination of the data reported by Shiffrin is warranted. Shiffrin's case in favor of a retrieval theory of forgetting is based on the fact that a greater proportion of words was recalled from short (.28) than from long (.12) lists. (We derived these values by averaging the data presented by Shiffrin for the three experiments.) However, when these proportions (mean probability of recall) are converted into average number of words recalled from short (1.40 words) and from long (2.40 words) lists, the interpretation of the data becomes less certain. The paucity of words recalled from any list, plus a difference between short and long lists in the direction opposite to that obtained with proportions, seriously questions the sensitivity of the DFR procedure for determining the relative contribution to forgetting of factors associated with either a trace degradation or retrieval theory.

The poor recall of both short and long lists suggests that subjects adopted a memory strategy enabling them to meet the task requirement peculiar to the DFR procedure. Specifically, DFR requires that subjects simultaneously store in memory words from two successive lists. It may be that subjects selectively attend to certain ("easy") words and ignore others, so that the total number of words stored across lists will be small enough to assure that some words will be remembered from each list. It is interesting to note that the average number of words (3.80) recalled from short (1.40) and long (2.40) lists lies within the proposed limits (5 ± 2 words) of immediate memory (*2*). Thus, if subjects did, in fact, selectively attend to certain words, then Shiffrin's procedure may not have provided for an adequate test of the effect of list length on forgetting. In order to make such a test, it is necessary to ensure that subjects store in memory all words of a list. If the subjects do not store all words, effects attributable to list length cannot be determined. In short, because subjects may have effectively reduced list length through selective attention, Shiffrin's results do not permit unequivocal conclusions about trace degradation and retrieval theories of memory.

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There are four points raised by Slaybaugh *et al.* in their "technical" comment. The first is logically fallacious, and the others are directly contradicted by the data. To take them in the order given:

1) More words are recalled from longer lists, even though per word recall is less.

As far as I know, this is always the case in free recall—the fact is not in dispute by anyone. But what conclusions are Slaybaugh *et al.* trying to draw: that forgetting is less for the longer lists? The fallacy in this argument can be seen by analogy. Suppose I note that Willie Mays bats .500 in 100 times at bat before he is hurt. Suppose also that John Q. bats .200 in 400 times at bat. I therefore conclude that