Psychopharmacologia (Berl.) 29, 231–238 (1973)
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Marihuana and Retrieval from Short-Term Memory

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Received October 20, 1972

Abstract. Twelve subjects received an oral dose of marihuana extract calibrated to 20 mg of Δ^1-tetrahydrocannibinol on Day 1 of the experiment and performed a short-term memory task before and after administration of the drug. The subjects were then split into two groups, receiving either marihuana or placebo on the evenings of Days 1 to 4 and between two memory test sessions on Day 5. Placebo subjects showed little change in performance between the two test sessions on Day 5; however, results from Day 1 for all subjects and Day 5 for the drug group showed that reaction time increased from before- to after-challenge sessions. This increase in time under marihuana was explained as a change in encoding and/or response processes, rather than processes involved in the search of the memory store.

Key words: Marihuana — Memory Search — Retrieval from Memory — Encoding Processes — Response Speed.

An important component of perceptual and cognitive functions is the retrieval of information stored in memory. In some cases, information experienced and stored by an individual in the distant past must be recalled and applied to a task. On the other hand, information experienced a few seconds earlier may be applicable to the task. One common view of the human memory is that it consists of two stores: a large and relatively permanent long-term store (LTS) and a limited capacity short-term store (STS). Incoming information is held in STS for a short time until it decays and/or is replaced by other information. While the information resides in STS, some or all of it may be transferred to LTS, where it is permanently maintained (Atkinson and Shiffrin, 1968).

Because quick and accurate retrieval of information from these memory stores is so important to the optimal performance of many complex tasks, the study of how marihuana affects memory retrieval is an important topic for both practical and theoretical reasons. The present study is concerned with retrieval from just one of the memory stores, the STS. An excellent paradigm for examining retrieval from short-term memory has been developed by Sternberg (1966, 1969). In this paradigm a subject is presented a set of items (memory set) on each trial of the experiment; next a test stimulus is presented which may or may not

be in the memory set. The subject must make a positive response if the test stimulus is a member of the memory set, and a negative response otherwise. Subjects are invariably correct in their response and thus the principal measure of performance is reaction time (RT), defined as the interval between presentation of the test stimulus and the response. Because the size of the memory set varies from trial to trial, functions may be plotted relating RT to memory-set size for both positive and negative responses. These functions typically are linear and increasing with memory-set size; the slopes of the positive and negative functions are approximately equal, but the negative function usually has a slightly higher intercept.

The usefulness of this memory-search paradigm for drug research lies in Sternberg's theoretical analysis, which identifies three independent components or stages in the task. The first stage represents the time necessary to encode the test stimulus, which is assumed to take time e. In Stage 2, the test stimulus must be compared with each of the memory-set elements. The time required to compare the test stimulus with a single memory-set element is α, so the total time for this stage of the task is αd, where d is the size of the memory set. Once these comparisons are made, the subject must decide upon a response (positive or negative), and execute it. This third stage requires time r_y for a positive response and r_n for a negative response. The expected RT as a function of the memory-set size, d, may be represented by the sum of the times necessary to complete the three stages, namely,

$$\mathrm{RT}(d) = \begin{cases} (e + r_y) + \alpha d, \text{ for a positive response} \\ (e + r_n) + \alpha d, \text{ for a negative response.} \end{cases}$$

Averaging RTs for positive and negative responses yields

$$\mathrm{RT}(d) = (e + \bar{x}) + \alpha d,$$

where $\bar{x}$ is the average of r_y and r_n. Note that the intercept of the RT function $(e + \bar{x})$ depends upon the time taken to complete Stages 1 and 3. The slope of the function (α) represents the time necessary to compare the test stimulus with each member of the memory set during Stage 2 of the task. Thus, the observed RT function can be fitted with a straight line; the slope of that line is an estimate of α and the intercept is an estimate of $e + \bar{x}$. Note, however, the RT data does not permit an estimate of e and $\bar{x}$ separately, but only their sum.

If, as this analysis implies, the time necessary to complete the comparison stage of the search task is separable from the encoding and

response times, then the effect of marihuana intoxication upon these separate components may be examined. The crucial question is, does a marihuana "high" change the slope (comparison time) or intercept (encoding and response times) of the RT function?

Methods

Subjects were 12 adult males, all of whom were moderate (not more than once per week) social users of marihuana. Each participated for 6 days. Day 0 was a practice day during which the subjects became familiar with the search task by performing on a series of 128 trials. Day 1 was the first testing day during which all subjects first received 128 trials on the task, then were administered an oral dose of marihuana, and finally received another 128 trials beginning 45 min after drug ingestion. The subjects were then randomly assigned to two groups, a drug group and a placebo group; neither the experimenter nor the subjects knew to which groups they had been assigned. Because laboratory measures not discussed here were taken in order to test for possible cumulative effects of repeated doses of marihuana, during the evenings of Days 1 to 4 each subject received an oral dose of either marihuana or placebo, depending on the group assignment. No tests were administered on Days 2 to 4. Day 5 was identical to Day 1, with testing sessions before and after challenge, the only change being that the placebo group received placebo rather than marihuana between testing sessions.

Memory sets were composed of words selected randomly from the Toronto Word Pool, which consists of common two-syllable English words not exceeding eight letters in length with proper nouns, homophones, contractions, and archaic words omitted (Murdock and Walker, 1969). Set sizes ranged from 1 to 4. Within a session of 128 trials a given word appeared in only one memory set. Test stimuli for negative trials were drawn from the same pool of words and also were never repeated. Memory-set sizes and positive and negative trials were randomly mixed within a session with the restriction that the different set sizes occurred equally often, and that there were equal numbers of positive and negative trials for all memory-set sizes. On each trial the memory set was read aloud to the subject; the subject then pushed a button which caused the test word to be exposed tachistoscopically for 800 msec. Upon seeing the test word, the subject was to strike one of two response keys as quickly as possible, indicating either a positive or a negative response. The procedure employed here is described in detail elsewhere (Juola and Atkinson, 1971).

The marihuana used in this study was supplied by the National Institutes of Mental Health. Oral doses of the active drug were administered in the form of brownies containing marihuana calibrated to 20 mg of Δ^1-tetrahydrocannibinol, whereas placebo subjects received brownies identical in taste and appearance containing marihuana from which all cannibinoids had been removed. Doses were ingested after at least an 8-hour fast.

Results and Discussion

The data from Day 1 are presented in Table 1. The mean RTs for positive and negative responses for each memory-set size are presented, along with the corresponding standard deviations of the mean RTs over

Table 1. Mean reaction time and the standard deviation of mean reaction times for individual subjects, for each memory-set size. Also shown are overall reaction time, standard deviation, and error rate. Data presented are for both positive and negative responses, before and after challenge, for Day 1 (all subjects) and Day 5 (drug and placebo subjects)

			Reaction time (msec)					Error proportions
			Size of memory set				Overall	
			1	2	3	4		
Day 1								
Positives	Before	Mean	489	555	607	622	568	0.03
		SD	55.2	68.7	79.4	85.2	69.6	
	After	Mean	500	590	615	643	587	0.03
		SD	53.9	56.0	70.0	68.7	57.8	
Negatives	Before	Mean	545	593	623	631	598	0.03
		SD	61.0	67.7	74.2	71.8	66.9	
	After	Mean	563	613	632	659	617	0.03
		SD	51.2	65.3	68.1	71.0	62.2	
Day 5 (Drug subjects)								
Positives	Before	Mean	485	567	593	613	565	0.03
		SD	51.3	60.1	40.8	44.9	45.1	
	After	Mean	520	587	632	645	596	0.03
		SD	78.6	55.8	57.2	70.7	63.1	
Negatives	Before	Mean	541	585	619	627	593	0.02
		SD	46.6	47.7	38.4	47.8	44.0	
	After	Mean	558	609	634	640	610	0.02
		SD	44.4	81.8	55.6	46.7	56.5	
Day 5 (Placebo subjects)								
Positives	Before	Mean	489	547	589	609	559	0.03
		SD	68.5	62.0	65.7	65.8	63.1	
	After	Mean	475	558	587	591	553	0.03
		SD	63.6	61.1	80.5	62.9	65.4	
Negatives	Before	Mean	539	577	604	619	585	0.01
		SD	67.3	74.3	60.7	76.6	67.7	
	After	Means	526	586	606	610	582	0.01
		SD	60.4	91.7	84.9	92.6	81.3	

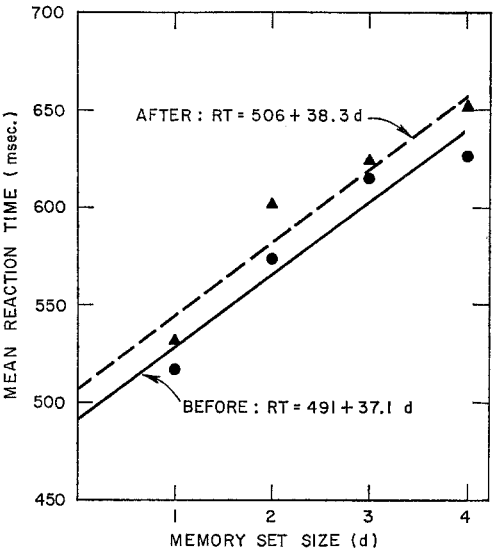

Fig. 1. Performance on Day 1 for before- and after-challenge sessions. Mean reaction time for combined data from positive and negative responses is plotted as a function of memory-set size (d)

subjects. Only trials on which the subject made a correct response were used in calculating these values. Overall error percentages are also shown in Table 1. The mean RTs of the combined data from positive and negative trials from Day 1, before and after challenge, are presented in Fig. 1; also displayed are the best-fitting straight lines obtained by the method of least squares[1].

Results from studies using the memory-search paradigm described here usually show a slight practice effect for early experimental sessions, that is, RTs decrease over trials. As subjects become more competent, this practice effect asymptotes. Therefore, if performance on the present task were unaffected by the administration of a dose of marihuana, the expected result would be a slight decrease in overall RT between the two test sessions on Day 1 (or possibly no change given that the subjects already had extensive practice). The results in Fig. 1 indicate that this result is not obtained. Mean overall RT increases from 583 msec

1 The separate positive and negative functions show some departures from linearity and are not equal in slope, as the previously presented model predicts. However, such deviations from the model have been noted before, particularly for positive responses (Juola and Atkinson, 1971).

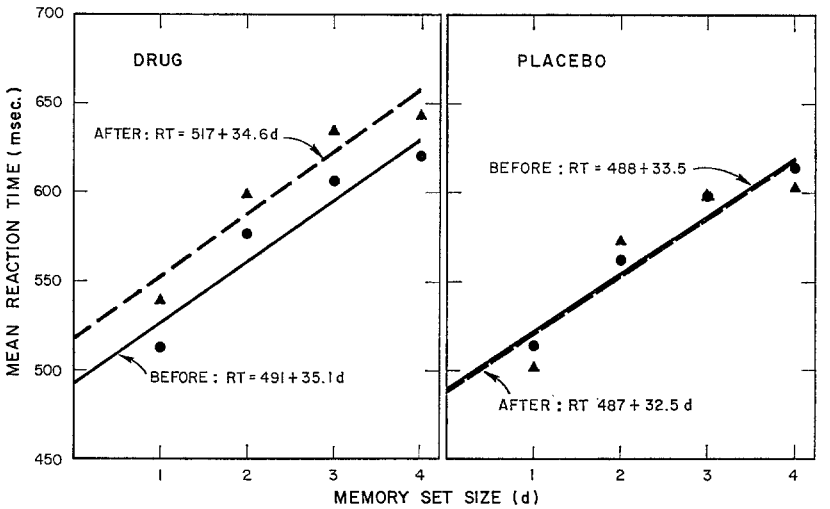

Fig. 2. Performance of drug and placebo subjects on Day 5 for before- and after-challenge sessions. Mean reaction time for combined data from positive and negative responses is plotted as a function of memory-set size (*d*)

for the before-challenge session to 602 msec for the after-challenge session. This difference is accounted for by the intercept difference of 15 msec. Neither the intercept nor overall RT differences are significant statistically, but since the expected difference without drug is in the opposite direction from that obtained here, the data suggest that the drug is slowing performance on the task. Furthermore, the drug is only affecting those components which contribute to the intercept value. As shown in Table 1, overall error rates were identical (3%) for before- and after-challenge sessions.

On Day 5, half the subjects received a placebo between sessions and half received an active dose of marihuana. The only other difference between these groups was that the placebo subjects were administered placebo on the evenings of Days 1 to 4, whereas the drug subjects were given the active drug. The placebo subjects provided a control group with which to compare differences in performance between before- and after-challenge sessions for the drug subjects. The mean RTs for positive and negative responses, standard deviations, and error rates for drug and placebo subjects on Day 5 are presented in Table 1.

Fig. 2 presents mean RT as a function of memory-set size for the two groups, before and after challenge. Again, data from positive and negative trials are averaged, and best-fitting straight lines are shown.

Mean overall RT decreases from before to after challenge for placebo subjects, although the difference of 5 msec is slight. In contrast, the drug subjects show an increase in overall RT from before to after challenge, a difference which approaches statistical significance for negative responses and reaches the 0.05 level of significance for positive responses. The intercept difference of 26 msec for the combined data from negative and positive trials (shown in the left panel of Fig. 2) accounts for the difference in overall RT. As on Day 1, the overall error rates for positive and negative trials did not change from before to after challenge for either group.

Other investigatiors have shown that marihuana intoxication increases both simple (Hollister and Gillespie, 1970) and complex (Clark, Hughes, and Nakashima, 1970) RT. The present study confirms these findings. In addition, the theory proposed to account for performance in a task of the sort used in this study permits us to identify the probable locus of the effect of marihuana. The results from Days 1 and 5 show that only the intercept of the RT function is affected by administration of the drug. If the model presented here accurately describes the processes involved, then our results suggest that decrements in performance resulting from marihuana intoxication are caused by an increase in encoding and/or response time and are not due to change in the search rate for information in STS. The question of which component, encoding or response, is affected cannot be answered here, because their effects are not separable by the analysis we have used. The fact that simple RT is slowed following marihuana intake (Hollister and Gillespie, 1970) suggests that the intercept effect in this study may be primarily in the response stage; however, increases in encoding time cannot be ruled out.

This research was supported by grants MH-03030 and MH-19918-02 from the National Institute of Mental Health and a grant from the Van Ameringen Foundation. The authors thank Pat Murphy for her assistance in collecting data.

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