Rate of Forgetting in H.M.: 6-Month Recognition

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The picture-recognition performance of H.M. and six control subjects was evaluated 6 months after initial learning, using materials from an earlier study in which H.M. received additional study time in order to equate his yes–no and delayed-match-to-sample (DMNS) performance 10 min after learning to that of control subjects. In the study detailed here, 6-month recognition performance was assessed with no intervening exposure to the target items. H.M. performed at chance levels when tested using the standard yes–no recognition procedure. When the yes–no procedure was modified so that distractor stimuli required positive responses, H.M.’s performance was comparable with that of control subjects. In addition, H.M.’s DMS and delayed-nonnatch-to-sample (DNMS) performance were comparable with that of control subjects 6 months after learning. Conclusions regarding H.M.’s 6-month recognition performance are thus dependent on the procedures used to assess memory.

H.M. is not strikingly dissimilar to the slope for control subjects. This last fact contradicts Huppert and Piercy’s hypothesis.

A recent study further calls into question Huppert and Piercy’s (1979) hypothesis that temporal-lobe pathology is associated with rapid forgetting. Freed et al., (1987) attempted to replicate and extend the original findings in H.M. using the yes–no recognition technique employed by Huppert and Piercy as well as a delayed-match-to-sample (DMS) forced-choice procedure. These authors noted that H.M. displayed normal levels of forgetting at delays up to 1 week when the mean of four experiments was examined, provided that H.M. was given additional study time in order to equate his performance 10 min after learning to that of control subjects. These findings contradict the view that bilateral medial temporal-lobe lesions result in rapid forgetting. In addition, this study suggests that H.M.’s recognition performance is quite variable and that different recognition procedures yield discrepant results when administered to H.M.

Our study was undertaken in order to evaluate forgetting in H.M. over a period of 6 months. If H.M.’s forgetting is normal at this extended delay interval, it would be further evidence of a normal rate of forgetting in H.M. In addition, this experiment examined H.M.’s 6-month recognition performance using a variety of recognition procedures, including DMS and delayed-nonnatch-to-sample (DNMS), yes–no, and a new variant of the yes–no procedure. These different recognition techniques were employed in order to evaluate the possibility that different procedures may yield different results in amnesiac subjects (Freed, 1984, 1985) and to investigate whether heightened attention to novelty may underlie certain forms of memory impairment (Freed & Corkin, 1985b; Freed, Corkin, Gadowdon, Nissen, in press-a, in press b).

Method

Subjects

The subjects of this study were H.M. and a group of six healthy individuals who served as control subjects. The control subjects were...
six employees of Massachusetts Institute of Technology who agreed to participate in this and other research protocols. As a group, the control subjects were matched with H.M. with regard to age (58.2 years old vs. 58 years old, respectively) and with regard to education (12.0 years vs. 12 years). As previously mentioned, H.M. underwent a bilateral medial temporal-lobe resection in 1953 at the age of 27 for the relief of intractable epilepsy. The bilateral resection included the uncus, amygdala, and the anterior 8 cm of the hippocampus and hippocampal gyrus (Scoville & Milner, 1957). All subjects participated in an earlier experiment investigating recognition performance 1 week after learning (Freed, Corkin, & Cohen, 1984; Freed et al., 1987).

Test Materials

Three different forms of the picture-recognition task were assembled from a total of 720 color slides of complex photographs, reproduced from foreign language magazines. The material for each form of the test was organized into two sets of 120 slides. Each set of 120 contained an equal number of slides from each of six categories related to the subject of the slide: animals, interiors, buildings, people, nature, and single objects. One set of 120 slides was designated to serve as targets and the other set as distractors. Duplicate slides of the targets were randomly assigned to one of 120 positions in the target set used in the learning phase. Test construction has been described elsewhere (Freed et al., 1987). The targets were used in this earlier experiment, which was designed to assess memory performance at retention intervals of up to 1 week. During recognition testing in the experiment detailed here, the targets were paired with new distractor stimuli, which as a set were similar to the targets, as well as the distractor stimuli used in the earlier experiment.

Procedure

Six months after the 1-week retention test used in an earlier experiment (Freed et al., 1984, 1987), with no intervening exposure to the target items, the recognition performance of the same group of subjects was evaluated with a retention test. In other words, a 6-month recognition test was administered without allowing the subjects from the earlier experiment further study of the target items.

Subjects were administered the picture-recognition task individually. In the learning phase that occurred 6 months prior to recognition testing, control subjects viewed each slide in the target set for 1 s. H.M. viewed each slide in the target set for 10 s and then immediately viewed the same set again in the same order, thus receiving a total of 20 s of exposure to each slide in order to equate his yes–no and DMS recognition with that of control subjects 10 min after learning. DNMS and yes–no (new) recognition performance, to be described later, were not assessed at the 10-min retention interval that was used in the earlier experiment.

H.M.'s 6-month recognition performance was assessed on three occasions using three different forms of the picture-recognition test (Table 1). These three forms have been shown to be equivalent in terms of degree of difficulty (Freed et al., 1987). During the period in question, there was no major change in H.M.’s neurological status. Each of the control subjects was administered one of the three forms in this study.

H.M.’s initial exposure (the learning phase) to the second set of targets occurred 1 month after his initial exposure to the first set of targets, which means that H.M. was exposed to two sets of targets prior to being administered the first 6-month recognition test. H.M.’s initial exposure to the third set of targets occurred after the first two 6-month recognition tests were administered. The results of our experiment are thus quite conservative, because H.M. was required to study two sets of targets before his 6-month recognition performance was assessed for the first set of targets. This procedure would be expected to have a detrimental influence on memory performance, because it maximizes interference effects for the first two sets of targets.

In assessing recognition performance, both forced-choice and yes–no procedures were used. The forced-choice procedures included both DMS and DNMS recognition tasks, as described in an earlier study (Freed et al., in press-a). In forced-choice testing, subjects viewed two slides (a target and a distractor), presented via two slide projectors. For the DMS procedure, subjects were instructed to indicate which one of the two pictures they had seen before. For the DNMS procedure, subjects were instructed to indicate which one of the pictures was new. In the yes–no procedure, subjects were told that half of the pictures would be targets and half would be distractors. Subjects then viewed a single slide (target or distractor) and were asked to make a judgment as to whether they had seen that slide before. In addition, the subjects were administered a new variant of the standard yes–no procedure. In what we will call the yes–no (new) procedure, subjects viewed a single slide (target or distractor) and were asked to make a judgment as to whether that slide was new. For each subject, the DMS, DNMS, yes–no, and yes–no (new) recognition procedures were administered in a single retention test, with the targets appearing in a random order that was different from the order used 6 months earlier.

The order of administration of the four recognition procedures was randomized for each subject. Because 120 targets were used in the learning phase, each retention test contained 120 targets: 30 targets were used for DMS testing, 30 for DNMS testing, 30 for yes–no testing, and 30 for yes–no (new) testing. An equal number of distractor items were employed in each recognition procedure.

Results

H.M.'s 6-month recognition performance, as assessed in three experiments, are presented in Table 1. Note that H.M.’s recognition performance is consistent across the three different forms of the test, despite the fact that he was required to study two sets of targets before his 6-month recognition performance for the first set of targets was evaluated. Table 2 presents the 6-month recognition performance of the six control subjects who participated in this study. In Figure 1 are shown the yes–no recognition data for H.M. and the control subjects at the 10-min and 6-month delay intervals. The T-bars in this and the other two figures represent a range of ±1 standard deviation (SD). It should be noted that the following analyses violate an assumption concerned with the

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Yes–No</th>
<th>Yes–No (new)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>TP</td>
<td>TN</td>
</tr>
<tr>
<td>1</td>
<td>50.0</td>
<td>43.3</td>
</tr>
<tr>
<td>2</td>
<td>53.3</td>
<td>36.6</td>
</tr>
<tr>
<td>3</td>
<td>50.0</td>
<td>50.0</td>
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</tbody>
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Note. TP = total positive; TN = total negative; TC = total correct; DMS = delayed-match-to-sample; DNMS = delayed-nonmatch-to-sample.
Table 2
Six-Month Recognition Performance of Six Control Subjects

<table>
<thead>
<tr>
<th>Subject</th>
<th>Yes-No (TP)</th>
<th>Yes-No (TN)</th>
<th>Yes-No (TC)</th>
<th>DMS</th>
<th>DNMS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>50.0</td>
<td>75.0</td>
<td>62.5</td>
<td>75.0</td>
<td>45.0</td>
</tr>
<tr>
<td>2</td>
<td>57.5</td>
<td>85.0</td>
<td>71.25</td>
<td>80.0</td>
<td>45.0</td>
</tr>
<tr>
<td>3</td>
<td>40.0</td>
<td>77.5</td>
<td>58.75</td>
<td>45.0</td>
<td>65.0</td>
</tr>
<tr>
<td>4</td>
<td>65.0</td>
<td>52.5</td>
<td>58.75</td>
<td>85.0</td>
<td>25.0</td>
</tr>
<tr>
<td>5</td>
<td>22.5</td>
<td>90.0</td>
<td>56.0</td>
<td>65.0</td>
<td>22.5</td>
</tr>
<tr>
<td>6</td>
<td>27.5</td>
<td>77.5</td>
<td>52.5</td>
<td>70.0</td>
<td>25.0</td>
</tr>
</tbody>
</table>

Note. TP = total positive; TN = total negative; TC = total correct; DMS = delayed-match-to-sample; DNMS = delayed-nonmatch-to-sample.

independence of subjects, because the data for H.M. was treated as that of three subjects, rather than that of one individual tested on three occasions. However, for all four recognition procedures used in this study, namely the yes-no, DMS, DNMS, and yes-no (new) procedures, the variance for control subjects and H.M. was found to be homogeneous using an F test, justifying the violation of the independence assumption. With these considerations in mind, H.M.'s yes-no (total number correct) performance differed significantly from that of the control subjects 6 months after learning, t(7) = 3.53, p < .005, despite the fact that H.M.'s performance was closely matched to that of the control subjects 10 min after learning, t(7) = .083, p > .25.

The mean DMS performance of H.M. and the control subjects at the same delay intervals are shown in Figure 2. Note that H.M.'s mean DMS performance 10 min after learning did not differ significantly from that of the control subjects, t(7) = .10, p > .90. H.M.'s mean DMS performance 6 months after learning also did not differ significantly from that of the control subjects, t(7) = 1.55, p < .09, although the probability approaches significance.

In Figure 3 are shown the mean DNMS data for H.M. and the control subjects 6 months after learning. It should be noted that the subjects' DNMS performance was not assessed at the 10-min retention interval used in an earlier experiment (Freed et al., 1984, 1987). H.M.'s yes-no and DMS recognition performance, however, was matched to that of control subjects at the 10-min retention interval. In three experiments, H.M.'s DNMS performance 6 months after learning was equal or superior to the mean performance of the control subjects. Accordingly, H.M.'s mean DNMS performance did not differ significantly from that of the control subjects 6 months after learning, t(7) = .46, p > .25.

The mean yes-no (new) data for H.M. and the control subjects 6 months after learning are also shown in Figure 3. As previously stated, H.M.'s yes-no (new) recognition performance was not assessed at the 10-min retention interval used in an earlier experiment, although his yes-no and DMS performance were comparable with that of control subjects 10 min after learning. In three experiments, H.M.'s mean yes-no (new) performance 6 months after learning did not differ significantly from that of the control subjects, t(7) = .59, p > .25.

H.M.'s mean DNMS performance was superior to his mean DMS performance 6 months after learning, t(4) = 2.57, p < .05. By contrast, the control subjects' mean DMS and DNMS performance did not differ significantly 6 months after learning, t(10) = .89, p > .10. Similarly, H.M.'s mean yes-no (new) performance was superior to his mean yes-no performance 6 months after learning, t(4) = 5.23, p < .005. By contrast, the control subjects' mean yes-no and yes-no (new) performance did not differ significantly 6 months after learning, t(10) = 1.13, p > .10.

Discussion

It has been noted that the recognition performance of patients with memory disorders is more variable when assessed with yes-no recognition procedures than with forced-choice procedures (Freed et al., 1987). These observations imply that forced-choice procedures are superior to the yes-no procedure in assessing the memory performance of amnesic subjects. Despite the apparently conflicting results yielded by the yes-no and forced-choice procedures in our experiment, there are some important similarities. For example, it has been noted that patients with memory disorders give a higher percentage of false-positive responses than do control subjects when their recognition performance is assessed using the standard yes-no procedure (Freed et al., 1987). This observation suggests that these patients may react to aspects of novelty during recognition testing, which motivated us to use the yes-no (new) procedure in this experiment. It is demonstrated in Figure 3 that H.M.'s recognition performance is equal or superior to the mean performance of control subjects when assessed with DNMS and yes-no (new) recognition procedures. Techniques that focus on aspects of novelty. By contrast, it is clear from Figures 1 and 2 that H.M.'s recognition performance suffers when assessed with
DMS and the standard yes–no procedure, both of which focus on previously seen stimuli.

The results of this study suggest that the amnesiac subject H.M. displayed a bias for aspects of novelty during forced-choice recognition testing. For example, H.M.'s DMS performance 6 months after learning did not differ significantly from that of control subjects, although the probability approached significance at the .09 level. In three experiments, however, H.M.'s DNMS performance 6 months after learning was equal or superior to the performance of control subjects. In addition, H.M.'s mean DNMS performance was superior to his mean DMS performance 6 months after learning. By contrast, the control subjects' mean DMS and DNMS performance did not differ significantly 6 months after learning. Similarly, H.M.'s mean yes–no (new) performance was superior to his mean yes–no performance 6 months after learning, whereas no such difference was noted for control subjects. These results suggest that H.M.'s memory disorder may be related in part to a preference for novel stimuli over previously seen items. In addition, both the yes–no and forced-choice findings support the idea that a response bias to novelty may underlie H.M.'s memory disorder.

It is important to note that H.M. received 20 s of exposure to each slide in the learning phase in order to equate his initial performance with that of control subjects (who received 1 s of exposure to each slide). It could be argued that novelty adds a determining feature to H.M.'s recognition performance, but because H.M. required 20 s of exposure during the learning phase, novelty (as seen from this perspective) must be a rather small factor in the overall character of his memory disorder. It is possible, however, that novelty plays a significantly greater role than this view suggests.

Preliminary data has revealed that H.M. can display nearly normal levels of recognition performance after brief exposures, provided that his memory is assessed with the DNMS procedure (Freed & Corkin, 1985a). H.M.'s preference for novel stimuli may prevent him from demonstrating adequate recognition performance because novel stimuli are used as distractors in the testing procedure. When this bias for novel stimuli is taken advantage of during DNMS and yes–no (new) recognition testing, H.M.'s memory performance improves. This view would suggest that the additional study time is needed by H.M. in order to have a memory trace strong enough to be discriminated from novel stimuli, which are subject to an attentional bias. This view also predicts relatively intact recency and frequency discriminations in H.M., because the stimuli used in testing are no longer completely novel.

Taken together with the results of a previous experiment in which researchers noted normal levels of forgetting in H.M. over a 7-day delay interval (Freed et al., 1984, 1987), it is apparent that bilateral lesions of medial temporal-lobe structures do not invariably result in abnormally rapid forgetting, provided that amnesic subjects are given additional study time in order to equate their initial performance with that of control subjects. The results of our experiment also suggest that different recognition procedures yield different results when administered to amnesic subjects.

Rather than contradicting the idea that studies of forgetting will delineate different etiologies of amnesia, this experiment raises the possibility that different patterns of performance on a battery of recognition procedures will discriminate between types of amnesic subjects. The observation that H.M. displays a preference for aspects of novelty during recognition testing suggests one possible explanation for the memory impairments resulting from medial temporal-lobe pathology. It is conceivable that other etiologies of amnesia are associated with different patterns of recognition performance. In order
to evaluate this hypothesis, it will be necessary to administer a battery of recognition procedures to amnesic subjects. The results of this experiment suggest that different recognition procedures yield discrepant results when administered to amnesic subjects. It may prove useful to look for differences in the pattern of recognition performance displayed by amnesic subjects of different etiologies.

References


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