The contribution of recollection and familiarity to yes–no and forced-choice recognition tests in healthy subjects and amnesics

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Abstract

Recent reports suggest that some amnesic patients perform relatively normally on forced-choice recognition memory tests. Their preserved performance may reflect the fact that the test relies more heavily on assessments of familiarity, a process that is relatively preserved in these patients, than do other recognition tests such as yes–no tests, which may rely more on recollection. The current study examined recognition memory using yes–no and forced-choice procedures in control and amnesic patients in order to determine whether the two tasks differentially relied on recollection and familiarity, and whether the extent of the recognition memory deficit observed in amnesia was dependent upon the type of recognition test used to measure performance. Results using the remember–know procedure with healthy subjects showed that there were no substantial differences in recognition accuracy or in the contribution of recollection to these two tasks. Moreover, amnesic patients were not found to perform better on a forced-choice test than on a yes–no test, suggesting that familiarity contributed equally to these two types of recognition test.

Keywords: Dual process; Signal detection; Memory assessment; Remember–know

1. Introduction

Damage to the medial temporal lobe or diencephalon results in anterograde amnesia; this deficit is most often reflected as a pronounced reduction in free recall performance. However, the effects on recognition memory performance are less clear. Some studies have reported that recognition is preserved in amnesia, while others have reported that recognition is impaired \cite{3,9–11,13,19,24}. In a recent meta-analysis of amnesic data, Aggleton and Shaw \cite{1} found that amnesics with restricted hippocampal lesions exhibited near normal performance in the Recognition Memory Test (RMT) \cite{23}, but that patients with additional damage outside this region exhibited recognition deficits.

The relatively preserved performance of some amnesics on tests such as the RMT may reflect the fact that the test is based on a forced-choice procedure. This type of procedure may rely more heavily on assessments of familiarity, and less on recollection, than do yes–no recognition procedures. Previous studies have shown that amnesia is associated with a pronounced reduction in recollection (i.e., the ability to retrieve qualitative information about a previous episode), but that familiarity (i.e., the ability to evaluate the contextual memory strength, or familiarity, of an item) is relatively preserved \cite{11,22,26}. In a forced-choice test, subjects may select the more familiar of the two test items, and thus they may not attempt to recollect qualitative information about the study event. Thus, amnesics may exhibit relatively normal performance...
on this task. In contrast, old and new items are not presented together in pairs in a yes–no test and this may reduce the subject’s ability to rely on assessments of familiarity, forcing a greater reliance on recollection. Thus, amnesics may be expected to perform poorly on yes–no tests.

There is in fact, some reason to think that familiarity assessments may be more prone to error in a yes–no test then in a forced-choice test. For example, MacMillan and Creelman [15] have suggested that with time, noise may be added to the original memory trace and as a result, without another stimulus item available for a direct comparison, subjects may find it difficult to use assessments of familiarity in a yes–no test.

The aim of the current study was to contrast recognition memory performance on yes–no and forced-choice procedures in amnesics and healthy subjects, in order to determine if the tasks differentially relied on recollection and familiarity, and to determine whether amnesics performed better on the forced-choice compared to the yes–no procedure. To our knowledge, yes–no and forced-choice recognition has never directly been compared in amnesic patients. Moreover, the contribution of recollection and familiarity to these two procedures has not been directly compared. The results of the current study will be critical in understanding the effects of amnesia on recognition memory, and will be useful in understanding how recollection and familiarity contribute to performance in these two test procedures.

Experiments 1–3 contrasted yes–no and forced-choice recognition in healthy subjects under a variety of study and test conditions. The remember–know procedure [21] was used to assess the contribution of recollection to performance [6,7]; subjects were required to respond ‘remember’ when they could recollect qualitative information about the study event and respond ‘know’ if it was familiar in the absence of recollection. Experiment 4 contrasted yes–no and forced-choice performance in amnesics and age-matched control subjects, to determine whether amnesics performed better on the forced-choice test procedure, and whether the task relied more heavily on familiarity than the yes–no procedure.

2. Experiment 1

We began our investigation by examining recognition memory for words encoded under shallow and deep processing conditions. Deep processing was expected to lead to higher levels of recognition accuracy than was shallow processing [4], and this allowed us to examine performance at two different levels of performance. Subjects were tested either with a yes–no procedure or a forced-choice procedure, and they were required to make remember–know responses for each recognized item. Overall recognition accuracy was examined by calculating $d'$ measures for each subject, and remember responses were used as a measure of recollection.

2.1. Methods

2.1.1. Subjects and materials

Thirty-two undergraduates aged 18–28 at the University of California, Davis participated in exchange for partial credit in an introductory psychology course. Eight hundred words, 6–8 letters long, that were medium frequency and medium imageability were obtained from the Oxford Psycholinguistic database and served as study and test stimuli. The words were randomly divided into four equal sets. The assignment of these word sets to experimental conditions were rotated across subjects.

2.1.2. Design and procedure

Words were presented on a PC-compatible computer in the middle of the computer screen in upper case letters (~3 × 5 mm) and subjects responded on the computer keyboard.

During the study phase, subjects were presented with two lists of words (50 words each) to be studied. Words were presented on the computer screen one word at a time. For one of the lists, subjects were instructed to generate two vowels not present in the study word (shallow encoding) and enter that response into the computer. They were instructed to give different vowel pairs for each subsequent word, otherwise the experiment would not further proceed until the subject entered two new vowels. For the other list, subjects were instructed to generate an associate for each study word (deep encoding) and enter their response into the computer. The order of presentation of the deep and shallow encoding conditions were blocked and counterbalanced across subjects. Subjects were told to proceed at their own pace and not to worry about memorizing the words, but instead to concentrate on performing the encoding tasks.

Following a one week retention interval, subjects returned for testing. Subjects were randomly assigned to either the yes–no or forced-choice test condition. In the yes–no condition, 50 words from the deep encoding list, 50 from the shallow encoding list, and 50 new words were presented one word at a time in a random order. Subjects were instructed to respond ‘old’ if the word was from either of the study lists, and to respond ‘new’ if it was not previously studied. After each ‘old’ response, they were required to make a remember–know judgment [21]. Subjects were instructed to respond ‘remember’ if they could recollect some quali-
Fig. 1. Recognition memory and remember performance for Experiments 1–4 in the yes–no and forced-choice tests.
tative information about its prior occurrence, and respond ‘know’ if the word was recognized on the basis of familiarity in the absence of recollection.

In the forced-choice test, pairs of items (an old and a new item) were presented together, one word above the other. On half of the trials, the ‘old’ word was in the top position. Fifty trials containing a deep encoded item and 50 trials contained a shallow encoded item were presented in randomized order. Subjects were instructed to select the previously studied ‘old’ word from each pair, and to make a remember–know response for each selected item. In both test conditions, subjects proceeded at their own pace.

2.2. Results and discussion

A difficulty in comparing performance across yes–no and forced-choice testing conditions is the difference in response criterion in the two tasks. For example, in a yes–no procedure, subject performance is heavily influenced by the placement of the response criterion. In contrast, forced-choice performance is an unbiased testing procedure since criterion placement does not influence task performance. To examine subject performance in these two tasks independent of response criterion overall recognition accuracy between the two conditions were converted into $d'$ values, this is a signal detection measure that allows one to evaluate yes–no and force choice recognition discrimination independent of response biases [15]. Hits and false alarms in the yes–no condition and percent correct in the forced-choice condition were used to derive $d'$ by using the equations provided in Macmillan and Creelman [15].

Fig. 1a presents the average $d'$ scores for the deep and shallow conditions for the yes–no and forced-choice tests (proportion of recognition scores for all the experiments are presented in Table 1). An examination of Fig. 1a suggested that there was a slight advantage for the forced-choice test over the yes–no test. However, an ANOVA showed that the difference was not significant ($F(1,30) = 1.36, P > 0.252$). There was a significant advantage for deeply encoded words ($M = 0.84$) compared to shallowly encoded words ($M = 0.42$) ($F(1,30) = 43.94, P < 0.001$). Finally, there was no significant task by encoding condition interaction ($F < 1$).

Recollection was assessed by examining the proportion of correct remember responses (Fig. 1b). False recollection were not incorporated into the measures of recollection because false remember rates were often so low that the corresponding $d'$ values were at ceiling (i.e. false alarm rates close to 0.01) and an ANOVA revealed that the proportion of false remember responses (see Table 1, yes–no, $M = 0.078$; forced-choice, $M = 0.063$) did not differ between the two test conditions.

<table>
<thead>
<tr>
<th>Table 1</th>
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<tbody>
<tr>
<td>The proportion of hits and false alarms for the yes–no and forced-choice procedures in Experiments 1–4 (the proportion of remember responses are presented in parentheses)</td>
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<table>
<thead>
<tr>
<th>Experiments</th>
<th>Yes–no</th>
<th>2AFC</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Old items, hits ($R$)</td>
<td>New items, false alarms ($R$)</td>
</tr>
<tr>
<td>Experiment 1</td>
<td>Deep encoding</td>
<td>0.60 (0.26)</td>
</tr>
<tr>
<td></td>
<td>Shallow encoding</td>
<td>0.45 (0.16)</td>
</tr>
<tr>
<td>Experiment 2</td>
<td>0.51 (0.18)</td>
<td>0.30 (0.049)</td>
</tr>
<tr>
<td>Experiment 3</td>
<td>R/K instructions</td>
<td>0.51 (0.33)</td>
</tr>
<tr>
<td></td>
<td>No R/K instructions</td>
<td>0.59</td>
</tr>
<tr>
<td>Experiment 4</td>
<td>Young</td>
<td>0.59</td>
</tr>
<tr>
<td></td>
<td>Age match</td>
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</tr>
<tr>
<td></td>
<td>WM</td>
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</tr>
<tr>
<td></td>
<td>AL</td>
<td>0.75</td>
</tr>
<tr>
<td></td>
<td>WP</td>
<td>0.63</td>
</tr>
<tr>
<td></td>
<td>EM</td>
<td>0.78</td>
</tr>
</tbody>
</table>

<sup>a</sup> The proportion of remember false alarms given is for the new items which were neither deeply nor shallowly encoded.

<sup>b</sup> The proportion of remember false alarms is given for the type of old items (deep or shallow encoding) the new item was paired with in the testing condition.
conditions \((F(1,30)=0.619, P > 0.44)\). An ANOVA revealed that the proportion of correct remember responses was significantly greater for deeply encoded words \((M = 0.29)\) than for shallowly encoded words \((M = 0.15)\) \((F(1,30)=57.41, P < 0.001)\). Most importantly, there was no main effect of task \((F < 1)\), showing that the probability of correct recollection did not differ in the yes–no and forced-choice tests. The interaction between task and encoding conditions condition \((F(1,30)=3.66, P = 0.065)\) approached significance. In the deep encoding condition there was a small non-significant advantage for recollection scores \((yes–no, M = 0.31; forced-choice, M = 0.26)\). However, a post-hoc t-test for the proportion of recollection scores in the deep encoding condition as a function of task revealed no significant performance differences \((t(16)=1.89, P > 0.122)\).

The results of Experiment 1 showed that there was no significant difference between yes–no and forced-choice tests with respect to overall performance or recollection. Numerically there was a slight trend for performance to be higher in the forced-choice task compared to the yes–no task. However, this pattern was not observed in any of the subsequent experiments and thus likely reflects measurement error. The failure to find a significant difference may have been due to the fact that the type of test was a between-subjects variable, and we may have lacked the power to detect such an effect. To address this issue the next experiment examined performance under conditions in which the type of test was varied within-subjects.

3. Experiment 2

Experiment 2 was similar to Experiment 1 except that each subject completed both a yes–no and forced-choice recognition test; the retention interval was reduced; and only a shallow encoding condition was used. Moreover, for the first five remember–know responses, subjects were required to provide a written description of how they made each response. This was added to ensure that they were using the remember and know responses in accord with the test instructions. Also, note that unlike Experiment 1 there were equal numbers of new items in the yes–no and forced-choice conditions.

3.1. Method

3.1.1. Subjects and materials

Twenty-six subjects from the same subject pool as Experiment 1 participated in exchange for partial credit in an introductory psychology class. The materials were the same as those used in Experiment 1.

3.1.2. Design and procedure

The design and procedures were the same as Experiment 1 with the following exceptions. During the study phase of the experiment, subjects encoded 200 words under shallow processing conditions; subjects were instructed to generate two vowels not present in each word. During the retention interval (30 min), subjects were engaged in an unrelated spatial distracter task. Following the retention interval, subjects were tested for their recognition memory in blocks of 100 forced-choice trials and 200 yes–no trials (100 old items and 100 new items). The order of yes–no and forced-choice tests was counterbalanced across subjects. As in Experiment 1 subjects made remember–know judgments for each recognized item. In addition, subjects wrote short explanations for their choice of response for their first five remember–know judgments.

3.2. Results and discussion

Three subjects were excluded from the analysis because their explanation for why they chose a remember response was the same as for their know responses (these three subjects had false alarm rates greater then 50%). The average \(d'\) values and correct remember responses for the forced-choice and yes–no recognition tests are presented in Fig. 1c,d. There was no significant difference in recognition accuracy \((d')\) between the yes–no \((M = 0.56)\) and forced-choice tests \((M = 0.54)\) \((t(22)=-0.71, P = 0.49)\). Moreover, there was no significant difference in the probability of a correct remember responses between yes–no \((M = 0.18)\) and force-choice tests \((M = 0.18)\) \((t(22)=-0.47, P = 0.64)\).

The average rate of false remember responses (Table 1) did not differ between the yes–no and forced-choice tests \((t(46)=0.0, P = 1.00)\).

The results of Experiment 2 are consistent with those of Experiment 1; there were no significant differences in overall recognition performance or in correct remember responses between the yes–no and forced-choice tests.

4. Experiment 3

Experiment 3 was similar to Experiment 2 except that only half of the subjects were required to make remember–know responses. Although we did not find a difference between the tests in the first two experiments, this may have been due to the inclusion of the remember–know judgments. That is, requiring subjects to make explicit judgments about recollection may have prompted them to rely more on recollection, and possibly less on familiarity in the forced-choice test then they would have if the remember–know responses were not required. If this is true then differences
between the yes–no and forced-choice tests may arise when subjects are not required to make remember–know responses.

4.1. Method

4.1.1. Subjects and materials
Thirty-two subjects for the same subjects pool as Experiment 1 participated in exchange for partial course credit for an introductory psychology class. The materials were the same as those used in the previous experiment.

4.1.2. Design and procedure
The procedures were the same as those used in Experiment 2 except that only half of the subjects were required to make remember–know judgments for the recognized items.

4.2. Results and discussion
The average recognition accuracy scores are presented in Fig. 1e. There was no significant difference between performance, as indexed by $d'$, on the yes–no ($M = 0.75$) and forced-choice memory tests ($M = 0.73$) ($F(1,30) = 3.75, P < 0.062$). Accuracy was slightly higher for the subjects who were required to make remember–know judgments ($M = 0.82$) compared to those not required to make remember–know judgments ($M = 0.65$) but the effect failed to reach the level of significance ($F(1,30) = 1.48, P = 0.27$). There was no significant task by instruction interaction ($F < 1$).

The remember responses for the subjects who were given remember–know instructions were examined (Fig. 1f). Three subjects were excluded from analysis in the remember–know condition because they had false alarm rates greater than 50% for their remember responses. For the remaining subjects there was no significant accuracy difference between forced-choice ($M = 0.64$) and yes–no tasks ($M = 0.67$) ($t(15) = -1.40, P = 0.18$). In addition, there was no difference between the proportion of correct remember responses between forced-choice ($M = 0.32$) and yes–no ($M = 0.33$) tasks ($t(15) = -0.203, P = 0.84$). The average rate of false remember responses (Table 1) did not differ between the yes–no and forced-choice tests ($t(30) = 0.0594, P > 0.953$).

The results of Experiment 3 showed that even when subjects were not required to make remember–know judgments, recognition accuracy was equivalent in the yes–no and forced-choice tests. Moreover, as with the previous experiments, an examination of the remember–know judgments showed that recollection did not contribute differentially to the two tasks.

5. Experiment 4
Experiments 1–3 showed that in healthy subjects there was no significant difference in overall recognition performance between the yes–no and forced-choice test procedures. Moreover, there was no evidence for a difference in terms of the contribution of recollection to these two tasks. These results suggest that the two tasks do not rely differentially upon recollection and familiarity. The current experiment aimed to examine performance on these two tests in amnesic patients, to determine whether the earlier results generalized to a memory impaired group. We tested four patients with left medial temporal lobe lesions. Previous testing has shown that these patients exhibit pronounced deficits in recollection, and only modest deficits in familiarity [27], thus they provide a relatively pure index of familiarity-based recognition. If familiarity is more useful in the forced-choice tests, then these patients should perform better in the forced-choice than the yes–no test.

The procedures used in Experiment 4 were similar to the previous experiments except that the forced-choice and yes–no trials were randomly intermixed instead of blocked. Age-matched controls and a group of young subjects were also tested in this mixed design procedure. These latter groups were tested under conditions designed to lead to overall performance that was roughly equivalent to the amnesics.

5.1. Method

5.1.1. Subjects and materials
The materials were the same as those used in the previous experiments. Four patients (ages 40, 67, 75, 82) with lesions in their left medial temporal cortex participated in this experiment. The patients had left medial temporal lob lesions caused by a stroke due to infarction of the posterior cerebral artery from embolus or atherosclerotic occlusion (see Fig. 2 for lesion reconstructions). Their WAISr and WMSr scores are shown in Table 2; these patients had delayed recall scores that were more than 3 SD below normal, showing that they were amnesic for verbal materials. The effects of unilateral posterior infarction on memory

<table>
<thead>
<tr>
<th>Patients</th>
<th>Verbal WAISr</th>
<th>Delayed WMSr</th>
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<tbody>
<tr>
<td>WM</td>
<td>96</td>
<td>69</td>
</tr>
<tr>
<td>AL</td>
<td>113</td>
<td>69</td>
</tr>
<tr>
<td>EM</td>
<td>118</td>
<td>63</td>
</tr>
</tbody>
</table>

* WAISr and WMSr scores are not available for WP.
have been reviewed in more detail by Kroll, Knight, Metcalfe, Wolf and Tulving [14].

Six age-matched controls (ages 62–73) were recruited from the local community and were paid for their participation. Twelve undergraduates (ages 18–28) participated in the experiment in exchange for partial class credit.

5.1.2. Design and procedure

The age-matched controls and the young subjects studied 200 words under a shallow processing task (count the number of syllables in each word). After a 30-min delay, they were presented with a random mixture of 200 yes–no and 100 forced-choice test trials.

The amnesics were tested in four study-test blocks. They studied 50 words in each block under shallow processing conditions (count the number of syllables in each word). Immediately after each study list they were presented with the test phase that consisted of 25 forced-choice and 50 yes–no test trials randomly intermixed. Patients were given short breaks (5–10 min) between each study-test block. All subjects received study and test items visually while the experimenter read each word aloud.

5.2. Results and discussion

A preliminary analysis showed that the young subjects performed similarly on the yes–no ($d' = 0.41$) and the forced-choice tests ($d' = 0.43$) ($t(11) = -0.192, P > 0.851$), showing that the mixed test lists used in the current study led to similar conclusions as the blocked tests used in the previous experiments. The average $d'$ values for amnesics and the age-matched controls are presented in Fig. 1g (the individual patient scores are presented in Table 1). An examination of Fig. 1g showed that the amnesics’ performance on the forced-choice test was almost identical to their performance on the yes–no test. For the age-matched control subjects there was a slight advantage for the yes–no over the forced-choice tests. However, as with the previous experiments, there was no significant difference between performance on the yes–no and forced-choice test procedures ($F < 1$), and no other effects were sig-
significant. An examination of individual scores showed that two of the amnesics performed slightly better on the forced-choice test, but two exhibited the opposite pattern.\footnote{Exposing the lesion reconstructions it appears that EM and AL have the most extensive damage (Fig. 2: cranially from slice 1 to slice 7). On initial examination, it appears that there is a relationship between the size of the lesion and performance in the yes–no test (Table 1). However, by controlling for their false alarm rates by calculating $d'$, only EM showed an advantage for the yes–no task. From the amnesic data there does not appear to be a relationship between the size of the lesion and task performance differences.} Similarly, three of the control subjects performed slightly better on the forced-choice test, but the other three exhibited the opposite pattern.

The results from the current experiment showed that there was no advantage for the forced-choice over the yes–no procedures for amnesics or healthy control subjects. Given that the amnesics rely heavily on familiarity [27], these results suggest that familiarity does not differentially support performance on the yes–no and forced-choice tests.

6. General discussion

In the present study, performance in two-alternative forced-choice and yes–no recognition testing procedures was examined in healthy subjects and amnesic patients. In addition, the contributions of recollection and familiarity to these two tasks were examined. In healthy subjects overall recognition memory performance did not differ between the two tasks and there was no evidence that recollection contributed more to one task than the other. These conclusions held across a variety of encoding conditions (from semantic to perceptual processing), across various delay conditions (from several minutes to one week), and across various test conditions (blocked and mixed test lists, within and between-subject designs). The results from the amnesic patients converged with those of the healthy subjects in showing that memory performance was equivalent in the two tasks. Because the amnesics' recognition judgments are assumed to be based primarily on familiarity, these results suggest that familiarity in the absence of recollection does not differentially support forced-choice or yes–no performance.

These results show that the relatively normal recognition performance of amnesics reported in some previous studies [1] cannot be attributed to the fact that forced-choice procedures were used. The current results suggest that performance of the amnesics or the healthy subjects would not differ if yes–no procedures had been used. The preserved recognition performance of amnesics in previous studies must then be due to some other factor. For example, as Aggleton and Shaw [1] argued, it may be that only some types of amnesic patients, such as patients who sustained limited damage to the hippocampus proper, do not exhibit recognition memory deficits.

The current results indicate that forced-choice and yes–no tasks cannot be used by themselves to separate the contributions of recollection and familiarity to recognition memory performance; subjects use both familiarity and recollection to the same extent in the yes–no and forced-choice procedures. Instead, other procedures such as the remember–know procedure [21], the receiver operating characteristics procedure [25] and the process dissociation procedure [12] would appear to be more useful in examining the contribution of recollection and familiarity since they were designed explicitly to separate the contributions of these two retrieval processes.

An important debate that has arisen in the memory literature is how to use the remember–know procedure to estimate the contributions of familiarity [12,17]. Gardiner et al. [7] have suggested that the raw proportion of ‘know’ responses can be used to measure familiarity. In contrast, Yonelinas and Jacoby [26] have argued that because ‘know’ responses are mathematically constrained by the proportion of ‘remember’ responses in the remember–know procedure, ‘know’ responses are not an accurate index of the contribution of familiarity to performance. Instead, they argue that familiarity should be estimated as a proportion of the number of know responses, given that the subjects are allowed to make such a response (i.e., $F = K/(1 - R)$). This is an important debate however in the current study we have not relied on either interpretation of the ‘know’ responses. Rather we have focused on overall recognition accuracy and the proportion of ‘remember’ responses. The results from the healthy subjects demonstrate that overall recognition accuracy and rates do not differ across the yes–no and forced-choice procedures. Furthermore, amnesic patients who rely primarily on familiarity perform equally on yes–no and forced-choice tasks indicate that familiarity contributes equally to those two tasks.

The current results are consistent with dual process models that postulate that recollection and familiarity based judgments reflect distinct retrieval processes [2,12,16]; but they are also consistent with simpler single process models such as signal detection theory [20]. The current experiments, however, were not designed to contrast these different models, and numerous previous studies have already shown that recollection and familiarity reflect distinct retrieval processes. For example, several experimental variables have been found to have differential effects on recollection and familiarity [12]. Moreover, lesion studies in amnesics [27], electrophysiological studies [5,18], and
brain imaging studies [8] show that recollection and familiarity involve distinct neural regions.

The current study included a variety of different study and test conditions, however there may be other conditions under which yes–no and forced-choice performance are found to differ. For example, it is not clear whether the current results will generalize to non-verbal materials. Moreover, future studies that contrast yes–no and forced-choice performance of a variety of different memory impaired patients will also be necessary in order to determine the generalizability of these results.

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