When recognition memory is independent of hippocampal function

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Hippocampal damage has been thought to result in broad memory impairment. Recent studies in humans, however, have raised the possibility that recognition memory for faces might be spared. In five experiments we investigated face recognition in patients with hippocampal lesions (H) or large medial temporal lobe (MTL) lesions, including patients where neurohistological information was available. Recognition of novel faces was unequivocally intact in H patients but only at a short retention interval. Recognition memory for words, buildings, inverted faces, and famous faces was impaired. For MTL patients, recognition memory was impaired for all materials and across all retention intervals. These results indicate that structures other than the hippocampus, perhaps the perirhinal cortex, can support face recognition memory in H patients under some conditions. The fact that the faces were novel when recognition memory was intact does not fully account for our findings. We propose that the role of the hippocampus in recognition memory is related to how recognition decisions are accomplished. In typical recognition tasks, participants proceed by forming an association between a study item and the study list, and the recognition decision is later made based on whether participants believe the item was on the study list. We suggest that face recognition is an exception to this principle and that, at short retention intervals, participants can make their recognition decisions without making explicit reference to the study list. Important features of faces that might make face recognition exceptional are that they are processed holistically and are difficult to verbally label.

amnesia | long-term memory

The hippocampus and related medial temporal lobe (MTL) structures are essential for the formation of long-term declarative memory. Damage to these structures has traditionally been thought to result in a broad memory impairment that extends across all sensory modalities, across all domains of material (e.g., scenes, words, objects), and across different testing methods (e.g., recall and recognition) (1–3).

An early hint that the impairment might not be so pervasive came from a study of recognition memory in a mixed group of memory-impaired patients (4). Three patients thought to have hippocampal lesions were impaired at word recognition but not at face recognition. Subsequently, recognition scores on the same test were reported for a larger group ($n = 6$, including the earlier three patients). Again, word recognition was poor, but face recognition was variable and not significantly impaired ($P < 0.08$) (5). Because of this marginal finding, and the finding that face recognition was unequivocally impaired at a retention delay of 24 h (5, 6), the possibility that face recognition might be special in some way was not noted. Face recognition also drew no comment when it was reported to be intact in a single patient (patient BE) (7).

An early review of the literature suggested that the performance of hippocampal patients was good for face recognition but concluded that performance was also good for recognition memory more broadly (8). Similarly, an extensive study of hippocampal patient YR emphasized the relative sparing of recognition memory, including face memory, against a background of impaired recall (9). Other studies suggested that what was spared was recognition of nonverbal material (10) or single-item recognition, compared with associative recognition (11).

Perhaps the first proposal that the capacity for face recognition itself deserved special attention came from the study of a patient with hippocampal lesions and spared face recognition memory but impaired recognition memory for words and buildings (12). Subsequently, three single-case studies and one group study ($n = 3$) also reported spared memory for faces after hippocampal lesions and impaired memory for other kinds of nonverbal material (e.g., buildings or scenes) (13–16). The evidence for sparing of face recognition became even stronger when scores on the Recognition Memory Test [RMT, a standard memory test for faces and words (17)] were brought together for 10 patients with hippocampal lesions from earlier studies (18). The findings were unmistakable. Recognition memory was impaired for words but intact for faces. The authors suggested that hippocampal lesions might spare recognition memory for material that, like faces, was unfamiliar to patients before testing.

In five experiments, we explored the conditions under which face recognition memory might be spared in patients with hippocampal lesions (H) or larger lesions of the MTL. We first examined scores on a standard test (the RMT). For four patients (three H patients and one MTL patient) neurohistological information was available to characterize the lesions. For six patients the lesions were characterized by quantitative neuroimaging

Significance

Hippocampal damage has been thought to impair memory for all domains of material (sounds, objects, words, odors). We investigated face recognition memory in patients with hippocampal lesions or large medial temporal lobe lesions. Recognition of novel faces was unequivocally intact in hippocampal patients but only at a short retention interval. Recognition memory for words, buildings, famous faces, and inverted faces was impaired. For medial temporal lobe patients, memory was impaired in all conditions. Ordinarily, recognition memory judgments depend on an association between study items and the study context. We suggest that face memory is spared because face processing is specialized (and holistic), and that participants can make recognition judgments without making explicit reference to the study context.

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(Table S1). Testing occurred both immediately after study and 24 h later (Exp. 1). Next, for the six patients still living (five H patients, one MTL patient), we assessed recognition memory for faces, buildings, and words across four retention intervals from immediate to 1 d (Exp. 2). We then tested face recognition memory again after matching the difficulty of the faces and buildings tests (Exp. 3). Next, we tested recognition memory for faces that were potentially familiar to participants before testing (i.e., famous faces from before 1970; Exp. 4). Finally, we tested recognition memory for upside-down faces (Exp. 5).

Results

Experiment 1. The findings were the same for patients whose lesions had been characterized by postmortem neurohistology (Fig. 1, *Left*) and for living patients whose lesions were characterized by MRI (Fig. 1, *Right*). When memory for faces was tested immediately, the H patients performed like controls (Ps > 0.60) (Fig. 1), but they performed worse than controls after a 24-h delay (Ps < 0.05). For faces, the MTL patients (EP and GP) were impaired relative to controls at both retention intervals ($P < 0.01$). In contrast to the findings for faces, the H patients and the MTL patients were impaired at remembering words at both retention intervals (Ps < 0.05).

Experiment 2. Exp. 2 examined memory for faces, buildings, and words at four retention intervals (immediate, 15 min, 2 h, and 24 h)

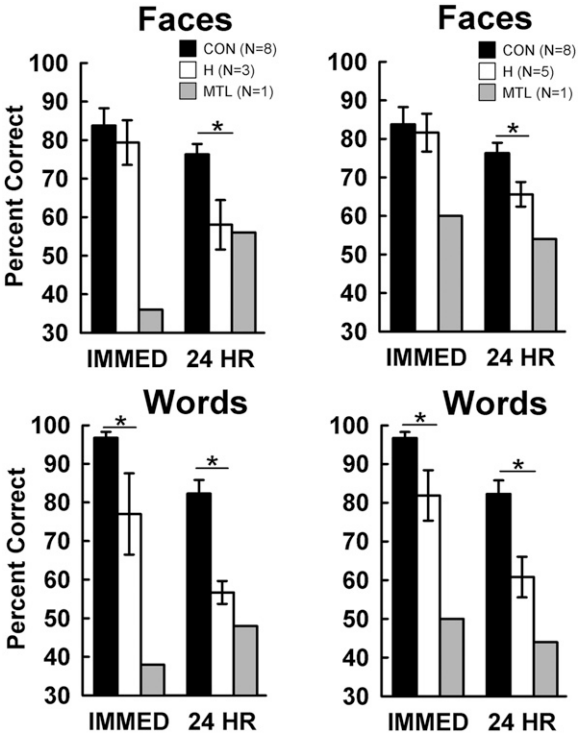

Fig. 1. Exp. 1. Performance of a control group (CON; black bars) and memory-impaired patients with damage limited to the hippocampus (H; white bars) or larger lesions of the MTL (gray bars) on two versions of the Words and Faces test (RMT) (17). Testing occurred either immediately after study (IMMED) or 1 d later (24 HR). (*Left*) Patients whose lesions have been characterized by postmortem histology. (*Right*) Patients whose lesions were estimated from quantitative structural neuroimaging. For H patients, memory for faces was intact when tested immediately after study but impaired when tested the next day. Memory for words was impaired regardless of the retention interval. MTL patients (EP on the left, GP on the right) were impaired in all conditions. Asterisks indicate a significant difference between patients and controls (*P < 0.05). Brackets indicate SEM.

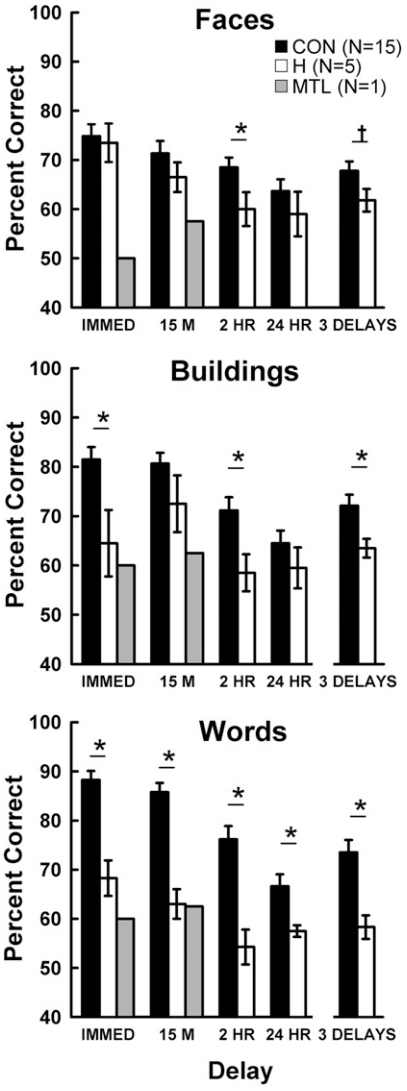

Fig. 2. Exp. 2. Recognition memory for faces, buildings, and words for a control group (CON; black bars) and for memory-impaired patients with damage limited to the hippocampus (H; white bars) or larger lesions of the MTL (gray bars). After studying a list of items (80 faces, 80 buildings, or 160 words), memory was tested immediately (IMMED), 15 min, 2 h, and 24 h later. The MTL patient was tested only at the immediate and 15-min retention test. Each test involved 20 old and 20 new faces or buildings (or 40 old and 40 new words). For faces, H patients performed as well as the CON group when tested immediately after study but were impaired on the delay tests (3 DELAYS: the mean score for the 15 min, 2 h, and 24 h retention tests). For buildings and words, the patients were impaired in all conditions tested. Differences between patients and controls are indicated with asterisks (*P < 0.05) or with a dagger ($^{\dagger}P = 0.09$). Brackets indicate SEM.

(Fig. 2). As in Exp. 1, H patients performed as well as controls when face memory was tested immediately ($P > 0.70$). In contrast, patients performed worse than controls when memory for buildings or words was tested immediately after learning (Ps < 0.01). Memory for all three kinds of material was impaired at the 2-h test (Ps < 0.05). Findings were somewhat inconsistent across the delays, likely because only 20 study items were tested at each retention interval. Note that combining the data for the three delays (15 min, 2 h, and 24 h) yielded significant impairments for buildings and words (Ps < 0.05), and a marginally significant impairment for faces ($P = 0.09$). The MTL patient was impaired for all material and at all delays (Ps < 0.001). A similar pattern of

sparing and impairment was observed when recognition memory was measured as d', a measure of discriminability (Table S2). Note also that, measured as d', recognition memory was impaired for faces—as well as buildings and words—when the data were combined across the three longer delays (Ps < 0.05).

H patients and controls gave similar confidence ratings for face responses when tested immediately after learning (4.5 ± 0.2 vs. 4.5 ± 0.1, $P > 0.80$). In contrast, H patients gave lower confidence ratings than controls for building and word responses immediately after learning ($P < 0.01$). The MTL patient gave lower confidence ratings than controls for all immediate tests for all materials (Ps < 0.001). Combining the confidence ratings for the three longer delays, the H patients gave numerically lower confidence ratings than controls for faces ($P < 0.10$) and buildings ($P < 0.13$) and significantly lower confidence ratings for words ($P < 0.01$).

Experiment 3. In Exp. 2, performance of controls on the immediate faces test was lower than on the immediate test for buildings and words. In Exp. 3 we asked whether H patients still performed normally at immediate face recognition when the test was simpler and control performance was better. The result was that H patients still performed like controls ($P > 0.30$) (Fig. 3) and the MTL patient still performed poorer than controls ($P < 0.001$). The findings were similar when performance was scored as d' [controls = 2.7 ± 0.2, H patients = 2.2 ± 0.4, ($P > 0.20$), MTL = 0.4, ($P < 0.001$)]. Confidence ratings given by H patients and controls were similar (5.1 ± 0.2 vs. 5.1 ± 0.1, $P > 0.70$) but were lower for the MTL patient (4.0, $P < 0.001$).

A Note on Receiver Operating Characteristics. We examined receiver operating characteristics (ROCs) in the two conditions of the present study where H patients exhibited spared face memory (Exp. 2: immediate test for faces; Exp. 3: immediate test for faces). ROCs characterize recognition memory performance by plotting the relationship between hits and false alarms across different confidence levels. According to a model used to construct ROCs (unequal variance signal detection model, UVSD) (19), recognition memory is a single continuous process described by two parameters, slope and d. The slope is the ratio of the variances for the target and foil distributions, and d is the difference between the mean of the distributions.

The ROCs of patients were similar to the ROCs of controls. Specifically, its two parameters were similar for patients and controls [Exp. 2: d χ^2 diff(1) = 3.2, $P = 0.07$, slope χ^2 diff(1) = 1.4, $P = 0.23$; Exp. 3: d χ^2 diff(1) = 1.0, $P = 0.31$, slope χ^2 diff(1) = 0.0, $P = 0.94$]. By comparison, the parameter d was lower in patients than in controls for the immediate test of buildings [χ^2 diff(1) = 27.5, $P < 0.001$] and words [χ^2 diff(1) = 54.5, $P < 0.001$]. The slopes for buildings and words were similar for patients and controls (Ps > 0.20).

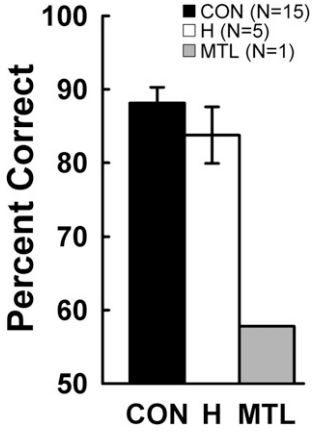

Fig. 3. Exp. 3. Performance on two 16-item recognition memory tests for faces when accuracy for controls was at least as good for faces as it was for buildings and words in Exp. 2. Memory-impaired patients with damage limited to the hippocampus (H; white bars) performed as well as controls (CON; black bars). A patient with larger lesions of the MTL (gray bar) was impaired. Brackets indicate SEM.

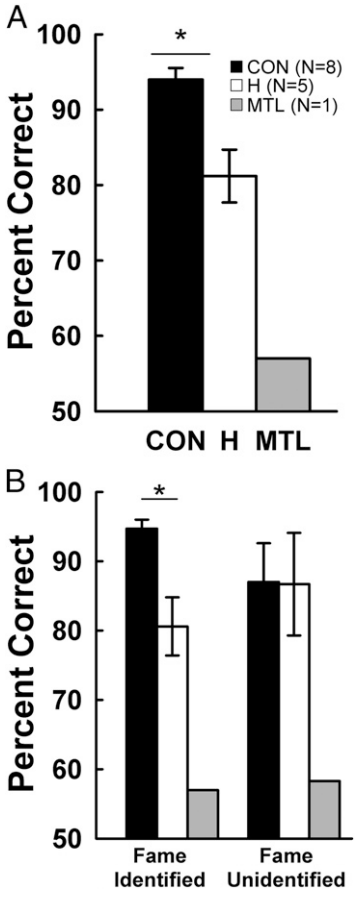

Fig. 4. Exp. 4. Performance on a recognition memory test for famous faces for a control group (CON; black bars) and for memory-impaired patients with damage limited to the hippocampus (H; white bars) or larger lesions of the MTL (gray bar). Participants studied 50 famous faces and then immediately took a recognition memory test involving the 50 previously studied faces and 50 new famous faces. (*A*) Both H and MTL patients were impaired. (*B*) Accuracy was examined separately according to whether the faces could be identified as famous. H patients were impaired for known famous faces but performed as well as controls for faces that they did not identify as famous. The MTL patient was impaired regardless whether he could identify the faces as famous. Asterisks indicate a significant difference between H patients and controls (*$P < 0.05$). Brackets indicate SEM.

Experiment 4. We next asked about the status of face recognition memory after H and MTL lesions when the faces were familiar before the experiment. Memory was impaired on the immediate test of famous faces according to percent correct scores ($P < 0.01$) (Fig. 4*A*) and according to d' scores (H patients, 2.0 ± 0.3; controls, 3.4 ± 0.3; $P < 0.01$). After the memory test, a fame judgment test determined that controls correctly identified 91.5 ± 1.9% of the faces and H patients correctly identified 79.6 ± 5.2% of the faces ($P < 0.05$). If H patients were intact at recognizing unfamiliar faces at an immediate test (Exps. 1–3), then they should also be intact at recognizing those famous faces in Exp. 4 that they did not identify as famous. Accordingly, the data in Fig. 4*A* were examined separately for faces that participants

identified as famous and faces that were not so identified. The finding was that H patients were impaired ($P < 0.01$) at immediate recognition for faces they identified as famous (Fig. 4*B*, *Left*) but were intact at immediate recognition for faces they did not identify as famous ($P > 0.90$) (Fig. 4*B*, *Right*). (A similar analysis using d' scores was not possible because two controls had insufficient data to calculate d' scores for faces they had not identified as famous.) The MTL patient performed worse than controls in all conditions (Ps < 0.001); he also performed more poorly than controls on the fame judgment test (81.0% correct, $P < 0.001$).

Confidence levels followed the pattern of the accuracy scores. The H patients gave lower confidence ratings than the controls overall (corresponding to data in Fig. 5*A*) (4.9 ± 0.2 vs. 5.6 ± 0.1, $P < 0.01$). Similarly, when faces identified as famous were examined separately (corresponding to data in Fig. 4*B*, *Left*), H patients gave lower confidence ratings than controls (4.9 ± 0.2 vs. 5.7 ± 0.1, $P < 0.01$). In contrast, for faces that participants failed to identify as famous, H patients were as confident as controls (corresponding to data in Fig. 4*B*, *Right*) (5.0 ± 0.4 vs. 5.0 ± 0.3, $P > 0.90$). The MTL patient gave lower confidence ratings than controls in all conditions (4.0 for all conditions, Ps < 0.001).

Experiment 5. In Exps. 1–4 recognition memory for novel faces was spared when testing occurred immediately after study but impaired for other kinds of stimuli [i.e., familiar (famous) faces, words, and novel buildings]. For stimuli that were familiar before testing (e.g., words and famous faces), one could not base the recognition memory judgment on a simple novel–familiar determination because all of the stimuli (both targets and foils) were familiar. Accordingly, one must decide, not whether the item has ever been encountered previously, but whether the item appeared on the study list. How then should one account for the findings with novel material? Why is recognition memory spared for novel faces but not for novel buildings? One difference between faces and other kinds of material is that faces are processed holistically (20–22), whereas buildings, objects, and pseudowords are not (23, 24). Holistic processing of faces occurs only in the case of upright faces and not for inverted faces, negative contrast faces, or faces that have an unusual arrangement of features (20, 25). With this in mind, we next tested recognition memory for inverted faces.

Unlike the other immediate tests of faces, H patients performed worse than controls when faces were inverted ($P < 0.05$) (Fig. 5). The MTL patient was also impaired ($P < 0.001$). The results were the same when performance was scored as d' [controls = 2.0 ± 0.2; H patients = 1.2 ± 0.3 ($P < 0.05$); MTL = 0.4 ($P < 0.001$)]. The confidence ratings given by H patients were numerically lower than the ratings given by controls (4.4 ± 0.3 vs. 4.8 ± 0.1, $P < 0.10$) and lower still for the MTL patient (3.7, $P < 0.001$).

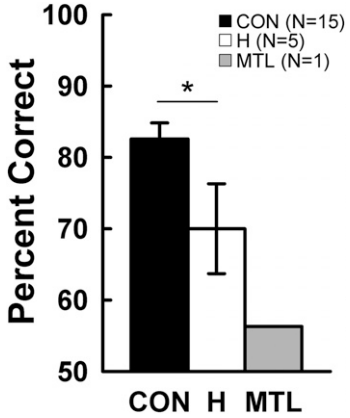

Fig. 5. Exp. 5. Performance on two eight-item recognition memory tests for inverted faces for a control group (CON; black bars) and for memory-impaired patients with damage limited to the hippocampus (H; white bars) or larger lesions of the MTL (gray bar). H and MTL patients were impaired relative to controls at discriminating old and new inverted faces. Asterisk indicates a significant difference between H patients and controls (*$P < 0.05$). Brackets indicate SEM.

Discussion

In five experiments, we examined recognition memory for faces in patients with hippocampal lesions or larger lesions of the MTL. Face memory was spared after hippocampal lesions when testing occurred immediately after study (Exps. 1, 2, and 3), but recognition memory was impaired for words and buildings (Exps. 1 and 2). When face memory was spared, confidence ratings were similar in patients and controls. Face memory was also impaired for H patients when the study–test interval exceeded 15 min (Exps. 1 and 2), when the faces were inverted (Exp. 5), and when the faces were familiar before study (i.e., famous faces; Exp. 4). Importantly, for famous faces, memory was impaired only for those faces that were identified as famous. Recognition memory was intact for faces that were not identified as famous (i.e., faces perceived as novel at the time of study). For MTL patients, memory was impaired for all types of material and at all retention intervals.

When making a determination about the relative sparing (or relative impairment) of memory for different types of materials, it is important to compare tests that are matched for difficulty. In Exp. 3, recognition memory was assessed for faces after matching the difficulty of the faces test to the difficulty of the buildings test in Exp. 2. In this circumstance, H patients exhibited spared memory for faces but impaired memory for buildings. Thus, the sparing of face memory after hippocampal lesions was not an artifact of task difficulty.

The finding that face memory was intact after hippocampal lesions accords with earlier studies (4, 5, 7, 9, 11–16). We additionally report here that face recognition memory is spared only when the retention interval is relatively short, when faces are presented in an upright orientation, and when faces are unfamiliar to participants before study.

It has been suggested that face recognition is intact after hippocampal lesions because the material to be remembered is unfamiliar to participants before the experiment (13, 18). The findings from Exp. 1 are consistent with this idea. Memory for unfamiliar faces was intact and memory for words (all of which were familiar) was impaired. The finding from Exp. 4 that patients were impaired when familiar famous faces were tested is also consistent with this idea. However, three other findings from the present study count against this proposal. First, patients were impaired at recognizing faces at long retention intervals, even though these faces were unfamiliar at the time of study (Exps. 1 and 2). Second, patients were impaired at recognizing novel buildings (Exp. 2). Third, patients were impaired at recognizing inverted faces (Exp. 5), although these faces were unfamiliar at the time of study in the same way as the upright faces.

Findings from other studies make this same point: that the familiar-unfamiliar status of material is not the important factor determining whether recognition performance after hippocampal lesions is intact or impaired. For example, recognition memory was impaired after hippocampal lesions for unfamiliar pseudowords and nonword letter strings (26, 27). Recognition memory was also impaired for junk objects (5) and novel sounds after hippocampal lesions (28). In summary, for face recognition memory to be spared after hippocampal lesions, it is necessary that the faces be unfamiliar, but their familiar-unfamiliar status does not fully account for spared face memory after hippocampal lesions.

We suggest that the role of the hippocampus in face recognition memory is importantly related to how recognition decisions are

accomplished. The key point is that in the typical recognition memory task, participants proceed by forming an association between a study item and the context in which it was learned. It is this rapid learning of relations that is at the heart of declarative memory and central to much of current discussion about the functions of MTL structures (29, 30). Although this approach to the recognition test is typical, it becomes especially important of course when study items are familiar at the time of study (e.g., words or famous faces). In these cases, participants are not being asked, "Have you even seen this item before?" They are being asked, "Did you see this item on the study list?"

The recognition of unfamiliar faces may proceed differently than for other kinds of material. In particular, faces are thought to be processed as holistic representations, not as arrangements of features (20–22). In contrast, other kinds of stimuli, such as buildings, objects, and pseudowords, are thought to be processed as a conjunction of individual parts (23, 24). The same is true for faces that are inverted, negative contrast face images, and faces that have an unusual arrangement of parts (20, 25). For stimuli that are not processed holistically, such as buildings and inverted faces, we propose that participants follow the typical strategy of deciding whether the item was on the study list. However, when items can be processed holistically and as a single item, recognition memory may be based on how novel or familiar the item appears to be (rather than on whether or not the item was on the study list). The difficulty for face recognition at long retention intervals may arise because the ability to make a simple novel–familiar determination may be short-lived. As a result, at long retention intervals, the recognition decision may need to be more deliberate and involve explicit reference to the study list. A similar idea about face recognition memory at long retention intervals was suggested by Bird and Burgess (18).

It is worth noting that the suggestion here that face recognition memory (unlike recognition memory for words, buildings, or inverted faces) can depend on a simple novel–familiar determination means only that the face recognition decision is made without explicit reference to the study list. Our findings are reminiscent of the proposal that recognition memory judgments based on familiarity alone are independent of the hippocampus (9). However, the suggestion here is different. We propose that most recognition memory tests involve referencing the study list, regardless whether the participant can or cannot recollect contextual information about the earlier presentation of the study item. That is, whether recognition decisions are based on remembering or knowing (31), or what is sometimes termed recollection or familiarity (32), we suggest that the recognition decision is typically made by virtue of an association that was made between the test item and the study list. In these cases, recognition memory performance depends on the hippocampus. For recognition of unfamiliar faces, however, we suggest that participants can make recognition judgments in the absence of any reference to the study list.

Although H patients exhibited spared face memory, MTL patients were impaired for all materials and across all retention intervals. This broad impairment accords with earlier studies of face memory in patients with large MTL lesions (8, 11, 16, 33). The fusiform gyrus within the temporal lobe is thought to be important for face perception in humans (20, 34). Although the two MTL patients have some damage to the fusiform gyrus, the impairment in face memory exhibited by our two MTL patients appears unrelated to difficulty in face perception itself or in working memory for faces (35–37). We suggest that structures in the parahippocampal gyrus, perhaps the perirhinal cortex rather than the hippocampus or fusiform gyrus, support face recognition at short retention intervals.

Face processing in humans and monkeys is supported by regions in the temporal lobe (20, 34, 38). These regions support perception of faces as well as nonface stimuli. Why might faces be processed holistically, whereas other stimuli are not? The temporal lobe contains face patches (specific regions where neurons are responsive almost exclusively to face stimuli) (20, 39), and this specialization might allow faces to be processed as a single entity. Whether this specialization is innate (40–43), dependent on extensive category-specific learning (44, 45), or both is an active topic of study. We suggest that face signals originate in temporal cortex and are communicated to targets in the MTL, perhaps by direct connections from temporal cortex to perirhinal cortex (46). The perirhinal cortex might then support a short-lasting recognition memory signal, even when the hippocampus is damaged.

In five experiments, memory for faces was examined in H and MTL patients. We found face memory to be intact in H patients, albeit only at a short retention interval. Recognition memory for words, buildings, inverted faces, and famous faces was impaired. For MTL patients, memory was impaired for all materials and across all retention intervals. It is possible that recognition memory for other kinds of material might also be spared after hippocampal lesions. Such materials should be ones that are processed holistically, be unfamiliar at the time of study, and be difficult to verbally label (because labels would create a test of familiar material). It is also possible that recognition memory would be intact for other unfamiliar material with which individuals have extensive experience (or expertise) (47, 48). The items to be learned also need to be sufficiently distinct from each other. Note that face recognition was impaired after hippocampal lesions when the targets and lures were very similar [e.g., when target and lure faces differed only in lighting, expression, or some other detail (49)]. One would also expect impaired recognition of face stimuli that are not processed holistically; for example, negative-contrast faces, compared with the positive-contrast faces used in the present studies, or faces with an unusual arrangement of features (20).

Materials and Methods

Experiment 1. ***Participants.*** Data are presented for 10 memory-impaired patients with damage limited to the MTL (Table S1). For four patients, the description of damage was based on postmortem neurohistological analysis. For the remaining six patients, estimates of MTL damage were based on magnetic resonance images. Eight healthy volunteers served as controls in Exp. 1.

Procedure. Exp. 1 used the two-choice Recognition Memory Test for Words and Faces (17). Participants studied 50 words one at a time (3-s duration) and rated each item as pleasant or unpleasant. Immediately following the study phase participants were given a two-alternative forced-choice recognition test for all 50 study words. The interval between the beginning of the study phase and the beginning of the test phase was approximately 3.5 min. The same procedure was then used to test recognition memory for 50 black and white photographs of unfamiliar faces (male). A second version of the same test using different words and faces was used to test word and face recognition memory after a 24-h retention interval (4). Means and SEMs are reported. H patients were compared with controls using two-sample *t* tests. Each MTL patient was compared with controls using one-sample *t* tests. This approach was followed for Exps. 2–5 as well.

Experiment 2. ***Participants.*** The six living patients described in Exp. 1 participated in Exp. 2. Fifteen healthy volunteers served as controls for Exp. 2 (six female, 62.5 ± 2.4 y of age, 14.6 ± 0.5 y of education).

Procedure. Three tests were constructed using black and white photographs of male Caucasian faces (Fig. S1), color photographs of buildings, and words (*SI Text*). For the tests of faces and buildings, participants first studied 80 images (5-s duration) and made pleasant/unpleasant judgments for each item. The subjects were further instructed to pay attention to the images because they would be asked about them later. Memory was assessed immediately, 15 min, 2 h, or 24 h after the study session. For the immediate test, the interval between the beginning of the study phase and the beginning of the test phase was approximately 7.5 min. (Note that because the MTL patient was impaired at remembering faces even at the immediate delay in Exp. 1, he was tested only at the immediate and 15-min retention intervals).

At each interval, participants viewed 20 previously studied items (targets) intermixed with 20 new items (foils) and made a recognition memory

judgment on a 1–6 scale (1 = "definitely new," 2 = "probably new," 3 = "maybe new," 4 = "maybe old," 5 = "probably old," and 6 = "definitely old"). Each set of 20 items was equally likely to serve as targets or foils. No time limit was imposed for the recognition judgment, and participants were encouraged to use the full range of confidence ratings. For the test of words, the same procedure was used but with twice as many items as in the other tests and with half the study time to obtain similar accuracy scores across all three tests. Thus, participants studied 160 words and then viewed 40 old and 40 new words at each of the retention intervals. The order of the three tests was counterbalanced across participants.

Experiment 3. ***Participants.*** The same patients and controls who completed Exp. 2 participated in Exp. 3.

Procedure. The purpose of Exp. 3 was to create an easier test of recognition memory for faces than in Exp. 2 (16 study items instead of 80). Participants studied 16 faces (5-s duration) constructed as in Exp. 2 and were tested immediately after study. The procedure was as in Exp. 2, except that the recognition test contained 16 old items and 16 new items. The interval between the beginning of the study phase and the beginning of the test phase was approximately 2.5 min. Following a 10-min break, the study–test procedure was repeated a second time with different material. Each set of 16 items was equally likely to serve as targets or foils, and the lists were counterbalanced across participants.

Experiment 4. ***Participants.*** The same patients who completed Exps. 2 and 3 participated in Exp. 4. Eight controls also participated (four female, 65.9 ± 3.1 y of age, 14.9 ± 0.9 y of education). Five of the controls were the same as in Exps. 2–4 and three were new.

Procedure. Participants studied 50 black and white photographs of famous men and women (5-s duration) (e.g., Elvis Presley, Marilyn Monroe) and then were given a recognition memory test (the 50 studied famous persons intermixed with 50 new famous persons). The interval between the beginning of the study phase and the beginning of the test phase was approximately 5 min. The old and new lists were matched according to sex, race, occupation, facial features (e.g., facial hair, glasses), and recognizability. The faces were prepared to resemble the style of the faces from Exps. 2 and 3. All of the photographs were of persons who became famous before the 1970s. Each photograph was from the time period in which the person became famous. The two sets of 50 faces were equally likely to serve as targets or foils. The procedure was the same as Exp. 3, except that participants studied 50 items and the memory test contained 50 old and 50 new items. Following the recognition memory test, we determined how many of the faces were recognized as famous. Each of the 100 images was presented again, and the participants were asked to provide the person's name or an identifying descriptor (e.g., former president of the United States).

Experiment 5. ***Participants.*** The same patients and controls who completed Exps. 2 and 3 participated in Exp. 5.

Procedure. Participants studied eight black and white inverted photographs of faces (male) constructed as in Exp. 2 (Fig. S1). The procedure was the same as in Exp. 3, except that the interval between the beginning of study and the beginning of test was shorter (1.5 min). Following a 10-min break, the study–test procedure was repeated a second time with different material.

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Editorial Expression of Concern and Correction

NEUROSCIENCE

Correction for "When recognition memory is independent of hippocampal function," by Christine N. Smith, Annette Jeneson, Jennifer C. Frascino, C. Brock Kirwan, Ramona O. Hopkins, and Larry R. Squire, which appeared in issue 27, July 8, 2014, of *Proc Natl Acad Sci USA* (111:9935–9940; first published June 23, 2014; 10.1073/pnas.1409878111).

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