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Intact Perceptual Memory in the Absence of Conscious Memory

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Declarative memory enables conscious recollection of the past and has been proposed to be distinct from priming, a perceptual form of memory that operates nonconsciously and improves the ability to detect or identify recently presented stimuli. Yet, it has been difficult to obtain unambiguous evidence for the independence of declarative memory and priming. The authors report the first demonstration, using matched tests, of fully intact perceptual memory (priming) in a profoundly amnesic patient (E.P.), despite at-chance recognition memory. The priming and recognition tests included tests that were matched with respect to test materials, length of the study and test lists, and the kind of cues available at test. Priming appears to reflect neural changes within perceptual processing systems that occur before information reaches the brain systems that transform visual perception into conscious visual memory.

An encounter with a visual stimulus has several distinct consequences. The stimulus can later be recalled or recognized through the effort of conscious recollection. In addition, the ability to later detect or identify the same stimulus is improved, a phenomenon known as *priming* (Shimamura, 1986; Tulving & Schacter, 1990). A major theme of recent work on memory has been the idea that there are multiple kinds of memory (Gabrieli, 1991; Schacter & Tulving, 1994; Squire, 1992; Weiskrantz, 1990). For example, declarative memory is considered to support conscious remembering, whereas priming is expressed nonconsciously as a change in performance. Evidence that declarative memory and priming are separate comes especially from studies of amnesic patients with bilateral medial temporal lobe or diencephalic lesions, who exhibit intact priming but severely impaired declarative memory (Hamann, Squire, & Schacter, 1995; Schacter, Chiu, & Ochsner, 1993; Squire, Knowlton, & Musen, 1993).

An alternative view that has been difficult to discount completely is that both priming and declarative memory depend on a single, underlying memory trace (Blaxton, 1989; Jernigan & Ostergaard, 1993; Masson, 1989; Shanks & St. John, 1994) and that priming tests are simply more sensitive than declarative memory tests at detecting whatever residual memory remains in amnesia. Proponents of this view have pointed out that the amnesic patients studied to date are only partially amnesic and have residual declarative memory that could support performance on priming tests. For example, even the well-studied, densely amnesic patient H.M. (Scoville & Milner, 1957) has some residual declarative memory (Corkin, 1984; Milner, Corkin, & Teuber, 1968). Conceivably, normal priming could occur in amnesic patients if the relationship between residual declarative memory and priming were highly nonlinear.

We addressed this issue by assessing declarative memory and priming in E.P., a profoundly amnesic patient who has no detectable declarative memory. Any priming exhibited by E.P. cannot depend on residual declarative memory because he effectively lacks the capacity for declarative memory. A finding of fully intact priming in E.P. would therefore provide strong evidence for the multiple-systems view that priming and conscious recollection are distinct forms of memory.

Method

Participants

Patient E.P. (Figure 1) is a 74-year-old retired laboratory technician with 12 years of education, who developed profound anterograde and retrograde amnesia in 1992 after herpes simplex encephalitis (Squire & Knowlton, 1995; Table 1). His amnesia is so severe that after more than 40 testing sessions at his residence he does not recognize the examiner and denies having been tested previously. In addition, he scored at chance on a variety of sensitive recognition memory tests, including tests that have detected residual declarative memory in patient H.M. For example, E.P. scored 48% correct (chance = 50%) on a test of picture recognition on which H.M. scored 78% correct (Freed, Corkin, & Cohen, 1987; 40 pictures presented twice at study for 10 s each followed after 10 min by a yes–no recognition test). E.P. also scored at chance (48%) on an even easier version of this same test (40 different pictures presented six times for study, 5 s each time, followed after 1 min by a two-alternative, forced-choice recognition test).

E.P.'s performance on priming tests and on recognition tests was compared with the performance of 7 control volunteers (2 men and

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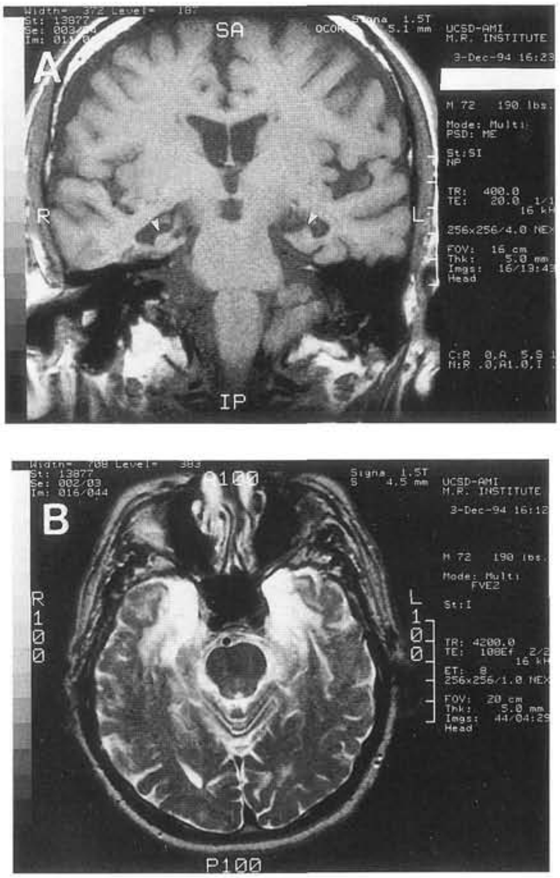

Figure 1. (A) Coronal T1-weighted magnetic resonance image of patient E.P. showing extensive bilateral damage to the hippocampal formation (arrows). Note the particularly severe atrophy of the right parahippocampal and inferotemporal gyri (left side of image). (B) Axial T2-weighted image, showing the extent of bilateral medial temporal lobe damage, which extends from the temporal pole caudally and damages the perirhinal cortex, amygdala, hippocampal formation, and parahippocampal cortex. In other images, small foci of damage were apparent in the right medial and dorsal frontal cortex, and reduced volume of the insular cortex and inferotemporal gyrus was apparently bilateral. R = right; L = left.

5 women; *M* age = 72.1 years with 12.1 years of education) and 3 amnesic patients with bilateral damage to the hippocampal formation (Table 1). Additional information about these 3 patients appears elsewhere (Hamann & Squire, 1995).

Procedure

E.P., along with the 3 other amnesic patients and the 7 controls, was given two types of priming tests and two types of recognition memory tests. For all participants, priming was tested both by word stem completion (6 different tests) and by perceptual identification for words (12 different tests). Recognition memory was tested both by a yes–no procedure (6 different tests) and by a two-alternative, forced-choice procedure (6 different tests). Each of these 30 tests was administered in an identical way by using different sets of words. For each test, 24 target words were first presented for study at a 3-s/item rate, preceded and followed by 3 buffer words (12 in the case of perceptual identification). At study, participants simply read each word aloud. Five minutes later, a priming or recognition test was given.

For word stem completion priming, each test consisted of 48 three-letter word stems (e.g., *MOT*) presented at a rate of 5 s/item. Each test began with 3 practice stems. Participants were instructed to say the first English word that came to mind beginning with each stem. Twenty-four stems corresponded to study list words, and the remaining 24 stems corresponded to words that had been predesignated but had not been studied. These latter stems provided a measure of baseline completion probability.

For perceptual identification, each test consisted of 48 words (24 studied words and 24 new words). Each word was presented briefly at an exposure duration (as determined earlier by a thresholding procedure) at which participants could successfully identify approximately 35% of the new words, and each word was followed by a 250-ms masking stimulus (#####). At test, participants attempted to identify each word by responding aloud. Guessing was encouraged. All 18 priming tests were completed before the 12 recognition memory tests were given.

For two-alternative, forced-choice recognition, each test consisted of 24 word pairs presented one at a time. Each pair consisted of a word from the study list together with a nonstudied word either to the right or to the left. Participants were asked to say aloud the word that had been shown previously. For yes–no recognition, each test consisted of 24 old (studied) and 24 new (nonstudied) words presented one at a time in a mixed order. Participants were asked to say yes if the word had been shown previously or no if it had not.

The full set of 30 study–test sequences (6 word stem completion tests, 12 perceptual identification tests, 6 yes–no recognition tests,

Table 1
Characteristics of Amnesic Patients

				WMS–R				
Patient	Age in years	Lesion	WAIS–R IQ	Attention	Verbal	Visual	General	Delay
A. B.	58	HF	104	87	62	72	54	<50
P. H.	73	HF	115	117	67	83	70	57
L. J.	58	HF	98	105	83	60	69	<50
M	63		106	103	71	72	64	52
E.P.[a]	74		103	94	59	82	68	56

Note: The WAIS–R and the WMS–R indexes yield a mean score of 100 in the normal population with a standard deviation of 15. The WMS–R does not provide scores for participants who score below 50. Therefore, the two scores below 50 were scored as 50 for calculating a group mean. WAIS–R = Wechsler Adult Intelligence Scale—Revised; WMS–R = Wechsler Memory Scale—Revised; HF = hippocampal formation.
[a]See Figure 1.

and 6 forced-choice recognition tests) was given in six different sessions during a 4-month period. E.P.'s performance on the priming tests and on the recognition tests was compared with the performance of the controls and the 3 amnesic patients.

Results

On the priming tests, E.P. performed consistently at the same level as the controls and other amnesic patients for both studied and nonstudied items (Figure 2). All three groups exhibited significant priming for both stem completion and perceptual identification: for E.P., $t(5) = 2.63$, $p < .05$, and $t(11) = 4.66$, $p < .001$, respectively; for the amnesic and control groups, all $ts > 4.3$. The amnesic and control groups performed indistinguishably. In addition, E.P. scored higher than 4 of 7 controls on stem completion and higher than 6 of 7 controls on perceptual identification.

By contrast, E.P. performed at chance levels on the recognition tests. The amnesic group performed above chance but was impaired relative to the control group on both yes–no recognition and two-alternative, forced-choice recognition ($ts > 2.9$, $ps < .05$). Thus, E.P. could not recognize as familiar the words he had read 5 min earlier, either when asked to choose which of two words was familiar or when asked to say yes or no to indicate which words had been presented earlier. Nevertheless, when asked to complete three-letter word stems to form the first word that came to mind, he performed like the other participants and completed word stems with words he had read earlier substantially more frequently than would be expected if the words had not been presented (29% for studied items vs. 14% for baseline items; for amnesic patients, 38% for studied items vs. 21% for baseline items; and for controls, 33% for studied items vs. 16% for baseline items).

Similarly, when asked to identify briefly flashed words, he

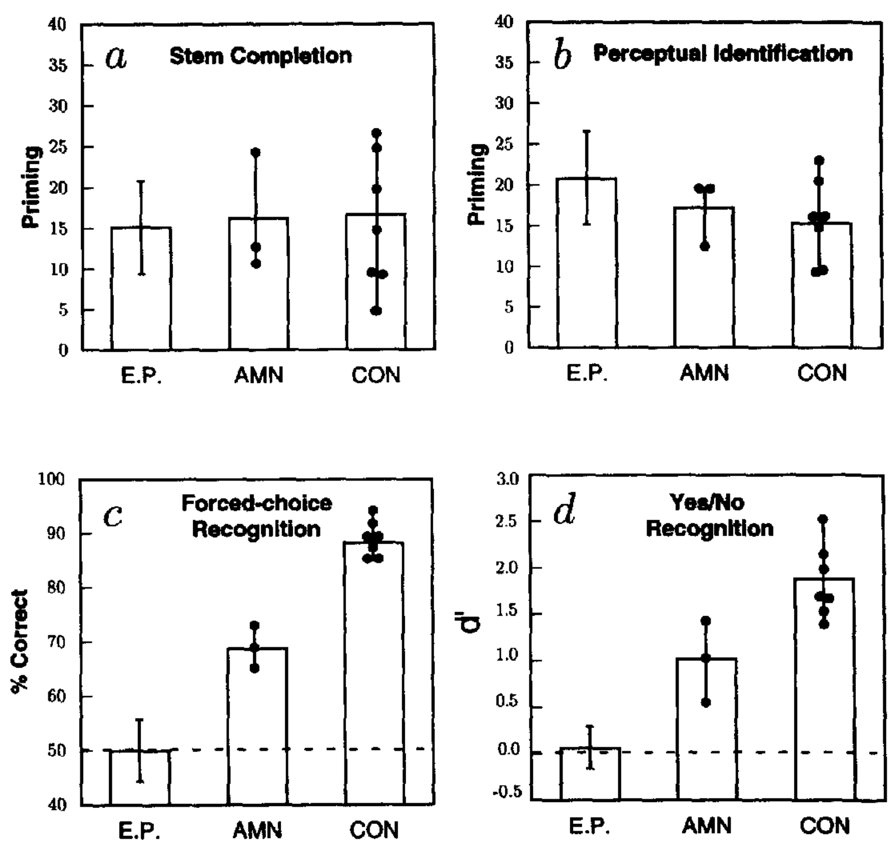

Figure 2. (a) Stem completion priming. Six priming tests were given to patient E.P., amnesic patients (AMN, $n = 3$), and normal controls (CON, $n = 7$). Priming scores were calculated as percentage correct for studied items minus percentage correct for baseline items. (b) Perceptual identification priming. Twelve tests were given to patient E.P., AMN patients, and CON participants. Priming scores were calculated as percentage of correct identifications of studied items minus percentage of correct identifications of nonstudied items. (c) Two-alternative, forced-choice recognition. Percentage correct across 6 tests for patient E.P., AMN patients, and CON participants. (d) Yes/no recognition. Discrimination accuracy (d'; Green & Swets, 1966) is shown across 6 tests for patient E.P., AMN patients, and CON participants. Percentage of correct scores (hits plus correct rejections) was 52%, 65%, and 81% for E.P., AMN patients, and CON participants, respectively. Brackets for E.P. indicate the standard error of the mean; the data points for AMN and CON groups indicate individual participant means across all the tests. Dashed lines indicate chance performance.

performed like the other participants and identified the words that he had read 5 min earlier much better than words he had not read earlier (55% correct for studied items vs. 34% correct for nonstudied items; for amnesic patients, 51% correct for studied items vs. 34% correct for nonstudied items; and for controls, 48% correct for studied items vs. 32% correct for nonstudied items). Exposure duration of test items was 28.5 ms, 25 ms, and 28 ms for E.P., amnesic patients, and controls, respectively. Because these data were obtained across 18 separate priming tests and 12 separate recognition tests, the results provide a stable and accurate estimate of E.P.'s priming and recognition memory abilities.

Discussion

These findings provide compelling evidence that priming depends on a separate and independent memory system from the system that supports declarative memory. Priming was fully intact in patient E.P. even though no declarative memory could be detected. Thus, priming is independent of conscious memory and independent of the medial temporal lobe and the diencephalic brain system that supports conscious memory (Squire & Zola-Morgan, 1991). Three previous studies involving the severely amnesic patients H.M. and K.C. made similar points on the basis of the finding of spared perceptual priming in the face of poor recognition memory performance (Gabrieli, Milberg, Keane, & Corkin, 1990; Keane, Gabrieli, Mapstone, Johnson, & Corkin, 1995; Tulving, Hayman, & Macdonald, 1991). However, it was not the objective of those studies to find intact priming performance, intact baseline performance, and at-chance recognition performance with tests that were fully matched with respect to test materials, length of the study and test lists, and the kind of cues available at test. The present study included a matched pair of tests (perceptual identification and yes–no recognition) that was identical in all these respects. Each type of test was administered a minimum of six times to assure the reliability of the results. The results provide, to our knowledge, the first demonstration of normal priming scores and normal baseline scores in amnesia despite at-chance recognition memory performance on a matched test.

An additional source of evidence also supports the conclusion that perceptual priming and recognition depend on separate and independent memory systems. Two studies reported the reverse dissociation from the one described here, that is, two patients with impaired perceptual priming and intact recognition (Gabrieli, Fleischman, Keane, Reminger, & Morrell, 1995; Keane et al., 1995). Three caveats regarding this dissociation are (a) the dissociation was based on only two tests of each type; (b) baseline performance in the priming test was abnormal in one of the patients (Keane et al., 1995; for the importance of this issue, see Hamann et al., 1995); and (c) as discussed by Gabrieli et al. (1995), recognition memory was not tested in such a way that it clearly depended on the same perceptual operations that supported priming. Thus, recognition memory might sometimes depend on the same perceptual processes that support priming but depend additionally on other processes. Nevertheless, these recent findings, taken together with the present results, rule out the idea that perceptual priming and recognition memory depend on the same, single memory system and that priming tests simply make less stringent demands on this system than recognition memory tests.

The present results also bear on the issue of when and to what extent recognition memory can be supported by some kind of familiarity process made available through priming (Cermak, Verfaellie, Sweeney, & Jacoby, 1992; Dorfman, Kihlstrom, Cork, & Misiaszek, 1995; Mandler, 1980). Recognition memory was at chance for E.P. and did not benefit from the processes underlying his fully intact priming. These findings agree with previous suggestions that performance on recognition memory tests is supported entirely by declarative memory and does not benefit from priming phenomena (Graf, Shimamura, & Squire, 1985; Haist, Shimamura, & Squire, 1992; Hayman & Tulving, 1989; Knowlton & Squire, 1995; Wagner, Gabrieli, & Verfaellie, 1997). Gabrieli et al. (1995) suggested that, when making recognition memory judgments, normal individuals and amnesic patients do not naturally consult the memory system that mediates perceptual priming. Additional studies are needed to try to identify conditions under which normal individuals might draw on information available from priming to support recognition judgments (cf. Jacoby & Whitehouse, 1989), as well as conditions under which amnesic patients might improve their recognition performance by drawing on information available from the system that supports priming (cf. Dorfman et al., 1995).

Neuroimaging data suggest that perceptual priming of visually presented stimuli depends on the extrastriate cortical visual pathways that are ordinarily involved in perceiving and processing visual stimuli (Buckner et al., 1995; Schacter, Alpert, Savage, Rauch, & Albert, 1996; Squire et al., 1992). Thus, visual priming appears to take place within perceptual processing systems, where neural changes occur well before information reaches the medial temporal lobe and diencephalic brain systems that transform visual perception into conscious visual memory.

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