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A Dissociation between Perceptual Explicit and Implicit Memory Processes

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Patient M.S., who underwent right-occipital lobe resection to treat intractable epilepsy, has intact recall and recognition memory for words, but impaired repetition priming in word identification and visual stem-completion tasks. This mirror dissociation to amnesia suggests that explicit recognition and visuoperceptual repetition priming are mediated by distinct neural systems. In prior studies, however, M.S.' recognition memory was tested only with tasks that drew upon his intact verbal knowledge. The present study examined M.S.' recognition memory for nonverbal perceptual information, namely, the modality and font of word presentation and line patterns. M.S.' recognition memory was intact, providing further evidence that perceptual explicit and implicit memory processes are subserved by functionally and neurally independent memory systems. © 1997 Academic Press

Characterization of the functional neural architecture of human learning and memory has been advanced through studies of patients who have undergone resection to treat pharmacologically intractable epilepsy. The most renowned example is the case of patient H.M. who, at the age of 27, underwent bilateral medial-temporal lobe excision for seizure control (Scoville & Milner, 1957). The surgery left H.M. with a circumscribed, and apparently pervasive, impairment in memory for recently experienced events (e.g., Drachman & Arbit, 1966; Milner, Corkin, & Teuber, 1968). It was later found, however, that although H.M. could not remember recent events, he was able to demonstrate memory acquired in these events indirectly through skill learning (e.g., Corkin, 1968; Gabrieli, Corkin, Mickel, & Growdon, 1993;

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Milner, 1962) or repetition priming (e.g., Gabrieli, Milberg, Keane, & Corkin, 1990; Gabrieli, Keane, Stanger, Kjelgaard, Corkin, & Growdon, 1994; Keane, Gabrieli, Mapstone, Johnson, & Corkin, 1995; Milner et al., 1968).

H.M.'s pattern of performance on memory tasks has since been characterized as a dissociation between *explicit* and *implicit* retrieval processes (Graf & Schacter, 1985). Explicit retrieval tasks, such as recall and recognition, require intentional reference to the study episode. Implicit retrieval tasks, on the other hand, do not require this intentional access; rather, memory is inferred from a change in behavior attributed to the study episode. Amnesic patients with bilateral limbic system lesions (i.e., medial-temporal and/or diencephalic regions) have normal or near normal implicit retrieval of many classes of information despite profoundly impaired explicit retrieval (e.g., Brooks & Baddeley, 1976; Cermak, Talbot, Chandler, & Wolbarst, 1985; Cohen & Squire, 1980; Graf & Schacter, 1985; Graf, Squire, & Mandler, 1984; Graf, Shimamura, & Squire, 1985; Haist, Musen, & Squire, 1991; Shimamura & Squire, 1984; Smith & Oscar-Berman, 1990; Verfaellie, Cermak, Letourneau, & Zuffante, 1991; Warrington & Weiskrantz, 1968; 1970). This dissociation suggests that explicit and implicit retrieval occur in separable neural systems—explicit retrieval requires the integrity of structures that lie within the medial temporal lobe and/or along the diencephalic midline, while implicit retrieval does not.

One measure of implicit retrieval is *repetition priming:* the change in speed, accuracy, or bias in processing a previously experienced stimulus relative to an appropriate baseline. In a repetition priming experiment, stimuli (usually a word or a picture) are processed in a study phase. In a test phase, the stimuli are reprocessed along with unstudied, baseline stimuli. The measure of priming is the difference in performance between studied and unstudied stimuli. Evidence from normative studies (reviewed in Roediger & McDermott, 1993) suggests a distinction between at least two kinds of mechanisms[1] that contribute to repetition priming. *Perceptual priming* is driven by processing of the physical attributes of the stimulus; it is reduced with study-test changes in those attributes (i.e., when a stimulus is studied auditorially and tested visually), but it is unaffected by study-phase semantic analysis. *Conceptual priming,* in contrast, is driven by processing of the semantic attributes of the stimulus; it is enhanced by consideration of stimulus meaning, but it is unaffected by study-test changes in physical attributes.

The neural dissociability of perceptual and conceptual priming has been demonstrated in neuropsychological studies of patients with Alzheimer's dis-

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[1] In addition, a third mechanism, *lexical,* has been distinguished from perceptual and conceptual processing. Accessing the target lexical (word-unit) representation appears to be a fundamental condition for obtaining priming on verbal implicit memory tests (e.g., Rajaram & Roediger, 1993; Weldon, 1991).

ease (AD). AD is a progressive, neurodegenerative disease that initially devastates medial temporal structures, causing a profound explicit retrieval deficit similar to that seen in amnesic patients with circumscribed limbic lesions (e.g., Corkin, 1982; Shimamura, Salmon, Squire, & Butters, 1987). Unlike amnesia, the multifocal neuropathology of AD progresses to involve neocortical regions, causing additional impairments in multiple cognitive domains (reviewed in Nebes, 1992). Repetition priming is intact in amnesic patients without regard to the perceptual or conceptual nature of the task (e.g., Keane, Gabrieli, Monti, Fleischman, Cantor, & Noland, 1997; Cermak, Verfaellie, & Chase, 1995; Vaidya, Gabrieli, Keane, & Monti, 1995; but see Blaxton, 1992). In AD, however, conceptual priming is impaired (Brandt, Spencer, McSorley, & Folstein, 1988; Huff, Mack, Mahlman, & Greenberg, 1988; Salmon, Shimamura, Butters, & Smith, 1988; Monti, Gabrieli, Reminger, Rinaldi, Wilson, & Fleischman, 1996) and visuoperceptual priming is intact (e.g., Gabrieli et al., 1994; Fleischman, Gabrieli, Reminger, Rinaldi, Morrell, & Wilson, 1995; Keane, Gabrieli, Fennema, Growdon, & Corkin, 1991; Keane, Gabrieli, Growdon, & Corkin, 1994). This functional dissociation may be explained by the nonuniform distribution of neocortical damage caused by AD—compared to the degeneration that occurs in temporal, parietal, and frontal association neocortices, occipital neocortex remains relatively preserved (Arnold, Hyman, Flory, Damasio, & Van Hoesen, 1991). Thus, it is plausible that the functional dissociation between perceptual and conceptual priming in AD reflects the preservation of a memory system that is located in occipital neocortex and supports the implicit retrieval of visuoperceptually processed information (Keane et al., 1991) and the damage to another memory system that is located in association neocortex and supports the implicit retrieval of conceptually processed information (Monti et al., 1995).

An alternative explanation for these functional dissociations is that all memory processes are supported by a single neural substrate that, when damaged, can no longer meet the processing demands of more difficult tasks, such as recall and recognition. In this view, preservation of repetition priming in amnesia, and of perceptual priming in AD, may reflect the residual processing abilities of a single, extensively damaged memory system. The demonstration of a *double dissociation* would argue against such a view because damage to a single memory system could not create opposite patterns of performance on memory tasks for patients with different brain lesions. This critical double dissociation has now been reported in three separate case studies. Patient M.S. (Gabrieli, Fleischman, Keane, Reminger, & Morrell, 1995; Fleischman, Gabrieli, Reminger, Rinaldi, Morrell, & Wilson, 1995) and patient L.H. (Keane, Gabrieli, Mapstone, Johnson, & Corkin, 1995) have lesions confined to the posterior cortical regions and are unable to implicitly retrieve certain visual information, although explicit retrieval for the same information is fully intact.

STUDIES OF PATIENT M.S.

M.S. is a 30-year old, right-handed man with 16 years of education who, at age 14, had most of his right occipital lobe removed for the treatment of pharmacologically intractable epilepsy. The excision included all of Brodmann's areas 17 and 18 and a portion of 19, resulting in a macula-splitting left homonymous hemianopsia. He has not had a seizure since the resection, and he no longer takes anti-convulsant medication. He is in good physical health and is neuropsychologically intact on standardized tests of attention, memory, language, perception, and reasoning (described fully in Fleischman et al., 1995).

Despite intact performance on standardized neuropsychological tests, including tests of explicit memory, Patient M.S. is impaired on at least two visuoperceptual implicit retrieval tasks: word identification and visual word-stem completion. In both tasks, subjects process single words in a study phase. In the word identification test phase, subjects are required to identify masked words that are shown very briefly (in increments of 16.7 msec until identified). The measure of priming is how much better subjects are at identifying studied versus unstudied words. In the word-stem completion test phase, subjects see three-letter stems and are asked to complete each stem into the first word that comes to mind. The measure of priming is how biased subjects are to complete stems into words that were either seen (visual word-stem completion) or heard (cross-modal word-stem completion) in the study phase. Gabrieli et al. (1995, Experiment 1) compared M.S. to normal controls, patients with focal lesions outside of the right occipital cortex (including one patient with a left occipital lobe lesion), and patients with amnesia. Compared to all other subjects, M.S. was impaired on the implicit word identification task and the amnesics were impaired on the explicit recognition memory task. Furthermore, despite intact word-stem completion priming for words heard in the study phase, M.S.' word-stem completion priming for words seen in the study phase was impaired (Gabrieli et al., 1995, Experiment 2). In another study, M.S.' impaired word identification priming and intact recognition memory was replicated and the reverse pattern of performance was found in AD patients with the identical materials (Fleischman et al., 1995). Thus, there is a double dissociation between memory performance in M.S. (intact explicit memory, impaired visuoperceptual priming) and in amnesic and AD patients (impaired explicit memory, intact visuoperceptual priming).

Patient M.S. shows the reverse dissociation to patients with AD on tasks of perceptual (word identification) and conceptual (category exemplar generation) priming. In the category exemplar generation task, subjects encode target exemplars drawn from semantic categories by answering either a perceptual study question (i.e., is the word in upper- or lowercase letters?) or a conceptual study question (i.e., is the word the name of something manufactured or natural?). In the implicit test phase, subjects see category names (e.g., vegetables) and are asked to generate the first eight exemplars they can think of that belong to each category. The measure of conceptual priming is how biased subjects are to include study-phase exemplars among the exemplars they generate. In the explicit test phase, subjects see category names as cues and are asked to recall the exemplars from the study phase that belonged to that category. M.S.' priming was similar to that of the control subjects, and he showed the normal pattern of better priming for exemplars studied conceptually than for those studied perceptually (Gabrieli et al., 1995). M.S. and the control subjects recalled a similar number of exemplars correctly, and all subjects showed the normal superiority in recall after conceptual study. AD patients, on the very same task, had impaired priming and recall, and failed to show any benefit of conceptual study on either memory measure (Monti et al., 1996). This result constitutes a double dissociation between visuoperceptual priming (impaired in M.S. and intact in AD) and conceptual priming (intact in M.S. and impaired in AD).

There is normative evidence (e.g., Blaxton, 1989; Jacoby, Levy, & Steinbach, 1992; Roediger & Blaxton, 1987a, 1987b; Weldon, 1991) suggesting that, although perceptual and conceptual processes in memory are dissociable, they may be invoked to varying degrees and integrated in the service of both implicit and explicit memory performance. Traditional explicit retrieval tasks, such as recall and recognition of words, emphasize conceptual processing and minimize perceptual processing (Roediger, 1990). M.S.' memory has been tested on traditional tasks that may have relied on his intact conceptual, verbal knowledge to guide explicit retrieval. The status of M.S.' explicit retrieval on tasks that emphasize perceptual processing, however, is unknown.

In the current experiments[2] M.S.' explicit retrieval for perceptual information was examined using tasks that placed greater demands on perceptual processing (e.g., memory for the presentation modality and font of words) or discouraged the use of a conceptual retrieval route (memory for nonmeaningful line patterns). Recognition memory should be impaired for M.S. if explicit retrieval for such material invokes processes common to perceptual priming. Alternatively, recognition memory should be intact for M.S. if explicit retrieval invokes processes that are dissociable from those linked to perceptual priming.

METHODS

Subjects

Eleven control subjects were matched to M.S. on age ($M = 26.5$, range = 24–30), education ($M = 16.3$, range = 16–18), gender, and IQ estimated by the National Adult Reading Test (NART; Nelson, 1982; $M = 118.6$, range = 113–122).

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[2] The time interval between the current testing sessions and the Gabrieli et al. (1995) testing sessions was approximately 2½ to 3 years. The time interval between the current testing sessions and the Fleischman et al. (1995) testing sessions was approximately 2 years.

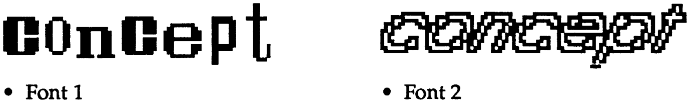

FIG. 1. Font Recognition stimuli.

Design and Procedures

M.S.' recognition memory was examined on three perceptual tests: (1) Font recognition, (2) Modality recognition, and (3) Line Pattern recognition. Five control subjects and M.S. participated in two separate sessions that counterbalanced task stimuli for studied and unstudied items. Thus, for each test, M.S.' mean performance over two sessions was compared to the mean control performance over 10 sessions. The same control subjects participated in all tests when possible, although it was necessary to use matched alternate control subjects in some instances.

Font recognition. The stimuli were 144 words, with an average length of 6.7 letters (range 3–8). Words were randomly assigned to three 48-word study lists and then reassigned to equate lists for word frequency (Thorndike & Lorge, 1944; $M = 21.4$, $SD = 67.6$) and word concreteness (Paivio, Yuille, & Madigan, 1968; $M = 4.8$, $SD = 2.0$). Half of the words were presented in 36-point, plain San Francisco (Font 1) and half were presented in 36-point, italicized, outlined Avant Garde (Font 2; see Fig. 1 for examples). Two forms of each study list were created by counterbalancing font presentation.

There were two recognition phases: word recognition and font recognition. Of the three study lists, two study lists were randomly selected for word recognition, and the remaining study list was used for font recognition. In the word recognition test phase, one test list consisting of 96 words was created by combining words from the two 48-word study lists. Two forms of the test list were created such that half of the words appeared in the same font as seen in the study phase (same condition), and half of the words appeared in the font that was not seen in the study phase (different condition). Thus, for any given subject, 24 words appeared in the same font as studied and 24 words appeared in the other font and 48 words were unstudied. Study and test lists were counterbalanced such that each word was studied in each font and each word was tested in the same and different font conditions. In the font recognition phase, two forms of one 48-item study list were created by reversing the font in which each word was presented. The test list consisted of the 48 targets words, which were presented in pairs adjacent to each other, one in each font. Two forms of the test list were created by reversing the positions of each font. Thus, each word was counterbalanced for font at study and for the left vs. right position of fonts at test.

In the study phase of both word and font recognition, subjects were asked to read each word aloud as quickly and as accurately as possible. Reaction times were recorded with a microphone and a voice-activated relay. Each trial consisted of a 500 msec fixation dot, a 500 msec blank interval, and a 2 sec appearance of a word. The word then disappeared, and the next trial began after a 500 msec delay.

In the test phase for word recognition, studied and unstudied words were presented individually in the center of the monitor. Subjects were required to answer ''yes'' if they had seen the word before and ''no'' if they had not. In the test phase for font recognition, studied words were presented individually in two different fonts, side by side, in the center of the monitor. Subjects were required to choose the font in which the studied word had been presented by saying ''Left'' or ''Right.''

Modality recognition. The stimuli were 96 words with an average length of 6.4 letters (range = 5–8), half of which contained the letter ''A.'' The words were pseudorandomly assigned to two 48-item study lists and then reassigned to equate for word frequency (Kuchera & Francis, 1967; $M = 15.3$; $SD = 14.2$) and word concreteness (Paivio et al., 1967; $M = 4.4$, *SD* = 2.3). Words in each study list were randomly selected for visual or auditory presentation (24 items each) and then further subdivided for shallow or deep encoding (24 items each).[3] Four forms of the two study lists were randomly ordered and counterbalanced for all presentation conditions (abstract/concrete, with/without an A, visual/auditory, shallow/deep), with the constraint that no more than three items of any one type occurred consecutively. Two filler words were included at the beginning and at the end of each study list. Thus, all subjects studied a single list of 48 words plus four filler items. Twenty-four of the words were encoded on a shallow level, following a decision about whether the word contained the letter A, and 24 words were encoded on a deep level, following a decision about whether they were abstract or concrete. A single test list of 96 words was created by combining words from the two study lists.

In the study phase, subjects were told they would be tested on their ability to make judgments about the meaning and the physical appearance of words. Each trial consisted of a 500 msec fixation dot, a 500 msec blank interval, a 1 sec appearance of one of two questions (''Does this contain the letter A?'' or ''Is this concrete?''), and a 1 sec appearance of the stimulus word. Visual words were presented in lowercase letters, and auditory words via speaker. After the subject responded, the experimenter initiated the next trial, which began after a 500 msec delay.

For the recognition test, subjects were told they would receive a test of their memory for the words they had just seen or heard. A centrally placed fixation dot preceded each trial for 500 msec. After a 500 msec delay, a word appeared and the subjects were asked to respond ''yes'' if they remembered seeing or hearing the word previously, or ''no'' if they did not. Reaction times were recorded via a voice-activated relay. For remembered words, the subjects were asked to recall whether they saw or heard the word. The word remained on the monitor until this decision was made. The experimenter then pressed the space bar, initiating the next trial after a 500 ms delay.

Line pattern recognition. The stimuli were 70 abstract visuospatial line patterns (see Blaxton & Theodore, this volume).[4] Each line pattern was created within a 3 × 3 dot matrix in which each dot was assigned a number from one to nine. Connections for each pattern were determined by randomly generating six unique digits from one to nine, connecting the dots in order using five straight line segments (with the constraint that a connection could not simultaneously traverse both a column and a row), and eliminating the dots (see Fig. 2 for an example). Patterns were randomly assigned to two, 35-pattern study lists. All 70 line patterns were used to create a single test list. Patterns were randomly arranged in the test list such that no more than three patterns from either study list occurred consecutively.

In the study phase, subjects were asked to study a series of line patterns carefully because their memory for them would be tested later. Each trial consisted of a pattern appearing in the center of the screen for 3 sec. Trials advanced automatically. In the test phase, subjects performed a yes/no recognition test. Each trial consisted of a centrally placed pattern remaining on the screen until the subject responded either ''yes'' or ''no'' to indicate whether the pattern appeared in the study phase. The experimenter then initiated the next trial by pressing the space bar.

RESULTS

For each result, M.S.' performance was considered normal if it fell within one standard deviation (SD) of the mean of the control group. Table 1 gives results for all tasks and conditions for M.S. and control subjects.

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[3] The levels of processing manipulation was included to provide a replication of M.S.' normal semantic processing.

[4] We thank Teresa Blaxton for providing the stimulus materials for this experiment.

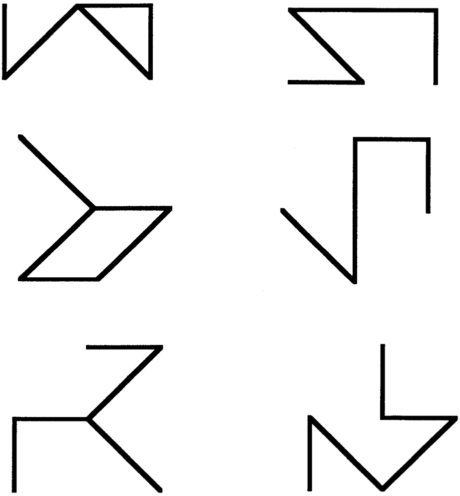

FIG. 2. Line Pattern Recognition stimuli.

TABLE 1
Mean Percentage for M.S. and Control Group

Recognition task	M.S.	Control (*SD*)	Control range
Font word[a]			
Hits	72.8	76.1 (18.6)*	35.4–97.8
Same font	72.5	78.6 (20.3)*	37.5–100.0
Different font	72.9	73.7 (18.6)*	33.3–95.7
False alarms	19.8	16.4 (14.5)	0.0–43.2
Font[b]			
Percent correct	59.6	62.8 (4.6)*	52.1–68.8
Modality word[a]			
Hits	78.1	69.9 (13.8)*	51.1–91.1
Deep, within	63.1	67.5 (18.5)*	31.6–95.8
Shallow, within	47.9	41.9 (14.9)*	20.8–62.5
Deep, across	71.7	72.0 (16.2)*	49.8–95.8
Shallow, across	60.4	48.7 (23.5)*	6.3–79.1
False alarms	18.8	12.4 (9.6)	2.1–29.8
Modality[a]			
Percent correct	51.6	52.9 (15.4)	25.5–75.6
Deep, within	50.0	52.1 (17.0)	30.0–81.8
Shallow, within	41.7	42.7 (16.2)	16.7–63.6
Deep, across	70.9	68.1 (19.5)*	45.5–100.0
Shallow, across	45.9	48.8 (26.6)	0.0–83.3
Line pattern[a]			
Hits	68.7	80.6 (12.4)*	60.0–100.0
False alarms	14.2	29.2 (11.4)	17.1–57.1

[a] Chance performance = 0.

[b] Chance performance = 50.

* Control performance significantly exceeds chance.

Font Recognition

Misread words and responses that mistriggered the voice-activated relay were excluded; less than 6% of study-phase responses were discounted for both M.S. and the control subjects. Study-phase reading performance, measured by accuracy and latency, did not differ between Font 1 and Font 2, *p*s $> .75$ and .19, respectively. Three scores were obtained for the word recognition phase: percentage of (1) hits for words that were presented in the same font at study and test, (2) hits for words that were presented in a different font at test, and (3) false alarms. Corrected recognition scores were calculated by subtracting false alarm rates from hit rates for same and different fonts. For the control subjects, there was no difference in memory for words presented in the same ($M = .62$, $SD = .20$) versus different ($M = .57$, $SD = .19$) fonts, $p > .21$. M.S.' memory for words was normal in both conditions (both M's $= .53$).

Recognition memory for font was measured as percentage correct. M.S.' performance ($M = .60$) was similar to the control subjects' performance ($M = .63$, $SD = .05$).

Modality Recognition

Words for which incorrect responses were given for the levels-of-processing questions were excluded; less than 4% of these items were discounted for both the control subjects and M.S.

Five scores were obtained for the word recognition phase: percentage of hits for words encoded (1) deep within-modality, (2) shallow within-modality, (3) deep across-modality, (4) shallow across-modality, and (5) false alarms. Corrected recognition scores were calculated by subtracting false alarm rates from hit rates for each condition, and the scores of the control subjects were then entered into a 2 × 2 ANOVA that crossed modality (within/across) with level of processing (deep/shallow) as within-subject factors. Recognition accuracy was superior for words encoded in the deep ($M = .70$, $SD = .17$) versus the shallow condition ($M = .45$, $SD = .20$; main effect of level of processing, $F\,(1,9) = 19.7$, $p < .01$), but there was no difference in accuracy for words studied and tested within modality ($M = .55$, $SD = .21$) versus across modality ($M = .60$, $SD = .23$; main effect of modality, $p > .16$). The two-way interaction was nonsignificant, $p > .76$. M.S.' pattern of results was similar to the control subjects' with superior memory for words encoded in the deep ($M = .67$) versus the shallow ($M = .54$) condition, and similarly accurate memory for words presented within ($M = .55$) and across ($M = .66$) modalities.

Four scores were obtained for the modality recognition phase: the percentage correct for words presented: (1) deep within-modality, (2) shallow within-modality, (3) deep across-modality, and (4) shallow across-modality. The scores of the control subjects were entered into a 2 × 2 ANOVA that crossed modality (within/across) with level of processing (deep/shallow) as within-subject factors. Recognition accuracy was superior for words encoded in the deep (*M* = .60, *SD* = .20) versus the shallow condition (*M* = .46, *SD* = .22; main effect of level of processing, $F(1,9) = 7.2$, $p < .05$), and there was a trend toward better recognition accuracy for words processed across modalities (*M* = .58, *SD* = .25) compared to within modality (*M* = .47, *SD* = .17). The two-way interaction did not reach significance, $p > .11$. It should be noted that control performance exceeded chance level (.50) on this task only for words processed in the deep condition across modalities. Although M.S.' performance was similar to the control subjects for words processed in the shallow condition within modality (*M* shallow = .44, *M* within = .46), floor effects in the control group preclude any statement regarding his ability to retrieve perceptual information under these particular conditions. However, where performance for the controls did exceed chance, M.S. performed normally (*M* deep = .60, *M* across = .58).

Line Pattern Recognition

Two recognition scores were obtained: percentage of (1) hits and (2) false alarms. Corrected recognition scores were calculated by subtracting false alarm rates from hit rates. M.S. (*M* = .55) and control subjects (*M* = .51, *SD* = .13) performed similarly.

DISCUSSION

There were two main findings in this study. First, M.S.' normal recognition memory for words and normal semantic processing (levels of processing effect) of those words was replicated. Second, it was found that M.S.' normal recognition memory extended to perceptual aspects of word presentation (font and modality) and to nonverbal material (nonmeaningful line patterns). Thus, M.S.' recognition memory was intact even when the tasks emphasized perceptual details or discouraged the use of a conceptual retrieval route. The findings suggest that early perceptual processes mediated by right-occipital cortex, which are critical for word identification and visual word stem-completion priming, are not necessary for recognition memory.

The dissociation between recognition memory and visuoperceptual priming in M.S. offers a neurological explanation for two common findings. First, when test-phase cues are held constant across tasks, amnesic patients have normal repetition priming and impaired recognition memory (e.g., Cermak et al., 1995; Graf & Mandler, 1984; Vaidya et al., 1995). Amnesic patients apparently cannot draw upon those processes underlying normal repetition priming to benefit recognition memory. Conversely for M.S., processes underlying some forms of repetition priming are impaired, but this impairment does not compromise his recognition memory. This functional double dissociation is clearly illustrated in the performances of H.M. and M.S. (see Table

TABLE 2

Intact	M.S.[a]	H.M.[c]
Impaired	H.M.[b] Explicit recall/recognition	M.S.[d] Implicit word-identification visual word-stem completion

[a] Gabrieli et al. (1995); Fleischman et al. (1995, 1997).
[b] Gabrieli et al. (1994); Keane et al. (1995).
[c] Keane et al. (1995); Gabrieli et al. (1994).
[d] Gabrieli et al. (1995); Fleischman et al. (1995).

2) and suggests that the underlying neural systems for some forms of repetition priming and recognition memory function independently.

Second, studies usually find that normal subjects' recognition performance does not benefit from the reprocessing of perceptually identical stimuli at study and test (e.g., Graf & Levy, 1984; Horton & McKenzie, 1989; Keane et al., 1991; Tardif & Craik, 1989). Indeed, control subjects in the current study showed no significant recognition memory advantage for stimuli that were perceptually reprocessed in the same font or the same modality. Conversely, manipulations of font and modality often affect perceptual priming (e.g., Jacoby, 1983; Jacoby & Dallas, 1981; Keane et al., 1991; Kirsner, Dunn, & Standen, 1989). This dissociation would be expected if the processes underlying recognition memory and perceptual priming were functionally and neurally separable. Perceptual specificity can occur in recognition memory, however, when subjects are instructed to attend to perceptual rather than semantic features at encoding (Graf & Ryan, 1990), and it is unknown whether a recognition memory impairment would occur for M.S. under such a condition.

The present findings also bear upon efforts to characterize the mnemonic process that mediates incidental recognition of the perceptual features of studied words. One possibility is that such recognition is based on a sense of familiarity derived from test-phase perceptual reprocessing of a word. In that case, recognition of perceptual features of words could be based upon the same process that mediates perceptual priming (e.g., Jacoby & Dallas, 1981; Kelley, Jacoby, & Hollingshead, 1989). An alternative account is that recognition of perceptual features is based not upon perceptual processes per se, but rather upon the same kind of post-perceptual processes that record semantic or temporal features of a study episode. In that case, recognition of perceptual features of words could be based upon the same processes that mediate explicit recognition memory and are dissociable from perceptual priming. M.S. shows exactly this dissociation between perceptual explicit and implicit memory processes. Further support for this dissociation comes from a study of normal aged subjects who showed the opposite pattern to M.S.: Impaired incidental recognition memory for presentation modality and intact word identification priming (Light, LaVoie, Valencia-Laver, Owens, & Mead, 1992). Thus, the incidental recognition of the perceptual features of studied words appears to be mediated by the same kind of memory mechanisms that mediate explicit recognition of studied words.

The present studies examined the accuracy of M.S.' recognition memory, but did not examine the basis of his recognition judgments. Dual-process theories (e.g., Atkinson & Juola, 1974; Gardiner, 1988; Jacoby & Dallas, 1981; Mandler, 1980) suggest that recognition memory judgments reflect the integration of recollection, or consciously controlled processing, and familiarity, or automatic influences of previous experience. As noted above, it has been argued that sensory or perceptual reprocessing plays a critical role in determining the subject's feeling of familiarity for an event (e.g., Jacoby & Dallas, 1981; Kelly, Jacoby, & Holingshead, 1989). If familiarity and perceptual reprocessing are indeed linked, M.S.' recognition memory may be impaired—but the impairment may be masked by compensatory processes in recollection. M.S., however, has demonstrated impaired perceptual priming but intact recollection and intact familiarity when these processes are dissociated[5] on inclusion/exclusion and remember/know judgment tasks (Wagner, Stebbins, Burton, Fleischman, & Gabrieli, 1997). Notably, amnesic patients have intact perceptual priming but impaired recollection and impaired familiarity as measured by the remember/know task (Knowlton & Squire, 1995). This double dissociation provides further support that the processes underlying recognition familiarity and perceptual priming exploit distinct neural circuitry.

Evidence from studies of normal young and old subjects, amnesic patients like H.M., AD patients, and the focal lesion patients M.S. and L.H., provide convergent evidence that neurally and functionally distinct memory systems mediate recognition memory and perceptual priming. The present results draw that boundary more securely by showing that the two retrieval processes invoked by these systems remain dissociable even when perceptual details are emphasized in recognition memory.

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[5] See Jacoby, Lindsay, and Toth (1992) or Roediger and McDermott (1993) for reviews of the process dissociation procedure.

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