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Spared Priming Despite Impaired Comprehension: Implicit Memory in a Case of Word-Meaning Deafness

Daniel L. Schacter, Susan M. McGlynn, William P. Milberg, and Barbara A. Church

Previous research has established that direct priming effects on implicit memory tests can be dissociated from explicit remembering. Evidence from studies of college students suggests that priming on various implicit tests can be characterized as a presemantic phenomenon: Priming can occur at full strength following nonsemantic encoding tasks that typically produce low levels of explicit memory. To provide a strong test of this idea, we examined auditory priming in a case of word-meaning deafness. Despite the patient's impaired auditory comprehension abilities, he showed normal priming on auditory identification tests after study-list exposure to spoken words. Results support the idea that priming depends on perceptual systems that operate at a presemantic level.

Explicit memory refers to conscious or intentional recollection of previous experiences, whereas implicit memory refers to changes in task performance that are attributable to previous experiences but do not involve conscious recollection of them (Graf & Schacter, 1985; Schacter, 1987). Considerable research has shown that implicit memory, as indexed by direct or repetition priming effects on such tests as word identification, word stem and word fragment completion, and lexical and object decision, can be dissociated experimentally from explicit memory in normal subjects and amnesic patients (for reviews, see Richardson-Klavehn & Bjork, 1988; Roediger, 1990; Schacter, 1987; Schacter, Chiu, & Ochsner, in press; Shimamura, 1986).

A striking feature of priming on various implicit tests is that it is little affected or entirely unaffected by manipulations of semantic versus nonsemantic study processing, which have large effects on explicit memory. Several studies have shown that whereas explicit memory is much higher after study tasks that require semantic elaboration than after study tasks that require low-level structural or perceptual analysis, priming effects on identification, completion, and similar tasks are of comparable magnitude following the two types of study tasks (cf. Bowers & Schacter, 1990; Graf & Mandler, 1984; Jacoby & Dallas, 1981; Roediger, Weldon, Stadler, & Riegler, 1992; Schacter, Cooper, & Delaney, 1990; Schacter & McGlynn, 1989). These and related observations have led to the proposal that priming is based to a large extent on a presemantic perceptual representation system (PRS) that is composed of modality-specific subsystems that represent information about the form and structure, but not the meaning and associative properties, of words and objects (Schacter, 1990, 1992a, 1992b; Tulving & Schacter, 1990; cf. Gabrieli, Milberg, Keane, & Corkin, 1990; Keane, Gabrieli, Fennema, Growdon, & Corkin, 1991).

Although the foregoing ideas have been directed largely toward visual PRSs, and are supported by observations from visual implicit memory tests, recent research has revealed a similar pattern of effects in the auditory domain. Schacter and Church (1992) examined priming effects from study-list exposure to spoken words on two auditory tasks: identification of words in white noise and completion of initial syllable stems with the first word that comes to mind. Previous research had shown that priming occurs on these tasks and that it is to a large extent modality specific (Bassili, Smith, & MacLeod, 1989; Jackson &

Daniel L. Schacter and Barbara A. Church, Department of Psychology, Harvard University; Susan M. McGlynn (now at Maclean Hospital, Belmont, Massachusetts) and William P. Milberg, Geriatric Research Education and Clinical Center, Department of Veterans Affairs Medical Center, West Roxbury, Massachusetts.

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Correspondence concerning this article should be addressed to Daniel L. Schacter, Department of Psychology, Harvard University, 33 Kirkland Street, Cambridge, Massachusetts 02138.

Morton, 1984). In a series of experiments, Schacter and Church manipulated type of study processing: Subjects encoded spoken words either by making semantic judgments (e.g., by indicating the category to which a word belongs) or by making nonsemantic judgments (e.g., by rating the pitch of the speaker's voice). Performance on explicit memory tests (recognition or cued recall) was much higher after semantic than nonsemantic encoding, whereas the magnitude of priming on the identification and completion tasks was either less affected or unaffected by the same manipulations.

Schacter and Church (1992) argued that the priming they observed was based to a large extent on a presemantic auditory PRS subsystem that represents the spoken form of words independently of their meaning and noted that converging evidence for such a subsystem is provided by observations of patients who exhibit the phenomenon of word-meaning deafness. These patients show a severe impairment in comprehending spoken words, but their ability to repeat words aloud and write them to dictation is relatively preserved (cf. Ellis, 1984; Kohn & Friedman, 1986). Although such patients are quite rare, their pattern of preserved and impaired abilities is theoretically important because it suggests that processing and representation of spoken word forms is handled by a subsystem that is distinct from semantic memory (Allport & Funnell, 1981; Ellis, 1984; Ellis & Young, 1988). One strong prediction of the PRS view is that patients who exhibit word-meaning deafness should show normal priming effects despite their semantic impairment (Schacter & Church, 1992).

In this article, we describe a case of word-meaning deafness and report the results of two experiments in which we examined whether this patient showed priming on auditory word identification tests. The key outcome of the study is that the patient showed intact priming relative to a group of matched control subjects.

Experiment 1

In the first experiment, we assessed priming with an auditory identification task used previously by Jackson and Morton (1984) and Schacter and Church (1992): After auditory study of a list of common words, both studied and nonstudied words were masked by white noise, and subjects attempted to identify them.

Method

Case report. JP is a 65-year-old right-handed man who was admitted to the hospital in October 1991 for a geriatric evaluation related to his safety at home. He had a history of hypertension, non-insulin dependent diabetes mellitus, and multi-infarct dementia. JP sustained a left middle cerebral artery infarct in 1977, which reportedly resulted in Wernicke's aphasia and a right visual field cut. Several additional infarcts have been documented since that time.

JP's magnetic resonance image (MRI) in May 1991 revealed a large infarction in the territory of the left middle cerebral artery (see Figures 1 and 2). The resulting dense lesion included the posterior inferior temporal gyrus, middle temporal gyrus, planum temporale (including Heschl's gyrus), and the white matter deep to these structures. The lesion becomes patchy as it extends to the supramarginal gyrus and angular gyrus. There also appears to be an additional small infarction affecting the inferior occipital cortex, including part of the calcarine cortex. In the right cerebral hemisphere, JP also appears to have suffered from a number of small (less than 1 cm in diameter) lacunes and infarctions involving the VPL nucleus of the thalamus, the lenticulostraiate area (including small areas of the globus pallidus, lenticular nucleus, lateral putamen, and the head of caudate), as well as the internal and external capsule.

JP had a 10th-grade education. He worked in construction and owned two liquor stores prior to his retirement. At the time of his hospitalization, he still owned property and collected rent from tenants living there. He was married for about 25 years and had three children, but his relationship with his wife had been quite distant for many years. His family was concerned about his ability to function independently at home. He was often left unsupervised at home and had forgotten about things on the stove. His wife reported that JP spent most of his time in front of the television, eating food that was contraindicated by his diabetes, and driving to the local restaurant despite two recent car accidents.

During his most recent neuropsychological evaluation as an inpatient, JP was frequently observed reading the newspaper. His spontaneous speech was fluent and characterized by appropriate grammar and prosody. However, he made a number of paraphasic errors (both phonemic and semantic) and exhibited a restricted vocabulary and vague responses to questions. He generally exhibited an appropriate range of affect, though he occasionally appeared disinhibited in his behavior. JP was cooperative, attentive, and motivated during several testing sessions, though he exhibited considerable frustration on tasks that he had difficulty understanding.

Assessment of JP's language functioning is summarized in Tables 1 and 2. The evaluation included the Boston Diagnostic Aphasia Examination (BDAE; Goodglass & Kaplan, 1972), the Controlled Oral Word Association Test (Benton & Hamsher, 1976), the Boston Naming Test

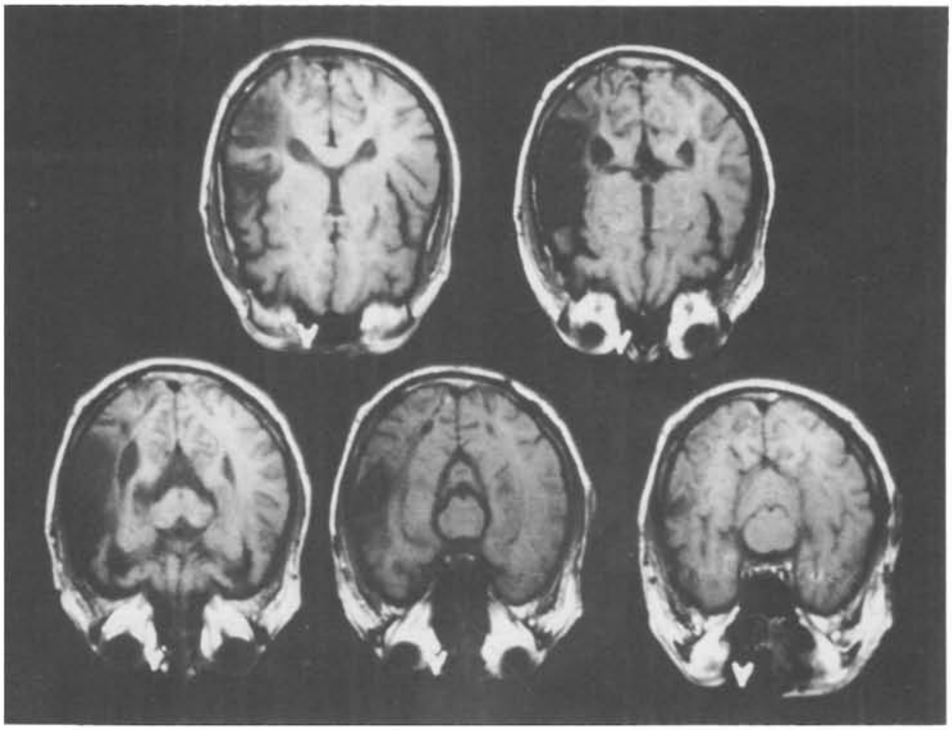

Figure 1. T1-weighted axial view of JP's lesions. (Image extends from the level of the midbrain to the trigone of the lateral ventricles. Left and right are reversed.)

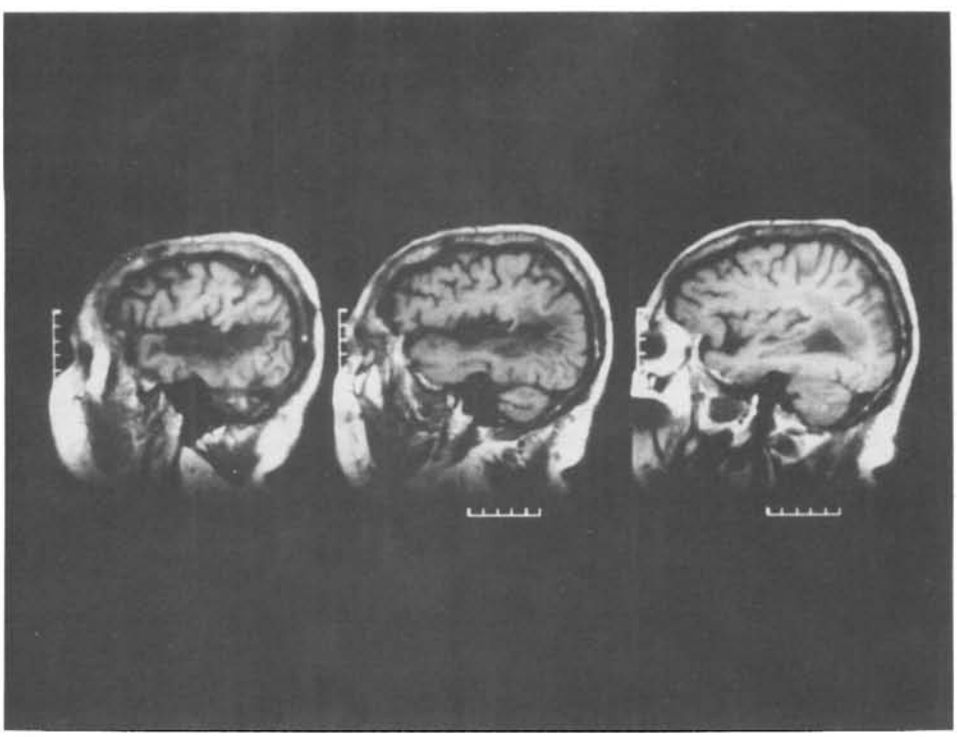

Figure 2. T1-weighted parasagittal view of JP's principal lesion in the left cerebral hemisphere.

Table 1
Boston Diagnostic Aphasia Examination Subscores

Scale/subscale	Score
Auditory Comprehension	
Word Discrimination	44/72
Body-Part Identification	6/20
Command	1/15
Complex Material	3/12
Naming	
Responsive Naming	15/30
Confrontation Naming	108/114
Animal Naming	6/23
Repetition	
Words	9/10
High-Probability Phrases	4/8
Low-Probability Phrases	1/8
Oral Reading	
Words	30/30
Sentences	8/10
Word Picture Match	10/10
Word Recognition	7/8
Reading Comprehension	
Sentences and Paragraphs	8/10
Oral Spelling	7/8
Writing	
Primer Dictation	14/15
Confrontation Naming	10/10
Spelling to Dictation	7/10
Sentences to Dictation	6/12
Narrative Writing	3/5

(Kaplan, Goodglass, & Weintraub, 1978), the Sound Recognition Test—Multiple Choice of Pictures (Spreen & Benton, 1969), and a modified version of the Peabody Picture Vocabulary Test (PPVT; Dunn, 1965). The PPVT was modified by dividing it into two parts such that odd-numbered items were presented auditorily and even-numbered items were presented visually in typewritten text.

Test results revealed severely impaired auditory comprehension on all BDAE subtests. Overall, JP's mean rank on the BDAE tests of auditory comprehension, relative to other aphasic patients, was at about the 20th percentile. In contrast, JP exhibited much milder problems when required to repeat single words or complex phrases or to write words to dictation, ranking at about the 70th percentile relative to other aphasics. JP's auditory comprehension deficit is also highlighted by the fact that he exhibited extremely poor performance on the PPVT when words were presented auditorily and exhibited relatively intact performance when words were presented visually (Table 2). JP's reading comprehension was slow but relatively intact, as was written confrontation naming, placing him at about the 80th percentile. The patient reported that he frequently has to write down words that he hears in order to understand their meaning. Interestingly, he had no difficulty identifying numbers or individual letters from auditory presentation, and he was able to recognize environmental sounds. For the present purposes, then, the critical feature of JP's performance on auditory tasks is a severe deficit in comprehending spoken words and a relatively intact ability to repeat them and write them to dictation.

An estimate of JP's level of premorbid intellectual functioning, based on his occupation and his score on the multiple-choice version of the Information subtest (19/29) of the Wechsler Adult Intelligence Scale—Revised (WAIS–R; Wechsler, 1981), places him in the average range. Other verbal subtests of the WAIS–R were not administered because of JP's language difficulties. He achieved a Performance IQ of 87 on the WAIS–R, a score in the low average range for his age. His Mini Mental State Exam (Folstein, Folstein, & McHugh, 1975) score (21/30) revealed cognitive decline from premorbid levels. A number of subtests from the Wechsler Memory Scale—Revised (WMS–R; Wechsler, 1987) were administered and revealed impaired delayed visual memory but intact verbal memory when information was presented in written form (Figural Memory = 6, Logical Memory = 18, Visual Paired Associates I = 8, Visual Reproduction I = 32, Digit Span = 9, Logical Memory II = 12, Visual Paired Associates II = 2, and Visual Reproduction II = 5). Additional neuropsychological testing revealed impaired facial recognition on Milner's (1968) Test of Unfamiliar Faces (6/12); impaired mental assembly of object puzzles (Hooper Visual Organization Test score = 20.5/30 [Hooper, 1958]); intact copying of the Rey–Osterrieth Complex Figure (29/36; Rey, 1964) but poor incidental recall on an immediate (7.5/36) and delayed trial (6/36); impaired word list generation to both phonemic cues (F = 6, A = 5, and S = 5) and a semantic cue (*grocery store* = 6; Controlled Oral Word Association test, Benton & Hamsher, 1976); impaired confrontation naming (on the Boston Naming Test, Kaplan, Goodglass, & Weintraub, 1978; spontaneous correct responses = 24, correct responses with stimulus cue = 5); and impaired ability to establish, maintain, and shift cognitive set on the modified Wisconsin Card Sorting Test

Table 2
Neuropsychological Assessment of JP's Language Abilities

Scale	Score
Boston Naming Test	
Spontaneous responses	24/60
Stimulus-cued responses	5/60
Total correct	29/60
Controlled Oral Word Association	
FAS	5
Grocery store	6
Sound Recognition Test—Multiple Choice Pictures	
Series A	11/13
Series B	12/13
Peabody Picture Vocabulary Test	
Auditory	44/87
Visual	72/87

(Hart, Kwentas, Wade, & Taylor, 1988; Nelson, 1976; categories = 4, perseverative errors = 21).

Control subjects. The controls were 4 men without any known neurological deficits who were matched to JP for age (M = 63 years, range = 62–68 years) and education level (M = 10. 3 years, range = 8–12 years) and who also had similar work backgrounds.

Design, materials, and procedure. Given the small number of observations concerning the performance of a single patient in a single paradigm, we attempted to increase the reliability of our observations by replicating the experiment on two different occasions, using different sets of materials on each occasion. The basic design and procedure was patterned after Schacter and Church's (1992) Experiments 1 and 2. Subjects initially heard a series of 24 familiar words, presented over headphones at normal conversation levels, that were spoken by either a man or a woman. The encoding task required subjects to repeat each word aloud and to indicate whether it was spoken by a man or a woman. Instructions were presented in written form for the encoding task and subsequent tests to ensure that JP understood task requirements. After presentation of the study list, there was a delay of several minutes during which subjects completed a brief filler task that involved generating names of states. Instructions for the word identification test were then given. Subjects were informed that they would be hearing a series of words presented in noise, that we were interested in their subjective perception of what the masked words sounded like, and that their task was to respond with the first word that came to mind for each stimulus presentation. The identification test consisted of 48 critical words, 24 old words from the study list, and 24 new, nonstudied words that provided an estimate of baseline identification performance. For the old words, half were spoken by the same voice as during the study list and the other half were spoken by a different voice; voice change always involved a change in the speaker's gender. For the new words, half of the words were spoken by a man and half by a woman. The noise level was the same as that used by Schacter and Church (1992), and it produced extremely degraded stimuli: College students were able to identify correctly approximately 25% of nonstudied words.

Immediately following the identification task, a yes/no recognition test was given for the same 48 words, except that no white noise was used. Subjects were instructed that we were interested in what they remembered from the beginning of the experiment, when they decided whether words were spoken in a male or female voice. They were instructed to answer yes when they remembered that a word had been spoken during the initial phase of the experiment and to answer no when they did not remember that a word had been spoken during the initial phase of the experiment. No mention was made of the voice manipulation. Several weeks after the conclusion of this session, all subjects were given the same sequence of study task, word identification test, and yes/no recognition test with a new set of 48 words; 24 of them appeared on the study list, and 24 served as nonstudied or baseline items.

The materials for the first study–test session were 48 medium-to-low frequency words used by Schacter and Church (1992). The two sets of 24 studied and nonstudied words were matched as closely as possible for word length, frequency, and concreteness. We also devised a second set of 48 words that was similar to the first, and in which the sets of 24 studied and nonstudied words were again matched as closely as possible for word length, frequency, and concreteness. For both sets of materials, the 24 study-list words were spoken by three men and three women, with four words randomly assigned to each speaker. Similarly, the 24 nonstudied words in each set were also spoken by three men and three women. Half of the words were tested in the same voice in which they were spoken during the study task, and half were tested in a different (opposite-gender) voice.

To examine JP's comprehension of words that were presented on the study lists, we administered two different tests after each of the priming sessions. The first test required JP and the control subjects to provide a definition of each word from the study list. Words were spoken individually by the experimenter, and subjects were given as much time as they needed to provide a definition. The definitions were scored by two independent raters—Susan M. McGlynn and a staff member who was unaware of the nature of the experiment and the identity of the subjects. The raters followed a scoring system similar to that used on the WAIS–R Vocabulary subtest: They assigned a score of 0, 1, or 2 to each definition, where 0 indicates an incorrect definition, 1 indicates a partially correct definition, and 2 indicates a complete definition. The second test involved making judgments of semantic relatedness: For each target word, subjects were given two alternatives and were asked to indicate which of the two was more related in meaning to the target. The correct choices were strongly related to the targets (e.g., *nail* for target word *hammer*), whereas the incorrect choices were weakly or only moderately related to the targets (e.g., *hook* for *hammer*). Informal pilot work indicated that normal subjects perform at a 100% level of accuracy on this test.

Results

Word identification. Table 3 presents the main word identification data for JP and the matched control subjects for the two test sessions and for studied and nonstudied words. Data were scored according to a strict criterion (only correct spellings allowed) and a more lenient criterion (misspellings counted as correct). The overall pattern of results was the same according to both criteria, and because misspellings were relatively infrequent, the more lenient scoring criterion was adopted.

Table 3
Proportion of Studied and Nonstudied Words Identified Correctly by JP and Control Subjects on the Auditory Identification Test in Experiment 1

	List 1			List 2			Overall		
Subject	Studied	Non-studied	Priming score[a]	Studied	Non-studied	Priming score[a]	Studied	Non-studied	Priming score[a]
JP	.208	.042	.166	.083	.042	.041	.146	.042	.104
Controls	.281	.167	.114	.167	.104	.063	.244	.136	.088

[a] Computed by subtracting proportion of nonstudied words identified from proportion of studied words identified.

The data in Table 3 are reasonably clear-cut. On the one hand, JP had difficulty with the word identification task, as indicated by his low level of baseline performance (.042) relative to that of the control subjects (.136). Nevertheless, the critical finding is that JP showed a normal priming effect on the identification task: When identification of nonstudied items is subtracted from that of studied items, he achieved a priming score of .104, whereas the control subjects achieved a priming score of .088. The performance of JP and the controls was similar inasmuch as both exhibited stronger evidence of priming on the first list than on the second, which may reflect differences in the materials that were used on the two lists. JP showed somewhat more priming than two controls, whose overall priming scores were each .063; he showed somewhat less priming than one control, whose priming score was .125; and he showed equivalent levels of priming to the other control, whose priming score was .104. Thus, it seems safe to conclude that the priming effect exhibited by JP falls well within the range of the matched control subjects.

It was also possible to examine the effect of changing the speaker's voice between study and test on priming, although the small number of observations per cell in same- and different-voice conditions (n = 12) renders such comparisons tentative. JP showed similar levels of performance in the same- and different-voice conditions, identifying one more word in the former condition than in the latter. Control subjects identified equal numbers of items in the same- and different-voice conditions. The lack of voice-change effects is consistent with previous investigations of college students that examined priming of words masked by white noise (Jackson & Morton, 1984; Schacter & Church, 1992).

Recognition memory. The recognition data, displayed in Table 4, are partitioned into hits (yes responses to words that had appeared on the study list) and false alarms (yes responses to words that had not appeared on the study list). These data contrast markedly with the priming results: JP exhibited essentially no recognition memory and was severely impaired relative to the control subjects. In fact, JP responded no to all items—both those that appeared on the study list and those that did not—and claimed that he simply did not remember having heard any of the test items previously. In contrast, when recognition performance was collapsed across the two lists, all of the control subjects had more hits than false alarms, and their overall hit rate (.547) was much higher than their false-alarm rate (.229). The control subjects' recognition performance was considerably lower on the first list than on the second, but this result is largely attributable to the unusually poor performance of one subject, whose false-alarm rate on the first list (.417) actually exceeded his hit rate (.375). However, this subject showed high levels of recognition on the second list (hit rate = .583, false-alarm rate = .125), which were comparable to the scores attained by the other control subjects, thus

Table 4
Proportion of Yes Responses to Studied and Nonstudied Words by JP and Control Subjects in the Explicit Recognition Test in Experiment 1

	List 1			List 2			Overall		
Subject	Studied	Non-studied	Recognition score[a]	Studied	Non-studied	Recognition score[a]	Studied	Non-studied	Recognition score[a]
JP	.000	.000	.000	.000	.000	.000	.000	.000	.000
Controls	.479	.302	.177	.614	.156	.454	.547	.229	.318

Note. For studied words, proportion indicates hit rate; for nonstudied words, proportion indicates false-alarm rate.
[a] Computed by subtracting false-alarm rate from hit rate.

suggesting that his poor performance on the first list was an aberration.

Comprehension of studied words. JP's comprehension of words from the study list, as assessed by his performance on the definition-production task and the forced-choice relatedness task, was markedly impaired relative to that of the control subjects.

For the definition-production task, interrater agreement was quite high (.896 agreement), so data were collapsed across the two raters. For each subject, a proportional score was computed by dividing the total number of points that the two raters awarded by the total number of possible points. For control subjects, the mean score was .942 (range = .885–.969). In contrast, JP achieved a proportional score of .115, thus exhibiting a severe impairment. It was of further interest to compare JP's definitions for words that he did and did not identify correctly, although the small number of words identified correctly renders such an analysis tentative. JP's proportional score was .143 for words identified correctly and .103 for words not identified.

On the two-choice semantic-relatedness test, all control subjects performed at a 100% level of accuracy for all items on both lists. Thus, the test was quite easy for normal subjects. JP scored considerably lower than the controls, although well above the chance level of .500, achieving .750 correct overall (.667 correct for the first list and .833 correct for the second list). There were no systematic differences for items that he identified correctly or incorrectly on the identification task: JP was .714 (5/7) correct for identified items and .756 (31/41) correct for nonidentified items. Thus, there does not appear to be a strong relation between whether or not JP showed priming on a word and his ability to gain access to semantic knowledge of that word.

Discussion

The main result of Experiment 1 was that JP showed a normal priming effect on the auditory identification test despite poor comprehension of target words and a lack of explicit memory for them. Although these results appear to provide strong support for the PRS view of priming, two cautionary points need to be made. First, the number of observations is small, and only List 1 yielded clear evidence of robust priming; both JP and the control subjects exhibited weak priming effects on List 2. Second, JP's baseline identification rate was near zero on both lists (.042) and lower than that of the control subjects (.136). In view of this nearly nonexistent level of baseline performance, it is difficult to make strong claims about normal priming effects.

To address these points and to obtain more information about auditory priming in JP, we performed an additional experiment using a different priming task, one in which used words are made difficult to identify by degrading them with a low-pass filter. We have recently observed robust priming effects on the low-pass filter identification task in college students (Church & Schacter, 1992). In addition to allowing us to obtain more observations on JP and thereby assess the reliability and generality of his priming, the low-pass filter task has two attractive features. First, identification difficulty can be varied by manipulating the level of decibel reduction that is produced by the filtering process. Thus, we hoped to raise JP's baseline identification rate well above the near-zero levels observed in Experiment 1. Second, our previous work with college students showed that priming on the low-pass filter identification task is influenced by study-to-test changes in the speaker's voice (Church & Schacter, 1992). Accordingly, we were able examine whether JP, like normal subjects, would show evidence of voice-specific priming.

Experiment 2

Method

Subjects. JP and the same four matched control subjects from Experiment 1 participated in the experiment.

Design, materials, and procedure. All features of the main experiment were similar to Experiment 1, with the following exceptions. The main difference was that the low-pass filter task was used to assess auditory identification. All target items were put through a low-pass filter in the SoundEdit program on a Macintosh computer. For patient JP, the filter reduced the decibel level of a distribution of frequencies between 1000 Hz and 2000 Hz by 0 to 20 decibels and reduced all frequencies above 2000 Hz by 20 decibels. The effect of the filtering was a slight muffling of the word. For control subjects, target words were degraded further in an attempt to produce more comparable levels of baseline performance: The maximal level of decibel reduction was 60 dB instead of 20 dB, and the filtered words sounded muffled. As in Experiment 1, six different speakers (three men and three women) were used, and each word was recorded in both a male and a female voice. Two new sets of moderate to low frequency words were used as target materials. Each set consisted of 48 words and was divided into two subsets of 24 studied and 24 nonstudied items. For each set, the two subsets were matched as closely as possible for frequency, length, and concreteness.

Because the purpose of this experiment was to assess the reliability of JP's priming, and because he responded no to all items on the recognition test in Experiment 1, we dropped the recognition test from Experiment 2. A final change involved the assessment of JP's comprehension of studied words: Because the definition-production task and relatedness-judgment task yielded similar patterns of results in Experiment 1, we assessed comprehension only with the definition-production task. In addition, because control subjects scored at ceiling levels on the definition-production task, we administered the task only to JP.

All testing was done in a single session. Instructions and procedure for the encoding task were as described for Experiment 1. Following completion of the same brief distractor task that was used in the first experiment, subjects were told that they would be exposed to a series of filtered words that would sound somewhat muffled, that we were interested in their subjective perception of what they heard, and that they should respond by writing down the first word that came to mind. After a short break, the same procedure was repeated for the second list. In addition, JP was given the definition-production task at the conclusion of testing for each list.

Results and Discussion

Word identification. The data from the low-pass filter task are presented in Table 5. Three points about these data are worth noting. First, JP exhibited a much higher level of baseline performance on both lists (.250) than he did in Experiment 1, although it was still lower than that of the control subjects. Second, JP showed a large overall priming effect, identifying .416 of the studied words correctly. As in Experiment 1, JP's performance varied across lists: He showed a large priming effect on List 2 and a weak priming effect on List 1. Third, the overall magnitude of priming exhibited by JP (.167) was quite similar to the mean priming score of the control subjects (.198), and as in Experiment 1, he scored well within the range of the control subjects. JP showed more priming than two controls, whose priming scores were .125 and .145, respectively, and less priming than the other two controls, whose priming scores were .270 and .250, respectively. Although JP's priming score on the first list was quite small (.042), one of the control subjects failed to show any priming on this list. Thus, both JP and the control subjects showed more robust priming on List 2 than on List 1.

We also examined identification of studied words as a function of the voice manipulation. JP showed strong evidence of voice-specific priming: His overall priming score in the same-voice condition (.292) was much higher than in the different-voice condition (.042). For control subjects, overall priming scores were also higher in the same-voice condition (.235) than in the different-voice condition (.162), but the magnitude of the voice-change effect was not as large. For both JP and the control subjects, nearly all of the evidence for voice-specific priming was provided by List 2. On List 1, JP identified one more item in the same-voice than in the different-voice condition, and the controls identified on average one item less in the same-voice than in the different-voice condition. In view of the fact that strong voice-change effects were observed on only one of the lists, and that the number of observations per cell is quite small for these comparisons, we must be cautious about interpreting the evidence on voice-specific priming. It seems safe to conclude, however, that JP and the controls showed the same overall pattern of voice-specific priming (i.e., greater voice-change effect on List 2 than on List 1) and that there is suggestive evidence that JP was more susceptible to voice-change effects than were the control subjects.

Comprehension of studied words. JP's performance on the definition-production task for studied words was scored by the two raters from Experiment 1 in the same manner as described previously, and the same proportional score described in Experiment 1 was computed from their ratings. As in Experiment 1, there was relatively high agreement between the two raters (.875), so their mean scores were used. Once again, JP exhibited little understanding of the target words, achieving a mean proportional score of

Table 5
Proportion of Studied and Nonstudied Words Identified Correctly by JP and Control Subjects on the Auditory Identification Test in Experiment 2

	List 1			List 2			Overall		
Subject	Studied	Non-studied	Priming score[a]	Studied	Non-studied	Priming score[a]	Studied	Non-studied	Priming score[a]
JP	.292	.250	.042	.542	.250	.292	.417	.250	.167
Controls	.635	.500	.135	.792	.510	.282	.703	.505	.198

[a] Computed by subtracting proportion of nonstudied words identified from the proportion of studied words identified.

.099. His scores were low both for words identified correctly (.113) and words that were not identified correctly (.089).

General Discussion

The critical finding of the present study was that JP showed intact priming of spoken words on two different kinds of auditory identification tests despite his comprehension deficit. Even though he exhibited a marked inability to understand the study-list words, as indicated by his severe impairment on the definition-production and semantic-matching tests, he showed just as much priming as did the controls: Collapsed across the four separate study and test sessions that constituted the two experiments, JP's mean priming score was .136, and the control subjects' mean priming score was .143. These results provide confirmation of the prediction made by the PRS account of auditory priming and are also consistent with related theoretical views that hold that priming on identification and similar implicit tasks depends heavily on perceptual processes (cf. Keane et al., 1991; Roediger, 1990; Squire et al., 1992). Taken together with Schacter and Church's (1992) finding that priming on the auditory identification test in normal subjects is robust following nonsemantic study tasks, our results provide converging empirical support for the idea that priming on perceptual or data-driven tasks such as auditory identification depends heavily on a presemantic system.

Although our data are entirely consistent with the PRS account, a number of qualifications and cautions should be noted. First, because this study is based on a single subject, we must reserve judgment concerning the generality of our results pending the investigation of additional patients. Second, as noted earlier, JP's baseline level of identification performance was lower than that of the control subjects. The comparison of priming scores at different levels of baseline performance is not entirely straightforward and calls for interpretive caution (for a discussion, see Keane et al., 1991; Schacter, Kihlstrom, Kaszniak, & Valdiserri, in press). Note, however, that JP showed robust priming both in Experiment 1, when his baseline score was quite low (.042), and in Experiment 2, when it was considerably higher (.250). Moreover, the magnitude of priming exhibited by JP was as large as that exhibited by the control subjects both when absolute priming scores were considered, as we did in both experiments, and when proportional priming scores (i.e., percentage increase over baseline) were considered. Thus, it appears that the priming exhibited by JP was not strongly related to baseline performance. Nevertheless, the fact that JP's baseline performance was substantially lower than that of the control subjects in both experiments means that we must be cautious about claiming that he exhibited entirely normal priming. What we can state confidently, however, is that JP showed robust priming despite his comprehension deficit.

A third cautionary note concerns the extent to which JP's priming can be characterized as presemantic. We have argued that the combination of JP's robust priming and impaired auditory comprehension support the notion that priming of auditory word identification operates at a presemantic level. The finding in both experiments that JP exhibited impaired comprehension of studied words that he identified correctly is consistent with this view. Nonetheless, it is possible that even when JP failed to understand a spoken word explicitly, some semantic information about it was activated. For example, previous research has demonstrated that Wernicke's aphasics show indirect or semantic priming of words that they fail to comprehend explicitly (cf. Blumstein, Milberg, & Shrier, 1982; Milberg & Blumstein, 1981; Milberg, Blumstein, & Dworetzky, 1988), and it is quite possible that JP would show similar evidence for implicit semantic activation. Given that this possibility exists, the appropriate conclusion from the present study is that priming of auditory word identification does not depend on explicit comprehension of a spoken word and in that sense can be thought of as a presemantic phenomenon.

If we assume that priming in JP depends on a presemantic auditory PRS, an important question concerns the neural basis of this system and the extent to which it is spared by JP's lesion. Recent data from neuroimaging studies using positron emission tomography (PET) indicate that cortical areas in the vicinity of the left angular gyrus and supramarginal gyrus play an important role in the processing and representation of auditory word-form information (Petersen, Fox, Posner, Mintun, & Raichle, 1989). We noted earlier that MRI evidence indicates that JP's major lesion is quite extensive in the anterior portions of Wernicke's area but becomes patchy in the regions of the angular and supramarginal gyri. Thus, it seems plausible to suggest that JP's spared priming is mediated by a largely preserved auditory word-form system that depends critically on the left angular and supramarginal gyri. The extensive lesion in other regions of

Wernicke's area may have effectively disconnected the output of the auditory word-form system from regions involved in semantic representation, which may be dependent on anterior cortical regions in the temporal and frontal lobes (e.g., Petersen et al., 1989).

It is also possible, of course, that JP's intact priming is mediated by his spared right hemisphere. We (Schacter, 1992a, 1992b; Schacter & Church, 1992) have suggested that there may be two components to auditory priming: a voice-specific component that depends primarily on the right hemisphere and an abstract, voice-independent component that depends primarily on the left hemisphere. This argument is based on three different types of observations: (a) Study-to-test changes in speaker's voice have no effect on priming when priming is assessed with the identification-in-noise test used in Experiment 1, whereas voice-change effects are observed when priming is assessed with implicit tests that do not use white noise (e.g., identification with low-pass filter or auditory stem completion); (b) the right hemisphere's ability to process spoken words seems to be especially impaired by background noise (Zaidel, 1978); and (c) in a recent study of auditory stem completion priming that used a dichotic listening procedure, it was observed that the left hemisphere showed significant priming in both same- and different-voice conditions, whereas the right hemisphere showed significant priming in the same-voice condition but failed to show any priming in the different-voice condition (Schacter, Aminoff, & Church, 1992; cf. Marsolek, Kosslyn, & Squire, 1992). The fact that JP exhibited a large voice-change effect in Experiment 2 is consistent with the idea that his right hemisphere played a role in the observed priming, and the apparent trend for larger voice-change effects in JP than in the controls raises the possibility that priming in JP depends to a greater extent on the right hemisphere than it does in the control subjects. However, when words are embedded in noise on the auditory identification test, as they were in Experiment 1, the right hemisphere may be effectively excluded from contributing to priming effects. Because JP showed robust priming with the identification-in-noise procedure, it seems unlikely that priming depended entirely on right hemisphere involvement. Nevertheless, we cannot rule out this possibility conclusively.

Our observations concerning auditory priming in JP raise the question of whether similar effects would be observed in patients who exhibit form versus semantic dissociations in visual domains, where priming may be mediated by modality-specific PRS subsystems. For example, patients have been described who can read regular and irregular printed words but do not understand them (cf. Funnell, 1983; Sartori, Masterson, & Job, 1987; Schwartz, Saffran, & Marin, 1980), and these observations have been cited in support of the idea that a presemantic visual word-form system supports visual word priming on a variety of implicit tasks (Schacter, 1990). Similarly, dissociations between relatively intact access to knowledge of the structure of visual objects despite impaired access to knowledge of their functional and associative properties (cf. Riddoch & Humphreys, 1987; Warrington, 1975, 1982; Warrington & Taylor, 1978) have provided a basis for arguing that a presemantic structural description system supports priming effects for visual objects (Schacter, 1990; Schacter et al., 1990). It would be of considerable interest to determine whether such patients, like JP, show robust perceptual priming for visual words or objects that they do not comprehend. Such research would yield information concerning the generality of the dissociation that we have observed, provide a strong test of the PRS account of priming, and illuminate the nature of the relation between perceptual and conceptual memory processes.

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Correction to Editorial

In the editorial "Some Comments on the Goals and Direction of *Neuropsychology*," by Nelson Butters (*Neuropsychology,* 1993, Vol. 7, No. 1, pp. 3-4), the name of the National Academy of Neuropsychology was misspelled. This was due to an incorrect change by the printer at a late stage in production, after the proofs were properly reviewed by the Editor.