Research Article

IMPLICIT MEMORY IN AMNESIC PATIENTS: Evidence for Spared Auditory Priming

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Abstract—*Previous observations of spared priming in amnesic patients have been based almost entirely on data from visual implicit memory tests. Our research examined perceptual priming in amnesic patients and control subjects on an auditory identification task in which previously spoken words and new words were presented in white noise. We manipulated type of encoding task (semantic vs. nonsemantic) and speaker's voice at study and test (same vs. different). Priming was little affected by either manipulation, and amnesic patients exhibited normal priming in all experimental conditions. On an explicit test of recognition memory, by contrast, amnesic patients exhibited severely impaired performance following the semantic study task; all subjects showed poor explicit memory following the nonsemantic study task. Results are consistent with the idea that auditory priming depends largely on a presemantic auditory perceptual representation system.*

The hallmark of the amnesic syndrome is a severe impairment in the ability to recollect recent experiences. Despite this pervasive deficit in explicit memory, amnesic patients exhibit robust and frequently normal implicit memory for various kinds of information on tests that do not require conscious recollection of specific experiences (for review, see Schacter, Chiu, & Ochsner, 1993; Squire, 1992). Perhaps the most extensively studied type of implicit memory in amnesic patients is repetition or direct priming: facilitated identification of words and objects as a consequence of recent exposure to them (Tulving & Schacter, 1990). Beginning with the seminal studies of Warrington and Weiskrantz (1974), a large and ever increasing number of experiments have revealed normal or near-normal priming effects on a variety of implicit memory tests in amnesic patients who exhibit significant impairments of explicit memory. These findings have important theoretical consequences for understanding the structure of both normal and abnormal memory (for review, see Bowers & Schacter, 1993; Shimamura, 1986).

Observations of intact priming in amnesic patients are based almost exclusively on data from visual implicit memory tests and have provided a basis for theorizing about the nature of visual processes and systems that may be preserved in amnesia. For example, it has been argued that spared visual priming in amnesic patients often depends on a cortically based perceptual representation system (PRS) that represents information about the form and structure, but not the meaning and associative properties, of words and objects (Schacter, 1990; Tulving & Schacter, 1990). Evidence for the PRS account is based on data indicating that priming in visual completion and identification tests is (a) unaffected or little affected by semantic-versus-nonsemantic study task manipulations that greatly influence explicit memory (e.g., Graf, Mandler, & Haden, 1982; Jacoby & Dallas, 1981), (b) strongly dependent on encoding of perceptual information (e.g., Roediger & Blaxton, 1987), and (c) associated with blood flow changes in extrastriate cortex (Squire et al., 1992).

By contrast, there has been a virtual absence of research concerning, or theorizing about, auditory priming in amnesic patients. The single auditory-priming paradigm that has been used is the homophone-spelling procedure introduced by Jacoby and Witherspoon (1982), and it has yielded mixed results. In this paradigm, subjects initially hear a homophone target preceded by a word that biases its low-frequency interpretation (e.g., *taxi–fare*) and are subsequently asked to spell the target word from auditory presentation. In their initial study, Jacoby and Witherspoon (1982) reported that amnesic patients, like control subjects, produced the low-frequency spelling more frequently for previously studied homophones than for nonstudied homophones. Cermak, O'Connor, and Talbot (1986) also observed biasing effects in Korsakoff's patients, but the effects were smaller and more fragile than in control subjects. In a case study of the severely amnesic patient H.M., Gabrieli, Keane, and Corkin (1989) reported impaired homophone-biasing effects after auditory study exposure. Taken together, these latter two studies raise the possibility that auditory priming, in contrast to visual priming, is impaired in amnesic patients.

According to the PRS framework, auditory priming should be spared in amnesic patients when it is assessed with tasks that resemble the perceptual implicit tests on which amnesics have consistently shown normal priming in the visual domain. Priming on the homophone-spelling task likely involves memory processes outside the PRS, such as the representation of context-dependent word meanings, and it is possible that these processes are compromised in amnesic patients (Cermak et al., 1986; Gabrieli et al., 1989). To test the PRS view, we used an auditory word identification test (Jackson & Morton, 1984) that is analogous to the frequently used visual word identification test. In this paradigm, subjects initially hear a series of spoken words and later attempt to identify previously studied and nonstudied words that are degraded by white noise. Jackson and Morton documented significant priming of spoken words in this paradigm, showed that visual study of target words produces significantly less priming than does auditory study, and also found that the magnitude of the auditory-priming effect was similar when words were spoken at study and test by the same voice or by different voices. More recently, we (Schacter & Church, 1992, Experiments 1 and 2) reported that priming on the identification-in-noise task is either little affected or entirely unaffected by semantic-versus-nonsemantic study task manipulations that have a large influence on explicit remembering. In addition, we found that the magnitude of the auditory-priming

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effect is similar in same- and different-voice conditions following both semantic and nonsemantic encoding tasks. We argued that the observed priming is mediated by an auditory PRS. Converging evidence for this view was provided by observations of normal priming on the auditory identification task in a patient with severe auditory comprehension problems (Schacter, McGlynn, Millberg, & Church, 1993).

In the present study, we used a modified version of our earlier procedure to examine priming on the auditory identification test in amnesic patients. For the study task, patients and control subjects listened to words that were spoken in either a male or a female voice; they performed a semantic encoding task for half of the words and a nonsemantic encoding task for the other half. Subjects then attempted to identify studied and nonstudied words presented in white noise. Half of the studied words were spoken by the same voice as during study, half were spoken by a different voice, and this same-versus-different voice manipulation was crossed factorially with the semantic-versus-nonsemantic study task manipulation. Finally, subjects performed a yes/no recognition test for all words.

This basic design allows for direct tests of the PRS view. First, we can determine whether amnesic patients, like normal subjects in our earlier work (Schacter & Church, 1992), exhibit comparable levels of auditory priming following both semantic and nonsemantic study tasks. Such an outcome is predicted by the view that priming in amnesics is mediated by an auditory PRS that operates at a presemantic level. This issue is also of interest because even within the visual domain, there has been relatively little work examining whether amnesics exhibit priming invariance (or near-invariance) across levels of processing manipulations. Research with the visual stem-completion task indicates that amnesic patients show more priming following a semantic (pleasantness rating) than a nonsemantic (vowel counting) encoding task in some experimental conditions (Graf, Squire, & Mandler, 1984, Experiment 1), and nearly equivalent priming following the two tasks in other conditions (Graf et al., 1984, Experiment 2; Squire, Shimamura, & Graf, 1987, Experiments 2 and 3). Thus, further data concerning this matter are needed. Second, the same-versus-different voice manipulation allows us to evaluate whether priming in amnesic patients survives changes in speaker's voice between study and test, as observed previously with normal subjects on the identification-in-noise task (Schacter & Church, 1992). If priming is indeed based on an auditory PRS that is spared in amnesia, then amnesics and control subjects should exhibit the same pattern of transfer across voice change. Note also that recent work on visual priming indicates that amnesic patients show normal transfer of priming across study-to-test changes in object size (Cave & Squire, 1992; Schacter, Cooper, & Treadwell, 1993). It would be desirable to determine whether amnesics also exhibit normal transfer across transformation of a perceptual attribute in the auditory domain.

METHOD

Subjects

Twelve amnesic patients and 24 control subjects participated in the experiment. The amnesic patients had all been screened at the Memory Disorders Research Center of the Boston Veterans Administration Medical Center. Six of the patients became amnesic as a consequence of alcoholic Korsakoff's syndrome, and 6 patients had nonalcoholic etiologies (encephalitis, anoxia, posterior communicating artery aneurysm, thalamic infarct). The amnesics' mean age was 52.9 years, and they had on average 12.3 years of education. The patients' overall level of intellectual function was in the middle of the normal range, as assessed by the Wechsler Adult Intelligence Scale-Revised. By contrast, they exhibited consistent and substantial memory impairments on the Wechsler Memory Scale-Revised and other tests of explicit memory for recent events. (Details on each of the 12 patients who participated in this experiment can be found in Table 1 of Schacter, Cooper, & Treadwell, 1993).

Twenty-four control subjects were matched to the amnesics for age and years of education. Twelve of the control subjects had a history of alcoholism, and the other 12 had no history of alcoholism. The controls' mean age was 49.3 years, and they had on average 13.1 years of education.

Materials

The target materials consisted of 48 familiar words, divided into two matched sets of 24. Both sets contained 6 words from each of four semantic categories: (a) animals, (b) food or drink, (c) places people can live, and (d) occupations or roles.

Two versions of each of the 24-word study lists were recorded, with each word spoken in a male voice on one version and in a female voice on the other; three male and three female speakers were used. Two versions of the auditory identification test and two versions of the recognition test were recorded in the same manner. Voice changes between study and test always included a change in the sex of the speaker. On the study list and recognition tapes, all words were spoken clearly. On the auditory identification tapes, all words were embedded in white noise. Tapes were presented during study and test using a cassette deck and headphones. Subjects responded verbally, and the experimenter recorded their responses in a test booklet (for details on materials and recording procedure, see Schacter & Church, 1992, Experiment 1).

Design and Procedure

The experiment employed a $2 \times 2 \times 2 \times 2 \times 2$ mixed factorial design. The between-subjects variable was subject group (amnesic patients vs. control subjects). Within-subjects variables were encoding task (category vs. pitch), speaker's voice at study and test (same vs. different), item type (studied vs. nonstudied), and type of test (identification vs. recognition). The identification test always preceded the recognition test.

For the encoding task, the study list was divided into two subsets, which were presented in a blocked manner. Subjects performed the category-encoding task for one subset of items and the pitch-encoding task for the other subset. Each item subset contained equal numbers of words assigned to the same-voice and different-voice conditions. For both the identification and the recognition tests, the experiment was counterbalanced so that each item appeared equally often in the experimental conditions that are defined by the orthogonal combination of the three main variables (i.e., encoding task, speaker's voice at study and test, and item type). In addition, each item appeared equally often in a male and in a female voice. We also balanced studied and nonstudied items for each of the two patient subgroups (6 Korsakoff's and 6 non-Korsakoff's) so that we could assess any differences in priming and baseline performance. However, it was not possible to counterbalance speaker's voice and type of encoding task within each subset of patients.

Subjects were tested individually. Prior to presentation of the study list, subjects were instructed either to rate the pitch (high, medium high, medium low, low) of each speaker's voice on a 4-point scale or to indicate to which of the four semantic categories (animals, food, places, occupations) each word belongs. The scale was placed in view of the subjects during task performance, and words were presented auditorily over the headphone set. There was a brief pause at the conclusion of the initial encoding task, and subjects were then instructed concerning the second encoding task. Five seconds were provided between words for making each judgment and recording each response.

Following the encoding task, subjects were given a distractor task in which 15 letters of the alphabet were presented to them, and they were asked to generate the name of a state that begins with each letter. Although there was no time limit for this task, most subjects required approximately 3 or 4 min to complete it. Finally, subjects were instructed to listen carefully to each of 48 degraded words in white noise, and to provide the first word that came to mind in response to each item. We emphasized that we were interested in their subjective perceptions of what they heard, and that there were no right or wrong responses on the task. Immediately following the conclusion of the identification test, subjects were asked to make a yes/no recognition judgment about the same words. They were informed that all of the words on the recognition test had just been presented on the identification task, and that their task was to try to remember which words they had heard earlier when they were performing the category- and pitch-rating tasks. They were instructed to say "yes" when they remembered that a word had been spoken during the encoding task and "no" when they did not. There were 7 s between words in both tasks for subjects to make their responses. After completing the tasks, subjects were debriefed concerning the nature of the experiment.

RESULTS

Identification Test

Table 1 depicts performance on the identification test by amnesic patients and control subjects as a function of item type, encoding task, and speaker's voice. The rightmost column shows probability of correct identification for nonstudied items (i.e., baseline performance). The other columns show probability of correct identification for studied items together with priming scores that were computed by subtracting the proportion of nonstudied items identified correctly from the proportion of studied items identified correctly.

Baseline performance for control subjects (.313) was somewhat higher than for amnesic patients (.257), although the difference did not reach statistical significance, $t(34) = 1.44$. More important, and in conformity with the PRS view, the overall magnitude of the overall priming effect was virtually identical in amnesic patients (.111) and control subjects (.092). A 2 × 2 analysis of variance (ANOVA) on the overall proportion of studied and nonstudied items identified correctly in the two subject groups revealed a highly significant effect of item type, $F(1, 34) = 21.68$, $MS_e = 0.008$, $p < .0001$, indicating that significant priming occurred, together with a nonsignificant main effect of subject group, $F(1, 34) = 2.00$, $MS_e = 0.021$, and a nonsignificant Subject Group × Item Type interaction, $F < 1$. Separate analyses revealed that the priming effect was significant for both amnesic patients, $t(11) = 2.24$, $p < .05$, and control subjects, $t(23) = 2.91$, $p < .01$.

Table 1 also indicates that priming scores of amnesics and control subjects behaved similarly across experimental conditions. Consistent with the predictions of the PRS account, over-

Table 1. *Proportion of target words reported on the auditory identification test as a function of encoding task and speaker's voice*

	Encoding task						
	Category			Pitch			
Subject group	S	D	*M*	S	D	*M*	NS
Amnesic patients	.375 (.118)	.403 (.146)	.389 (.132)	.333 (.076)	.361 (.104)	.347 (.090)	.257
Control subjects	.425 (.112)	.425 (.112)	.425 (.112)	.392 (.079)	.378 (.063)	.384 (.071)	.313
M	.400 (.115)	.414 (.129)	.407 (.122)	.363 (.078)	.369 (.084)	.366 (.081)	.285

Note. S = same voice; D = different voice; NS = nonstudied words. Values in parentheses are priming scores computed by subtracting the proportion of nonstudied target words reported from the proportion of studied words reported in a particular condition.

all priming scores did not differ significantly after semantic and nonsemantic encoding tasks, $F(1, 34) = 2.52$, $MS_e = 0.029$. Most important, this pattern was observed for both amnesics and control subjects, as indicated by a nonsignificant Subject Group × Encoding Task interaction, $F < 1$. Amnesics also exhibited normal transfer of priming across voice change: The ANOVA revealed a nonsignificant main effect of speaker's voice, $F < 1$, and nonsignificant interactions with subject group and encoding task, $F < 1$.

We also examined the performance of the Korsakoff's and non-Korsakoff's amnesics separately in comparison to their respective control groups. As noted in the method section, we were able to counterbalance studied and nonstudied items in each subgroup of amnesics, but could not counterbalance items within the various study conditions. Thus, only the overall proportion of studied and nonstudied items identified correctly can be meaningfully examined in the two subgroups. Proportion of nonstudied items identified correctly was lower for Korsakoff's amnesics (.222) than for the alcoholic control group (.317; $t[16] = 1.72$, $p = .10$, two-tailed), but the two groups exhibited similar amounts of priming: Korsakoff's patients identified .320 of studied items correctly, yielding a priming score of .098; alcoholic control subjects identified .387 of studied items correctly, yielding a priming score of .070 (for comparison of priming scores, $t < 1$). Proportion of nonstudied items identified correctly was about the same for non-Korsakoff's amnesics as for the nonalcoholic control subjects (.292 vs. .308, respectively; $t < 1$). These patients, too, exhibited intact priming: They identified .417 of studied items correctly, yielding a priming score of .125, whereas nonalcoholic control subjects identified .421 of studied items correctly, yielding a priming score of .113 (for comparison of priming scores, $t < 1$).

The most important result of the subgroup analysis is that intact priming was observed both in Korsakoff's patients, who exhibited low levels of baseline performance, and in non-Korsakoff's patients, whose baseline performance was nearly identical to that of the nonalcoholic control subjects. Comparison of priming scores is difficult when baselines differ across subject groups, but our observations indicate that intact priming can be observed in amnesic patients who exhibit normal baselines. Thus, priming scores in the present experiment are not dependent on the level of baseline performance.

Recognition Test

Table 2 shows recognition performance of amnesics and control subjects as a function of the experimental variables. The rightmost column depicts the proportion of "yes" responses to nonstudied items (i.e., false alarm rate), whereas the other columns show the proportion of "yes" responses to studied items (i.e., hit rate) along with corrected recognition scores that were computed by subtracting the false alarm rate from the hit rate. Amnesic patients exhibited a higher false alarm rate (.338) than did control subjects (.252), so all statistical analyses were performed on the corrected recognition scores.

The most striking feature of recognition performance is that both amnesics and control subjects exhibited quite low and comparable levels of memory following the pitch-encoding task, whereas control subjects showed much higher levels of memory than amnesics following the category-encoding task. An ANOVA revealed significant main effects of encoding task, $F(1, 34) = 23.43$, $MS_e = 0.049$, $p < .0001$, and subject group, $F(1, 34) = 13.11$, $MS_e = 0.058$, $p < .001$, confirming that overall recognition performance was higher in control subjects than in amnesic patients and was higher following the category task than the pitch task. More important, there was a significant Encoding Task × Subject Group interaction, $F(1, 34) = 29.79$, $MS_e = 0.049$, $p < .0001$, indicating that control subjects, but not amnesic patients, showed a significant depth-of-encoding effect in recognition memory. The corrected recognition scores of amnesic patients were nearly identical following the pitch (.103) and category (.087) tasks, $t(11) < 1$, in sharp contrast to the performance of control subjects (.073 vs. .477; $t[23] = 8.34$, $p < .0001$). Recognition performance of amnesics and control subjects did not differ following the pitch task, $t(34) = 1.03$, whereas it did differ significantly following the category task, $t(34) = 6.36$, $p < .0001$.

Table 2. *Proportion of hits and false alarms on the auditory recognition test as a function of encoding task and speaker's voice*

	Encoding task						
	Category			Pitch			
Subject group	S	D	*M*	S	D	*M*	FA
Amnesic patients	.383 (.045)	.466 (.128)	.425 (.087)	.466 (.128)	.416 (.078)	.441 (.103)	.338
Control subjects	.733 (.481)	.725 (.473)	.729 (.477)	.358 (.106)	.292 (.040)	.325 (.073)	.252
M	.558 (.263)	.596 (.301)	.577 (.282)	.412 (.117)	.354 (.059)	.383 (.088)	.295

Note. S = same voice; D = different voice; FA = false alarms. Values in parentheses are corrected recognition scores computed by subtracting the proportion of false alarms from the proportion of hits in a particular condition.

Table 2 indicates that there were trends for voice-change effects on recognition performance, particularly following the pitch-encoding task, in both subject groups. However, the main effect of speaker's voice was not significant, $F < 1$, and speaker's voice did not enter into any significant interactions, all Fs < 1.

We also examined the overall hit and false alarm rates separately for the two subgroups of amnesic patients and their corresponding control groups. Korsakoff's patients achieved a hit rate of .493 and a false alarm rate of .424, yielding a corrected recognition score of .069; the corresponding numbers for alcoholic control subjects were .492 (hit rate), .250 (false alarm rate), and .242 (corrected recognition). Non-Korsakoff's amnesic patients achieved a hit rate of .403 and a false alarm rate of .257, yielding a corrected recognition score of .176; the corresponding numbers for nonalcoholic control subjects were .567 (hit rate), .250 (false alarm rate), and .317 (corrected recognition). These analyses indicate that both amnesic subgroups exhibited impaired overall recognition performance with respect to their appropriate control groups. They also indicate that the Korsakoff's patients were the source of the elevated false alarm rate in the overall data; the false alarm rate in non-Korsakoff's amnesics was nearly identical to that of their control subjects. The two amnesic subgroups exhibited similar levels of recognition performance following the category and pitch study tasks, and both subgroups of control subjects exhibited much higher levels of recognition memory following the category task than following the pitch-encoding task.

To examine the relation between recognition memory and priming more directly, using the overall data from amnesic patients and control subjects, we performed an ANOVA that included type of test as a within-subjects variable. The dependent measures were priming scores and corrected recognition scores. The ANOVA revealed a significant Subject Group × Type of Test interaction, $F(1, 34) = 8.80$, $MS_e = 0.048$, $p < .01$, confirming that amnesic patients showed normal priming together with impaired recognition memory. In addition, there was a significant Subject Group × Encoding Task × Type of Test interaction, $F(1, 34) = 18.28$, $MS_e = 0.038$, $p < .0001$. The interaction indicates that on the identification test, amnesics and control subjects exhibited similar levels of priming following the two encoding tasks, whereas on the recognition test, control subjects but not amnesics showed higher levels of performance following the category-encoding task than the pitch-encoding task.

DISCUSSION

Previous reports of spared perceptual priming in amnesic patients have been based on visual implicit memory tests. In conformity with predictions made by the PRS framework, the results of the present experiment indicate that (a) intact perceptual priming in amnesia extends to the domain of auditory implicit memory, (b) amnesic patients, like control subjects, show comparable levels of priming after semantic and nonsemantic study tasks, and (c) amnesics exhibit normal transfer of priming across voice change. Moreover, both the Korsakoff's and the non-Korsakoff's subgroups exhibited normal priming. Thus, it seems safe to conclude that implicit memory for the kind of auditory information that is tapped by the identification-in-noise task is spared in amnesic patients.

Our data also shed light on previous observations of impaired auditory priming by amnesic patients in the homophone-spelling paradigm (Cermak et al., 1986; Gabrieli et al., 1989). The fact that amnesic patients exhibited fully intact priming in our paradigm indicates that the earlier results do not reflect a general auditory-priming deficit in amnesia. By our account, these findings are likely attributable to the fact that homophone-biasing effects depend on memory processes outside of the PRS.

Our data replicate and extend our (Schacter & Church, 1992) finding that priming of auditory identification performance is robust following a nonsemantic study task that yields low levels of explicit memory. Although there were nonsignificant trends for more priming following the category task than the pitch task, this observation is not entirely surprising. We observed similar trends in two experiments that used the pitch-encoding task, leading us to suggest that the pitch task may not always induce subjects to attend adequately to the target word itself (see Schacter & Church, 1992, Experiments 3–5, for relevant data). Most important, our data indicate that the pattern of amnesics' performance as a function of the study task manipulation is indistinguishable from that of control subjects. Taken together, the general pattern of results from the present study, from our earlier experiments (Schacter & Church, 1992) with college students, and from our (Schacter, McGlynn, et al., 1993) demonstration of normal auditory priming in a word-meaning-deafness patient supports the idea that priming on the identification-in-noise test depends largely, if not entirely, on a presemantic auditory PRS.

Whereas the study task manipulation had similar effects on priming in amnesic patients and control subjects, it had markedly different effects on the recognition memory performance of the two groups: Control subjects showed the expected depth-of-processing effect, but amnesic patients did not. This outcome is consistent with previous findings from other explicit memory tests (e.g., Cermak & Reale, 1978; Graf et al., 1984). Interestingly, the pitch-encoding task reduced the recognition performance of control subjects to the level of amnesic patients. This observation highlights that nonsemantic encoding tasks can be powerful tools for producing amnesic patterns of performance in normal subjects (cf. Graf et al., 1982). In addition, it renders even more impressive our finding that the pitch-encoding task produced levels of priming that were statistically indistinguishable from levels in the category-encoding task, in both amnesics and control subjects. More generally, these findings provide strong evidence that priming effects observed previously on the identification-in-noise test in college students (Jackson & Morton, 1984; Schacter & Church, 1992) depend on implicit and not explicit memory processes.

Amnesic patients also exhibited normal transfer of priming across a study-to-test change of speaker's voice: Priming scores of patients and control subjects were nearly identical in same- and different-voice conditions following both the category- and the pitch-encoding tasks. This finding replicates and extends our previous observations with college students (Schacter & Church, 1992). It also provides clues concerning the nature of the auditory information that supports amnesics' preserved priming on the identification-in-noise task. Priming in this paradigm apparently does not depend on acoustic information about specific aspects of speaker's voice, and is based instead on more abstract auditory word form information. In studies of college students, we have found that when we use auditory implicit tests that do not involve white noise, such as stem completion and identification of low-pass filtered words, priming is significantly higher in the same-voice condition than in the different-voice condition (Church & Schacter, in press; Schacter & Church, 1992). Indeed, we have found that auditory priming on these tests not only is sensitive to between-voice changes (e.g., male to female or female to male), but is also affected by study-to-test changes of intonation and fundamental frequency within a single voice (Church & Schacter, in press).

The foregoing findings indicate that auditory priming is composed of both a voice-specific component and a more abstract component that likely relies on phonological information. The present data indicate that the abstract component of auditory priming is preserved in amnesic patients. A critical task for future research will be to determine whether amnesic patients, like normal subjects, exhibit voice-specific priming on appropriate implicit tests. Examination of this issue will clarify the extent to which auditory priming is preserved in amnesic patients and should also provide important insights concerning the nature and locus of voice-specific priming effects.

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