Research Report

PRESERVED PRIMING OF NOVEL OBJECTS ACROSS SIZE TRANSFORMATION IN AMNESIC PATIENTS

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Abstract—*Previous research has indicated that amnesic patients can show normal priming of novel objects on a decision task in which subjects decide whether unfamiliar structures could or could not exist in the three-dimensional world. The present experiment reveals that amnesic patients exhibit normal priming on this task across a study-to-test size transformation despite impaired explicit memory. These results suggest that priming of novel objects in amnesia depends on a spared structural description system that computes size-invariant representations of visual objects.*

The amnesic syndrome is produced by various kinds of neurological insults to critical structures in the limbic system, such as the hippocampus and diencephalon (Squire, 1992; Weiskrantz, 1985). The hallmark of the syndrome is a profound inability to explicitly remember recent events and new information. However, numerous studies have demonstrated that amnesic patients can show normal *implicit memory* for recently encountered information on tests that do not require explicit recollection of previous experiences (for recent reviews, see Schacter, Chiu, & Ochsner, 1993; Squire, 1992). The most extensively studied type of implicit memory in amnesic patients is known as repetition or direct *priming*: facilitated identification of, or judgment about, words or objects from reduced perceptual cues as a consequence of a prior exposure to them (Tulving & Schacter, 1990). Amnesic patients have exhibited intact priming on a wide variety of implicit memory tests (for reviews, see Bowers & Schacter, in press; Shimamura, 1986).

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We recently extended the finding of preserved priming in amnesic patients to the domain of novel three-dimensional objects (Schacter, Cooper, Tharan, & Rubens, 1991). Amnesic patients and control subjects studied a series of line drawings depicting unfamiliar three-dimensional structures (Fig. 1); half of the drawings represented structurally possible objects that could exist in the real world, and half represented structurally impossible objects that contained structural ambiguities and inconsistencies that would prohibit them from existing in three-dimensional form. Implicit memory was assessed with an object decision test in which studied and nonstudied objects were flashed briefly, and subjects decided whether each object was possible or impossible; priming would be indicated if object decisions were more accurate for studied objects than for nonstudied objects. In previous research with college students, we had found priming for possible objects but not for impossible objects (Schacter, Cooper, Delaney, Peterson, & Tharan, 1991). Amnesic patients exhibited an identical pattern of results: They showed normal priming for possible objects and no priming for impossible objects. However, amnesics' explicit memory for the objects was impaired (Schacter, Cooper, Tharan, & Rubens, 1991).

These results have potentially important theoretical implications. First, they contribute to a growing body of evidence indicating that amnesic patients can exhibit priming for novel information that does not have a preexisting, unitized representation in memory. Although most studies of priming in amnesia have used materials that have preexisting memory representations (e.g., familiar words or objects), recent evidence indicates intact priming of nonwords (Haist, Musen, & Squire, 1991) and unfamiliar two-dimensional patterns (Gabrieli, Milberg, Keane, & Corkin, 1990; Musen & Squire, 1992). Taken together with our results on novel three-dimensional objects, these data indicate that theoretical accounts of priming in amnesic patients cannot appeal solely to the spared activation of preexisting memory representations.

Second, our findings support the hypothesis that object decision priming depends on a *structural description system* that computes representations of the global form and structure of visual objects and can function independently of the episodic memory system that underlies explicit recollection (Schacter, Cooper, Tharan, & Rubens, 1991). We have suggested that the structural description system can be viewed as a subsystem of a more general perceptual representation system (Schacter, 1990, 1992a, 1992b; Tulving & Schacter, 1990) and is based in posterior cortical regions that are typically spared by the lesions that produce amnesia. Accordingly, object decision priming should be intact in amnesic patients.

If priming of novel objects in amnesic patients does indeed depend on a spared structural description system, then it should exhibit properties that characterize the operation of this subsystem. One important property of object decision priming is size invariance: The magnitude of the priming effect is similar whether the retinal size of objects is changed or remains constant between study and test, even though recognition memory is impaired by study-to-test size change (Cooper, Schacter, Ballesteros, & Moore, 1992). This finding is theoretically important because independent lines of evidence indicate that regions of inferior temporal cortex are involved in size-invariant object representation, thus suggesting that these or neighboring cortical regions subserve object decision priming (Cooper et al., 1992; Schacter, 1992b; Schacter, Cooper, Tharan, & Rubens, 1991). Cave and Squire (1992) found that amnesic patients show priming of familiar objects on a picture-

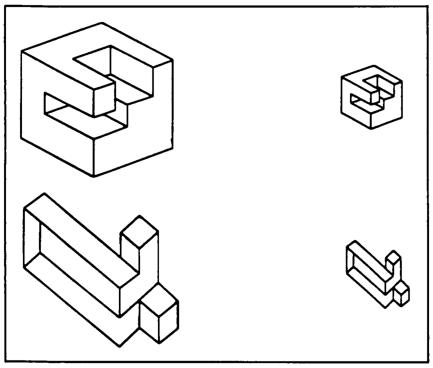

Fig. 1. Examples of target objects used in the experiment. The upper row depicts a possible object in large and small size, and the lower row depicts an impossible object in large and small size. See the text for further explanation.

naming task across size transformation, but no comparable data exist concerning novel objects or implicit tasks that do not require a naming response.

In the present experiment, we tested the structural description system hypothesis by investigating whether amnesic patients showed normal priming of novel objects across a study-to-test size transformation. If normal priming were observed, then we would have empirical support for the hypothesis that object decision priming in amnesics depends on a system that computes size-invariant object representations; if impaired priming were observed, we would have evidence against this hypothesis. In light of our previous finding that amnesic patients exhibit normal priming in a same-size condition, the latter outcome would suggest that amnesics rely on a less abstract and more "literal" visual representation than do control subjects.

METHOD

Subjects

Twelve amnesic patients and 12 control subjects participated in the experiment. The amnesic patients had all been screened at the Memory Disorders Research Center of the Boston Veterans Administration Hospital. 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). Because the experimental data revealed no notable performance differences between the alcoholic and nonalcoholic amnesics, we treat them as a single group. 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 well within the normal range: Mean full-scale IQ on the Wechsler Adult Intelligence Scale-Revised (WAIS-R) was 97.9, mean verbal IQ was 98.5, and mean performance IQ was 97.7 (Table 1). By contrast, the amnesic patients exhibited substantial memory impairments on the Wechsler Memory Scale-Revised (WMS-R): Mean score on the composite General Memory Index was 68.2, and mean score on the Delayed Memory Index was 57.7 (a score of 100 indicates normal performance). The amnesics did, however, exhibit normal attentional capacities, as indicated by a mean score of 103.7 on the WMS-R Attention Index. The large split between amnesic patients' scores on the Attention Index and Delayed Memory Index confirms the presence of severe memory disorder. Details on individual patients are presented in Table 1.

Twelve control subjects who were matched to the amnesics for age and years of education also participated in the experiment. Six of the control subjects had a history of alcoholism, and the other 6 had no history of alcoholism. The control subjects' mean age was 50.6 years, they had on average 12.9 years of education, and their mean verbal IQ on the WAIS-R was 111.4.

Materials, Design, and Procedure

The target materials consisted of 40 novel objects, 20 possible and 20 impossible, that had been used and described previously (Schacter, Cooper, Delaney, et al., 1991). Following Cooper et al. (1992), a large size and a small size, differing by a 2.5:1 ratio, were selected for each object. The large size subtended 19.2° of visual angle when viewed from approximately 50 cm, and the small size subtended 7.7° of visual angle when viewed from 50 cm. Within the large and small categories, all objects were normalized for size by scaling them to fit in a circular reference frame developed in a previous study (Schacter, Cooper, Delaney, et al., 1991); the visual angles

Table 1. *Characteristics of the amnesic patients*

			WAIS-R		WMS-R		
Etiology	Sex	Age	VIQ	PIQ	GM	ATN	DLY
Korsakoff	M	64	93	95	76	109	62
Korsakoff	M	57	87	98	84	93	65
Korsakoff	M	65	95	88	53	90	50
Korsakoff	M	49	96	84	65	83	51
Korsakoff	M	72	91	103	62	115	55
Korsakoff	M	70	119	106	85	110	62
Encephalitis	F	41	111	109	81	107	69
Encephalitis	M	64	126	126	102	114	<50
Anoxia	M	28	87	105	62	118	<50
Anoxia	F	33	104	95	78	121	<50
Thalamic	M	50	84	86	79	89	76
Posterior artery	F	42	89	77	70	95	52
Mean		52.9	98.5	97.7	68.2	103.7	57.7

Note. IQ scores are presented separately for the verbal (VIQ) and performance (PIQ) sections of the Wechsler Adult Intelligence Scale-Revised (WAIS-R). WMS-R is the Wechsler Memory Scale-Revised; scores are presented separately for the indices of general memory (GM), attention (ATN), and delay (DLY). The WMS-R does not provide scores below 50, and 50 was the lowest score used for computing means. In the normal population, each WMS-R index and the WAIS-R produce a mean of 100 and a standard deviation of 15.

noted above refer to the diameter of this reference frame.

The experiment was designed so that all subjects studied possible and impossible objects in the large size and were tested on them in the small size. We did not include a same-size condition because (a) previous research had established that amnesic patients show intact priming when object size is the same at study and test, (b) normal subjects' performance is indistinguishable in same- and different-size conditions (Cooper et al., 1992), and (c) we faced strict limitations on the available number of appropriate objects and amnesic patients, and could not tolerate the reductions in the number of observations per cell that would have been necessitated by inclusion of a same-size condition. We used only the large-to-small condition because our previous research had failed to uncover any differences between large-to-small and small-to-large conditions.

The experiment conformed to a 2 (amnesics vs. controls) × 2 (object decision vs. recognition test) × 2 (studied vs. nonstudied objects) × 2 (possible vs. impossible objects) mixed design; except for subject group, all variables were manipulated within subjects. Target objects were divided into two sets, A and B, which appeared equally often across subjects as studied or nonstudied items. Twenty objects (10 possible and 10 impossible) appeared on the study list. These same 20 objects also appeared on the object decision and recognition tests (in the small size), intermixed randomly with 20 nonstudied objects (10 possible and 10 impossible).

All objects were shown on the screen of a Macintosh IIsi computer. Subjects were seated about 50 cm from the screen. The appearance of each object was preceded by a fixation point (a cross) in the middle of the screen. For the study task, subjects were given a 5-s exposure to each drawing; they were instructed to inspect the object carefully in order to decide whether it faced primarily to the left or to the right. This task has produced significant priming in previous research with amnesic and normal subjects. The 20 target objects were preceded by two buffer objects that were not tested subsequently. Subjects responded verbally with either "left" or "right" responses.

The object decision test was given after a 2-min delay during which task instructions were administered. The experimenter explained the nature of and differences between possible and impossible objects and provided examples of both (for more details on instructions, see Schacter, Cooper, Delaney, et al., 1991). The experimenter also emphasized that objects would be flashed on the screen quite briefly, and that it was important for subjects to attend to the fixation point that would immediately precede each object. The object decision test was then initiated, beginning with the presentation of 10 practice items (5 possible and 5 impossible), and followed by the presentation of 20 studied and 20 nonstudied objects in random order. All objects were displayed for 100 ms, followed by a darkened screen. Subjects made their possible/impossible responses verbally.

The yes/no recognition test was given immediately after the object decision test. Subjects were instructed that they would view another series of drawings, and that some had been shown previously during the left/right study task while others had not. In addition, subjects were told that all of the objects had been flashed briefly on the previous object decision test. They were told to respond "yes" only if they remembered seeing an object during the left/right task and "no" if they did not remember seeing the object during the study task. Instructions emphasized that recognition responses should be based solely on the shape of the object and that size was irrelevant. Each object remained on the screen until the subject provided a verbal response.

RESULTS

The data from the object decision and recognition tests are presented in Table 2. The general pattern of results is clear. On the object decision test, both amnesic patients and control subjects showed higher levels of performance for studied than for nonstudied possible objects; the magnitude of the priming effect, though relatively small, was virtually identical in the two groups. Consistent with this description, an analysis of variance (ANOVA) performed on the data for possible objects revealed a marginally significant main effect of item type (studied vs. nonstudied), $F(1, 22) = 4.08$, $MS_e = .015$, $p = .056$, together with a negligible effect of subject group, $F(1, 22) < 1$, and a nonsignificant Subject Group × Item Type interaction, $F(1, 22) < 1$. For impossible objects, there was no evidence of priming in either amnesics or control subjects ($Fs < 1$). Note that baseline levels of performance for possible objects were about the same for both groups of subjects, thus allowing straightforward comparisons of the priming results. The amnesics performed somewhat less accurately than did the control subjects for studied and nonstudied impossible objects. However, the ANOVA performed on the data for impossible objects revealed no overall effect of subject group, $F(1, 22) < 1$, and a

Table 2. *Object decision and recognition data for amnesic patients and control subjects*

	Object decision task				Recognition task			
	Possible objects		Impossible objects		Possible objects		Impossible objects	
Group	ST	NS	ST	NS	ST	NS	ST	NS
Amnesics	.783	.717	.642	.633	.550	.383	.350	.250
Controls	.800	.725	.725	.700	.750	.392	.467	.208
Mean	.792	.721	.684	.667	.650	.388	.409	.229

Note. ST = studied objects; NS = nonstudied objects. For the object decision task, cell entries indicate the proportion of correct responses to studied and nonstudied objects; for the recognition task, cell entries indicate the proportion of "yes" responses to studied objects (i.e., hits) and nonstudied objects (i.e., false alarms).

combined ANOVA performed on the data for both the possible and impossible objects revealed a nonsignificant Subject Group × Object Type interaction, $F(1, 22) < 1$.

A different pattern of results was observed on the recognition test: Control subjects showed considerably higher levels of accuracy than did amnesic patients for both possible and impossible objects, as indicated by higher hit rates and similar false alarm rates. We analyzed corrected recognition scores that were computed by subtracting false alarm rates from hit rates. Control subjects' recognition scores were significantly higher than those of amnesic patients for both possible objects, $t(22) = 2.47$, $p < .05$, and impossible objects, $t(22) = 2.69$, $p < .05$.

To analyze the relation between object decision and recognition performance more directly, we performed a combined analysis in which the dependent measures were priming scores (computed by subtracting the proportion of correct object decisions for nonstudied items from the proportion of correct object decisions for studied items) and corrected recognition scores. The analysis revealed significant main effects of type of test, $F(1, 22) = 17.76$, $MS_e = .038$, $p < .01$, indicating that recognition performance was more influenced by study list exposure than was object decision performance; object type, $F(1, 22) = 4.42$, $MS_e = .032$, $p < .05$, indicating more priming and higher recognition performance for possible than for impossible objects; and subject group, $F(1, 22) = 7.27$, $MS_e = .034$, $p < .05$, indicating that control subjects showed higher overall levels of memory performance than did amnesics. Most important, however, was the significant Subject Group × Type of Test interaction, $F(1, 22) = 5.01$, $MS_e = .038$, $p < .05$, confirming that amnesics showed normal priming and impaired recognition memory.

DISCUSSION

The critical finding of the present experiment is that amnesic patients exhibit intact object decision priming across a size transformation. In addition to confirming previous findings (Schacter, Cooper, Tharan, & Rubens, 1991) that amnesic patients can show normal priming of novel three-dimensional objects despite impaired explicit memory, this study represents one of the few attempts to explore analytically the nature of the preserved system that supports priming in amnesic patients (Cave & Squire, 1992; Tulving, Hayman, & Macdonald, 1991). Our findings suggest that object decision priming in amnesic patients is based on relatively abstract, size-invariant representations of novel objects, representations that are established as a consequence of structural encoding operations performed during the study task.

One potential difficulty with our results is that the overall magnitude of the priming effect for possible objects was rather modest. This outcome is likely attributable to the fact that both amnesics and control subjects exhibited relatively high levels of baseline performance (over 70% correct for possible objects). In studies with college students, we have found that when baseline performance exceeds 70% correct, priming effects are relatively small and quite similar to those observed in the present study. It would be desirable to determine in future studies whether amnesics show size-invariant priming when baseline levels of performance are lower and larger priming effects can be observed. The critical point for our purposes, however, is that amnesic patients performed similarly to the control subjects on the object decision test despite exhibiting significant impairment on the recognition test.

Our findings confirm and extend previous reports of priming across size transformation with both novel objects (Cooper et al., 1992) and familiar objects (Biederman & Cooper, 1992; Cave & Squire, 1992). In our earlier experiment with college students (Cooper et al., 1992), priming effects on the object decision test were virtually indistinguishable in same- and different-size conditions. In the present study, we included only a different-size condition for pragmatic reasons noted earlier: We had limited numbers of patients and objects available for the experiment and could not tolerate the reductions in the number of observations per cell that would have been necessary had we included a same-size condition. However, because our previous research revealed size-invariant priming with college students, and normal priming in the same-size condition with amnesic patients, we reasoned that the same-size condition was not essential for the present experiment.

Despite the foregoing caveats, our data are generally consistent with, and provide support for, the hypothesis that priming on the object decision task depends on a structural description system that computes size-invariant representations of global shape and is based in posterior cortical regions. Because amnesic patients have generally not suffered damage to posterior cortex, the structural description system should be spared in such patients and support normal levels of object decision priming across size transformation. Explicit memory, however, depends on limbic structures that are damaged in amnesic patients, and that are necessary for gaining access to the kinds of contextual and semantic information that support conscious recollection.

Recent experiments with normal subjects have shown that object decision priming can be eliminated by a study-to-test transformation of picture plane orientation (Cooper, Schacter, & Moore, 1991). These findings suggest that the representation that supports priming includes a description of the relation between parts of an object and its central axis or reference frame. An important task for future research will be to determine whether amnesic patients, too, form axis- or reference frame-based representations that code information about an object's orientation.

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