Journal of Experimental Psychology:
Learning, Memory, and Cognition
1993, Vol. 19, No. 5, 995–1009

0278-7393/93/$3.00

Implicit and Explicit Memory for Novel Visual Objects: Structure and Function

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Six experiments compared the effects of structural and functional encoding tasks on implicit and explicit memory for novel objects. Implicit memory was assessed with a possible–impossible object decision test, and explicit memory was assessed with a yes–no recognition test. Results revealed that recognition memory was higher after functional than after structural encoding tasks, whereas priming effects on the object decision test were unaffected by the same manipulations. The priming effects that were observed after functional encoding tasks could be attributed to structural analyses that are carried out in the course of making judgments about functional properties of novel objects. Results are consistent with the hypothesis that implicit memory for novel objects depends on a presemantic structural description system that can operate independently of episodic memory.

The investigation of implicit memory has become a major focus of cognitive and neuropsychological research. Numerous experimental dissociations have been produced between implicit and explicit memory, and a variety of theoretical proposals have been put forward to account for them (for reviews, see Richardson-Klavehn & Bjork, 1988; Roediger, 1990; Roediger & McDermott, in press; Schacter, 1987; Schacter, Chiu, & Ochsner, 1993). The great majority of relevant studies have investigated implicit memory for materials that are verbal or that can be verbalized—words, word pairs, pseudowords, and nameable pictures of familiar objects—by examining repetition priming effects on such tests as fragment completion, stem completion, and perceptual identification. Accordingly, theoretical discussions of priming effects on implicit memory tests have often been inextricably intertwined with ideas about the nature of lexical processes and representations (cf. Carr, Brown, & Charalambous, 1989; Kirsner, Dunn, & Standen, 1989; Morton, 1979).

A number of recent studies have extended implicit memory research beyond the bounds of verbal materials and lexical processes by examining priming of novel nonverbal information. For example, Musen and Treisman (1990) showed subjects a list of novel dot patterns and observed substantial priming effects on a subsequent task that involved copying briefly exposed studied and nonstudied patterns. The priming effect persisted over a 1-week delay and exhibited stochastic independence from explicit memory. Musen (1991) found that priming in this paradigm was little affected by semantic versus nonsemantic study task manipulations that had large effects on explicit memory, and Musen and Squire (1991) observed that priming of novel dot patterns was robust in patients with amnesia. Gabrieli, Milberg, Keane, and Corkin (1990) found normal priming of similar dot patterns on a pattern completion task in H. M., a patient with severe amnesia.

We have investigated priming of novel nonverbal information in a series of experiments in which subjects were initially shown a study list consisting of two-dimensional drawings that depict novel, three-dimensional objects (Figure 1). Half of the drawings represent structurally possible objects that could exist in three dimensions, whereas the other half represent structurally impossible objects that contain surface and edge violations that would prohibit them from actually existing in three dimensions. Priming effects are investigated with an object decision task in which studied and nonstudied drawings are flashed briefly (e.g., 50 ms) and subjects judge whether the object is possible or impossible (for a different type of object decision priming paradigm, see Kroll & Potter, 1984).

Experiments to date have documented that significant priming effects are observed in this paradigm—that is, subjects' object decision performance is more accurate for studied drawings than for nonstudied drawings—and have revealed several important properties of the phenomenon (for a review, see Cooper & Schacter, 1992). First, whereas priming is observed reliably for possible objects, consistent priming is not observed for structurally impossible objects, even when subjects are given several study-list exposures to them (Schacter, Cooper, & Delaney, 1990; Schacter, Cooper, Delaney, Peterson, & Tharan, 1991). Second, priming of possible objects appears to depend on encoding global shape information, but the magnitude of the priming effect is not enlarged by semantic encoding manipulations and increasing numbers of study-list repetitions that greatly enhance explicit memory (Schacter et al., 1990; Schacter, Cooper, Delaney, Peterson, & Tharan, 1991). Third, study-to-test changes of object size and reflection have virtually no effects on priming despite producing significant decrements in explicit memory (Cooper, Schacter, Ballesteros, & Moore, 1992), whereas

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This research was supported by Air Force Office of Scientific Research Grant 90-0187 and National Institute of Mental Health Grant RO1 MH45398-01A3. We thank Dana Osowiecki and Mindy Tharan for help with various aspects of the research.

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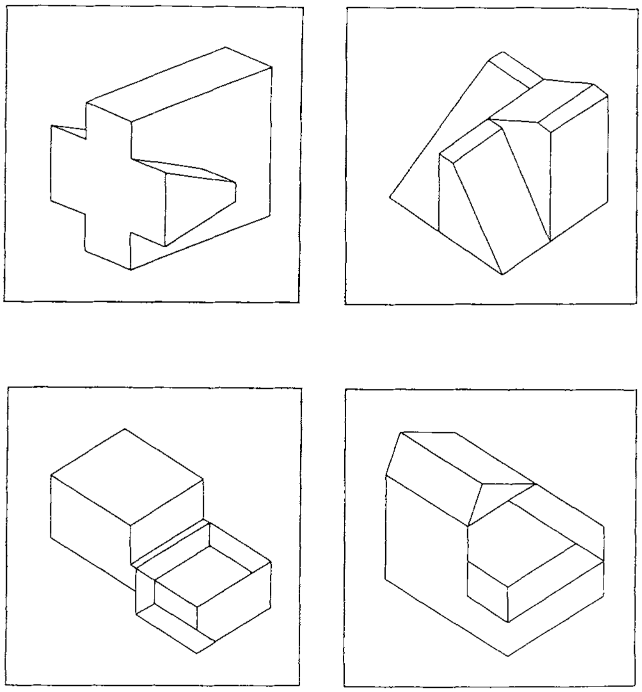

Figure 1. Sample of drawings used in the experiments. (The drawings in the upper row depict possible objects that could exist in three-dimensional form. The drawings in the lower row depict impossible objects that contain structural violations that would prohibit them from actually existing in three-dimensional form.)

study-to-test changes of picture plane orientation eliminate priming and reduce explicit memory (Cooper, Schacter, & Moore, 1991). Fourth, object decision priming is spared in patients with amnesia (Schacter, Cooper, Tharan, & Rubens, 1991; Schacter, Cooper, & Treadwell, in press) and elderly adults (Schacter, Cooper, & Valdiserri, 1992) who exhibit significant deficits of explicit remembering.

On the basis of these observations, we have argued that priming on the object decision task is mediated to a large extent by a structural description system (Riddoch & Humphreys, 1987) that computes global, axis-based representations of the three-dimensional structure of objects independently of their functional and associative properties. The structural description system can be viewed as a subsystem of a presemantic perceptual representation system that plays an important role in various priming effects (see Schacter, 1990, 1992a, 1992b; Tulving & Schacter, 1990). We have suggested that the structural description system can function independently of the episodic or declarative memory system that supports explicit recollection (e.g., Cooper & Schacter, 1992; Schacter, Cooper, Tharan, & Rubens, 1991).

One important hypothesized property of the structural description system (and other perceptual representation systems) is that it operates at a presemantic level—that is, the system does not represent information about the name of an object, where it is likely to be found, what its functional properties are, and so forth. Consistent with this suggestion, we found that requiring subjects to encode novel objects by elaborating on them in relation to their semantic knowledge of real-world objects yielded lower levels of priming (and higher levels of explicit memory) than a structural encoding task (Schacter et al., 1990, Experiment 2), apparently because the semantic encoding task did not require processing of three-dimensional aspects of object structure. When we used a semantic elaboration task that required encoding of three-dimensional object structure, we found similar levels of priming after semantic and after structural encoding together with higher levels of explicit memory after the semantic task than after the structural task (Schacter et al., 1990, Experiment 3).

Independent evidence for the idea that the structural description system operates at a presemantic level has been provided by studies of patients with brain damage who exhibit dissociations between impaired processing of structural aspects of visual objects and impaired processing of their functional properties. For example, Warrington (1975) reported that patients with dementia and with severe visual object agnosia performed poorly on a task that requires recognition of functions that everyday objects typically perform. However, they performed relatively normally on a test that tapped knowledge of object structure by requiring patients to match objects presented in conventional and unconventional views. Warrington and Taylor (1978) compared performance on this matching-by-structure task with performance on an analogous matching-by-function task in which patients were required to indicate which two objects in a set perform the same functions. Patients with posterior left-hemisphere lesions performed normally on the structure-matching task and poorly on the function-matching task, whereas patients with posterior right-hemisphere lesions performed poorly on both tasks (see Warrington, 1982, for further discussion). Riddoch and Humphreys (1987) observed a similar pattern of results in a patient with a left parieto-occipital craniotomy: The patient exhibited relatively intact performance on tasks that tapped processing and knowledge of object structure together with impaired performance on a task that probed functional properties of objects.

The structure–function dissociations observed in these neuropsychological studies may indicate that the structural description system is spared in some patients with object-processing deficits and that knowledge of object function is represented outside the structural description system, perhaps in a semantic memory system that is impaired in these patients (cf. Riddoch & Humphreys, 1987; Warrington, 1982). These observations and ideas have direct implications for our account of priming on the possible–impossible object decision task. If such priming is mediated by a structural description system, and if knowledge of object function is represented outside this system, then it follows that encoding tasks that require subjects to think about functions of novel objects—that is, ways in which they might be used—should have little or no effect on priming. By contrast, explicit memory should be improved by functional encoding relative to structural encoding: Thinking about functional properties of objects requires more than mere processing of their structure and likely involves encoding them elaboratively with respect to semantic knowledge of how objects are used in the real world. Accordingly, we are led to predict that structural versus functional encoding tasks will produce a dissociation in the object decision paradigm that is analogous to the structure–function dissociation observed in neuropsychological studies. The main purpose of the present series of experiments is to test and explore this prediction.

Experiment 1

In the first experiment we examined the effects of structural and functional encoding tasks on the object decision test and an explicit memory test (yes–no recognition). For the structural encoding condition, subjects judged whether each object faced primarily to the left or to the right. We have used this task extensively in previous studies (e.g., Schacter et al., 1990), and it consistently produces reliable levels of object decision priming together with moderate levels of recognition. For the functional encoding task, we developed a similar, two-choice judgment that requires subjects to think about functions that each of the novel objects might perform. Specifically, subjects were asked to indicate whether a particular object could be best used as a tool, to perform such functions as cutting, pounding, or scooping, or for support, that is, for standing on, sitting on, or leaning against. Pilot work indicated that subjects judge that approximately 50% of our target objects would be best used as a tool and about 50% would be best used for support.

Consider first our expectations concerning the relative effects of the two encoding tasks on explicit recognition memory. Whereas the left–right task requires processing only of object structure, the tool–support task requires going beyond structural analysis. To make the tool–support judgment, one must activate preexisting semantic knowledge of how objects are used in the real world to perform the two types of functions, and one is also likely to imagine a novel object being used in a specific situation to perform one or both of the candidate functions. These elaborative activities should produce a highly distinctive episodic representation that leads to more accurate explicit memory than does the left–right encoding task.

For the object decision task, we need to consider several possibilities. A strong and perhaps extreme prediction from our position is that because the functional encoding task does not involve specific encoding of object structure—that is, subjects are not explicitly required to make a judgment about the structure of the object—and because object decision priming is held to depend on encoding a description of three-dimensional object structure, no priming will be observed after the functional encoding task. By this view, then, the two encoding tasks would produce opposite effects on implicit and explicit memory. However, it seems quite plausible to argue that subjects must encode some information about object structure to make their functional judgment. After all, the target objects are entirely unfamiliar to subjects, and the major basis that the subjects have for making a judgment about function concerns the extent to which the structure of the object would permit or afford (e.g., Gibson, 1977) a particular type of activity. Thus, a more moderate version of our view predicts that some priming should be observed following the tool–support task. Nevertheless, the key prediction is still for an interaction between encoding task and type of test: No more priming should be observed after functional than after structural encoding, whereas explicit memory should be significantly higher after the functional task than after the structural task. Evidence against our view would be provided if the functional encoding task produces more priming as well as higher levels of recognition performance.

Method

Subjects. Seventy-two University of Arizona undergraduates participated in the experiment in exchange for course credits or for a payment of $5.00.

Materials. The target materials consisted of 20 possible and 20 impossible objects previously used and described by Schacter, Cooper, Delaney, Peterson, and Tharan (1991). All objects were selected for inclusion in the set on the basis of a pilot study in which a group of judges was given unlimited time to classify them as possible or impossible. For each object in the set, 95% or greater agreement that the object was possible or impossible was achieved across judges, with mean interjudge agreements of 99% for both possible and impossible objects. Objects were drawn in a standard reference frame that equated size across objects. The objects subtended a mean visual angle of approximately 8° when viewed from 60 cm. To present the drawings at study and at test, we used a Compaq 386 Deskpro computer and a 12-in. (30.48-cm) Princeton Ultrasync Monitor.

Design and procedure. The main design was a 2 (encoding task: structural vs. functional) × 2 (type of test: object decision vs. recognition) × 2 (item type: studied vs. nonstudied) × 2 (object type: possible vs. impossible) mixed design in which the first two factors were manipulated between subjects and the latter two were manipulated within subjects. In addition, an object decision test was given after the recognition test. Possible and impossible objects were completely counterbalanced across conditions so that each object appeared equally often in each of the eight experimental conditions defined by the orthogonal combination of Encoding Task × Type of Test × Item Type. Subjects were assigned randomly to one of the four between-subjects conditions defined by the crossing of encoding task and type of test, which yielded a total of 18 subjects per condition.

All subjects were initially instructed that they would be shown a series of drawings on the computer screen and that they would be asked to make a particular type of judgment about them. Subjects in the structural encoding condition were instructed that their task was to judge whether each object appeared to be facing primarily to the left or primarily to the right. They were told to pay careful attention to each object and to use all of the allotted time before making their left–right judgment. The study list was then presented at a rate of 5 s per item; the 20 target drawings (10 possible and 10 impossible) were preceded by five buffer items. Subjects in the functional encoding condition were told that their task was to judge whether they thought that they could best use a particular object as a tool, to perform such functions as scooping, cutting, or pounding, or whether they could best use the object for support, such as by stepping on it, sitting on it, or leaning on it. As in the structural task, subjects were told to pay careful attention to each object before making their judgment and to use all of the allotted time. Conditions of presentation were the same as for the left–right judgment.

After a delay of approximately 2–3 min during which test instructions were administered, half of the subjects in each encoding condition were given the object decision test and the other half were given a yes–no recognition test followed by an object decision test. Each test consisted of the 20 previously studied objects (10 possible and 10 impossible) intermixed randomly with 20 nonstudied objects (10 possible and 10 impossible). For the object decision test, subjects were told that they would be shown a series of briefly displayed drawings. They were informed that some of the drawings represented valid, possible three-dimensional objects that could exist in the real world, whereas other drawings represented impossible figures that could not exist as actual objects in the real world. It was explained that their task was to decide whether each object was possible or impossible. Several practice objects of each type were then shown to the subjects. The subjects were informed that all possible objects must have volume and be solid, that every plane on the drawing represented a surface on the object, that all surfaces could face in only one direction, and that every line on the drawing represented an edge on the object. The experimenter explained the impossibilities in sample objects and answered questions as needed. Subjects were also instructed to respond with a PC mouse that they controlled with their preferred hand; they were told to press the left key when they thought that the object was possible and the right key when they thought that the object was not possible. The object decision test then began with presentation of 10 practice items, 5 that had appeared as practice items at study and 5 that were new, followed by the 20 studied and 20 nonstudied critical drawings in a different random order for each subject. Each drawing was presented for 100 ms, preceded by a fixation point, and followed by a darkened screen.

For the recognition test, subjects were told that they would be shown a further series of drawings, some of which had just been exposed during the encoding task and some of which had not been exposed previously. Subjects were instructed to use the mouse and to press the left key if they remembered seeing the object during the encoding task and the right key if they did not remember seeing the object previously. As on the object decision task, 10 practice drawings (five old and five new) were presented prior to the 20 studied and 20 nonstudied critical drawings, and about 2 min elapsed between the end of the study list and the appearance of the first critical drawing. Objects remained on the computer screen for 6 s until subjects made their recognition response. For the object decision test that was administered after the recognition test, the same 20 studied and 20 nonstudied critical drawings were used.

After the conclusion of testing, all subjects were debriefed about the nature and purpose of the experiment.

Results

Because the objects that we used are not a random sample of a larger population, we carried out analyses of variance (ANOVAs) using both subjects and items as random factors. As we have observed previously (Schacter, Cooper, Delaney, Peterson, & Tharan, 1991), the same pattern of significant and nonsignificant results was observed in both types of analyses. Accordingly, in this and subsequent experiments we report only the results of the analyses that used subjects as a random factor.

Object decision. Table 1 presents the results for the object decision test as a function of encoding task and test order (i.e., object decision test given first or after the recognition test). These data indicate that for both test orders, a modest but consistent priming effect was observed for possible objects—object decision performance was .08–.10 higher for studied than for nonstudied objects—whereas there was essentially no evidence of priming for impossible objects. Most important, the priming effect was no greater after functional encoding than after structural encoding in either test order.

Analysis of variance revealed a significant main effect of item type (studied vs. nonstudied), $F(1, 140) = 11.22$, $p < .001$, $MS_e = .019$, which indicated that object decision performance was more accurate for studied items (collapsed across possible and impossible) than for nonstudied items. In addition, there was a significant effect of object type (possible vs. impossible), $F(1, 140) = 23.34$, $p < .001$, $MS_e = .039$, and, more important, a significant Item Type × Object Type interaction, $F(1, 140) = 19.90$, $p < .001$, $MS_e = .017$, which indicated that priming was observed for possible but not for impossible objects. The effects of encoding task and of test order did not approach significance, and neither of these variables entered into any significant interactions, all $Fs < 1.98$.

Recognition. The data from the recognition task, presented in terms of hits and false alarms (Table 2), contrast with the object decision results: Recognition accuracy was higher after the functional than after the structural encoding task. In addition, recognition memory was higher for possible than for impossible objects, which replicates a finding that

Table 1
Object Decision Performance (Mean Proportions Correct) in Experiment 1

	Type of study task–test order					
	Structural			Functional		
Type of object	First	Second	*M*	First	Second	*M*
Possible						
Studied	.78	.82	.80	.74	.77	.75
Nonstudied	.70	.73	.71	.64	.68	.66
Impossible						
Studied	.67	.65	.66	.60	.67	.63
Nonstudied	.65	.66	.66	.64	.67	.66
M						
Studied	.74	.73	.73	.67	.72	.69
Nonstudied	.68	.69	.69	.64	.68	.66

Note. Subjects in the structural condition were given 5 s to make a left–right judgment; subjects in the functional condition were given 5 s to make a tool–support judgment.

Table 2
Recognition Performance (Mean Proportions of Hits and False Alarms) in Experiment 1

	Type of study task		
Type of object	Structural	Functional	*M*
Possible			
Studied	.67	.81	.74
Nonstudied	.20	.17	.19
Impossible			
Studied	.65	.74	.70
Nonstudied	.29	.31	.30
M			
Studied	.66	.78	.72
Nonstudied	.25	.24	.25

Note. Studied = proportion of studied items called *old* (hit rate); nonstudied = proportion of nonstudied items called *old* (false-alarm rate). Subjects in the structural condition were given 5 s to make a left–right judgment; subjects in the functional condition were given 5 s to make a tool–support judgment.

we have reported and discussed in previous articles (see Schacter et al., 1990; Schacter, Cooper, Delaney, Peterson, & Tharan, 1991). Analysis of variance was performed on corrected recognition scores that were computed by subtracting false alarms from hits for each subject. The analysis revealed significant main effects of encoding task, $F(1, 70) = 9.07, p < .01, MS_e = .048$, and object type, $F(1, 70) = 27.07$, $p < .001$, $MS_e = .033$, together with a nonsignificant interaction between the two, $F(1, 70) = 2.59$, $p > .10$, $MS_e = .033$.

To examine the relation between recognition and object decision performance more directly, we performed additional ANOVAs in which corrected recognition scores were compared with priming scores that we computed by subtracting the proportion of correct object decisions for nonstudied items from the proportion of correct object decisions for studied items. In the first analysis, type of test was a between-subjects factor (i.e., recognition vs. object decision first). The key outcome was a significant Encoding Task × Type of Test interaction, $F(1, 140) = 5.03, p < .05, MS_e = .036$. In the second analysis, type of test was a within-subjects factor (i.e., recognition vs. object decision second). A significant Encoding Task × Type of Test interaction was again observed, $F(1, 70) = 6.61, p = .01, MS_e = .030$.

Discussion

The key outcome of Experiment 1 was that structural and functional encoding tasks produced nearly identical levels of priming despite higher recognition accuracy after functional than after structural encoding. For both structural and functional tasks, priming was observed for possible but not for impossible objects, and priming was unaffected by whether the object decision task was given before or after the recognition task. These data replicate previous observations with structural encoding tasks (Schacter et al., 1990) and indicate that the priming that is produced by functional encoding tasks exhibits similar properties.

The observed Encoding Task × Type of Test interaction follows from, and provides evidence for, our structural description system account of priming. The fact that some priming was observed following the functional encoding task is consistent with the idea noted earlier that subjects are likely to encode structural information about an object as a basis for making their functional judgment. The key point, however, is that by our view, functional encoding involves elaborative activities that go beyond encoding of object structure, that is, activities that support the higher levels of recognition performance observed after the functional task relative to after the structural task. Because such elaborative activities occur outside of the structural description system, priming should not be increased by them, as we have observed.

There are, however, two related empirical problems with Experiment 1 that raise questions about the extent to which the Encoding Task × Type of Test interaction provides support for our position. First, the levels of object decision performance for studied possible objects were rather high in several conditions, exceeding 80% correct. It is conceivable that some sort of effective ceiling on object decision performance was reached or approached in this experiment that thereby obscured potential encoding task effects that might have been revealed with lower overall levels of performance. Second, the magnitude of the priming effects in Experiment 1 was rather modest. For example, collapsed across possible and impossible objects, the priming effect (i.e., difference between studied and nonstudied objects) was only .04 for the left–right task and .03 for the tool–support task. Perhaps encoding task differences would be observed under conditions in which greater overall levels of priming are observed.

One straightforward solution to both of these problems is to lower the levels of baseline object decision performance. That is, if object decision accuracy for nonstudied items could be reduced, potential ceiling effects might be avoided and there would be more room for a larger priming effect to be observed. Pilot work indicated that this objective could be achieved by reducing the exposure time on the object decision test from 100 ms, which was used in Experiment 1, to 50 ms. Accordingly, we reduced the exposure duration to 50 ms and performed a partial replication of Experiment 1 in which subjects performed either the left–right or tool–support encoding task and were then given an object decision test followed by a recognition test.

Experiment 2

Method

Subjects. Thirty-two University of Arizona undergraduates participated in the experiment in exchange for course credits or for a payment of $5.00.

Design, materials, and procedure. Experiment 2 was identical to Experiment 1 except that the exposure duration for the object decision test was 50 ms instead of 100 ms and the recognition test was given after the object decision test. Thus, the basic design was a 2 (encoding task) × 2 (type of test) × 2 (object type) × 2 (item type) mixed design, with encoding task manipulated as a between-subjects variable and all other factors manipulated as within-subjects variables. We dropped the separate recognition group because in Experiment 1 we documented higher levels of recognition memory after the tool–support than after the left–right judgment with a between-subjects design. Thus, although giving the recognition test after the object decision test produces a technical confounding between type of test and test order, this does not create an interpretive problem as long as we observe a similar pattern of recognition results in Experiment 2 and Experiment 1 (i.e., if we assume that recognition is higher after the tool–support task than after the left–right task in Experiment 2, the data from Experiment 1 indicate that test order is not critical to obtaining this pattern of results). Indeed, previous research has indicated that there is a modest increase in the false-alarm rate when the recognition test follows the object decision test compared with when it is given alone but that the patterns of recognition performance are otherwise identical under the two conditions (Schacter, Cooper, Delaney, Peterson, & Tharan, 1991; Schacter et al., 1992).

Because the recognition test was given after the object decision test, subjects were told that half of the objects on the recognition test had been presented during the study task (either structural or functional) and half had not been presented during the study task but that all objects had been flashed briefly on the object decision test. Subjects were instructed to make a *yes* response only when they remembered seeing an object during the study task and to make a *no* response when they did not remember seeing the object during the study task.

Results

Object decision. The data in Table 3 indicate that reducing the exposure rate on the object decision test had the intended effect of lowering the level of baseline performance: Object decision accuracy for nonstudied items ranged from .53–.59, whereas it had ranged from .64–.73 in Experiment 1. Similarly, the overall magnitude of the priming effect was larger than in Experiment 1, and performance for studied objects did not approach the possibly near-ceiling levels observed in Experiment 1. Nevertheless, as in Experiment 1, we observed no evidence of greater priming after the tool–support task than after the left–right task. In fact, there was quantitatively more priming following the left–right task.

Analysis of variance revealed a significant main effect of item type, $F(1, 30) = 18.30, p < .001, MS_e = .022$, which indicated that overall object decision performance was more accurate for studied than for nonstudied items. We also observed the expected Item Type × Object Type interaction, $F(1, 30) = 4.99, p < .05, MS_e = .024$, which replicated previous findings of significant priming for possible objects but not for impossible objects. Although there was a trend for greater priming after structural than after functional encoding, the main effect of encoding task was not significant, $F(1, 30) = 1.65, p = .21, MS_e = .040$, and encoding task did not enter into any significant interactions, all $Fs < 1.10$.

Table 3
Object Decision Performance (Mean Proportions Correct) in Experiment 2

Type of object	Type of study task: Structural	Functional	*M*
Possible			
Studied	.73	.66	.70
Nonstudied	.55	.56	.56
Impossible			
Studied	.61	.55	.58
Nonstudied	.59	.53	.56
M			
Studied	.67	.61	.64
Nonstudied	.57	.55	.56

Note. Subjects in the structural condition were given 5 s to make a left–right judgment; subjects in the functional condition were given 5 s to make a tool–support judgment.

Table 4
Recognition Performance (Mean Proportions of Hits and False Alarms) in Experiment 2

Type of object	Type of study task: Structural	Functional	*M*
Possible			
Studied	.68	.76	.72
Nonstudied	.34	.33	.34
Impossible			
Studied	.46	.61	.54
Nonstudied	.29	.24	.27
M			
Studied	.57	.68	.63
Nonstudied	.32	.29	.31

Note. Studied = proportion of studied items called *old* (hit rate); nonstudied = proportion of nonstudied items called *old* (false-alarm rate). Subjects in the structural condition were given 5 s to make a left–right judgment; subjects in the functional condition were given 5 s to make a tool–support judgment.

Recognition. Table 4 presents the proportions of hits and false alarms on the yes–no recognition test. As in Experiment 1, recognition memory was higher in the tool–support than in the left–right condition. Analysis of variance revealed a significant main effect of encoding task, $F(1, 30) = 6.99, p = .013, MS_e = .047$. There was also a main effect of object type, $F(1, 30) = 4.89, p < .05, MS_e = .046$, which indicated more accurate recognition of possible than of impossible objects.

To compare object decision and recognition performance more directly, we performed a combined ANOVA on the priming scores (i.e., proportion correct for studied objects minus proportion correct for nonstudied objects) and corrected recognition scores (i.e., hits minus false alarms) with type of test as a between-subjects factor. Priming scores were larger after the left–right task than after the tool–support task, whereas corrected recognition scores showed the opposite pattern, as indicated by a significant Encoding Task × Type of Test interaction, $F(1, 30) = 8.60, p < .01, MS_e = .032$.

Discussion

The results of Experiment 2 provide a strong replication of all critical outcomes from Experiment 1 under conditions in which baseline object decision performance was lower: The overall magnitude of the priming effect was enhanced, and the possibility of ceiling effects' obscuring greater priming after functional than after structural encoding was eliminated. Indeed, under these conditions there was a trend for more priming after structural than after functional encoding, which thereby produced a crossover interaction with recognition performance, which exhibited the opposite pattern of effects. Taken together, then, the results of Experiments 1 and 2 provide clear support for our view that priming on the object decision test is mediated by a presemantic system and that the elaborative–semantic activities involved in the functional encoding task occur outside of this system and thereby enhance explicit but not implicit memory.

The fact that significant priming was observed following the tool–support encoding task is not surprising and is consistent with our theoretical viewpoint. As noted earlier, judgments about object function presumably must involve processing of object structure: Subjects have no prior knowledge of our objects and, hence, do not have a basis for making a tool–support judgment other than an analysis of the kinds of functions that the structure of a particular object permits. Thus, to the extent that making a judgment about function requires analysis of structure, it can be argued that the priming effects produced by the tool–support task are attributable to presemantic representations that are computed within the structural description system.

One question that arises from this analysis of Experiments 1 and 2 concerns the type of functional encoding task that will produce priming on the object decision task. Note that with the tool–support task, the putative function that an object might perform is directly constrained by its structure. That is, the structure of an object determines whether it could best be used as a tool or for support. One question that can be asked is whether such direct constraint between structure and function is necessary for a functional encoding task to produce significant object decision priming. By our view, priming is observed after a functional encoding task because making a functional judgment requires analysis of structure. That is, we assume that any judgment concerning a novel object's potential function must make some recourse to, and depend on, structural analysis. However, the exact relation or mapping between structure and function should not be important, because information about object function is represented outside the structural description system. We thus expect that significant priming will be observed after a functional encoding task both when structure directly constrains function and when structure does not directly constrain function, because the functional judgment is presumably based on an analysis of structure in both cases; the presence of a constraining structure-to-function mapping involves processes outside the structural description system and hence should not influence priming.

To explore this issue, we performed an experiment in which some subjects participated in a functional encoding task that involved a direct constraint between structure and function and other subjects performed a functional encoding task in which there was no direct constraint between structure and function. For the constrained encoding task, we required subjects to judge whether each object was better suited to store things inside of or to put things on top of. The general idea was that the structure of the object would provide a relatively direct constraint on which of the two functions it would best perform: Objects with relatively large, smooth surfaces would presumably be better used to put things on, whereas objects with numerous openings or discontinuous segments would be better used to store things inside of.

Generating an encoding task that does not involve direct constraint between structure and function is somewhat more difficult, because most potential functions for which an object could be used are constrained directly by their visual structure. However, one functional property of an object that is not directly constrained by its perceptible visual structure is the sound that an object makes. For example, the visual structure of a telephone does not constrain (for the perceiver) the kind of sound that the object makes in the same way that the visual structure of a telephone constrains other functions that it can perform (e.g., the fact that it can be used simultaneously for speaking and listening). We attempted to exploit this nonconstraining relation between perceptible visual structure and the functional property of sound by asking subjects to imagine whether they thought that each of our target objects would be more likely to make a loud, jolting noise (like a car horn, police siren, or fire alarm) or a soft, ringing sound (like a telephone, doctor's beeper, or microwave oven). The general idea was that subjects would base their judgments on some aspect of the object's structure but that the structure would not constrain the loud–soft sound judgment in the same way that it would constrain the store–put judgment. Thus, if priming depends on a direct constraint between structure and function, there should be robust priming effects on the object decision task after the store–put encoding task and little or no priming after the loud–soft encoding task. If, however, a direct constraint between structure and function is not crucial for priming—and according to our view it is not—then significant priming effects should be observed following both the store–put task and the loud–soft encoding task.

Experiment 3

Method

Subjects. Eighty University of Arizona undergraduates participated in the experiment either in exchange for course credits or for a payment of $5.00. They were assigned randomly to one of four groups.

Design, materials, and procedure. The experimental design conformed to a $2 \times 2 \times 2 \times 2$ mixed factorial, with encoding task (store–put vs. loud–soft) and type of test (object decision vs. recognition) manipulated as between-subjects variables and item type (studied vs. nonstudied) and object type (possible vs. impossible) manipulated as within-subjects variables. Twenty subjects were randomly assigned to each of the four groups that were formed by the orthogonal combination of encoding task and type of test.

Subjects in both encoding conditions were told that they would be shown a series of novel objects and that they would be required to use their imaginations to make a judgment about them. Subjects in the store–put encoding condition were instructed to judge whether each object would be better suited to store things inside of or to put things on top of. Subjects in the loud–soft condition were asked to imagine what kind of sound they thought the object might make—a loud, jolting noise like a car horn, a fire alarm, or a police siren or a soft, ringing sound like a telephone, a doctor's beeper, or a microwave oven. Objects remained on the screen for 5 s for both groups, and subjects were instructed to use the full 5 s to make their judgments.

After completion of the study task, object decision or recognition tests were administered in the manner described in Experiment 1 except that the exposure duration for the object decision test was 50 ms.

Results

Object decision. The data in Table 5 indicate that substantial priming of possible objects was observed in both encoding conditions, with a trend toward greater priming in the loud–soft condition than in the store–put condition. However, there were also trends for positive priming of impossible objects in the store–put condition and for negative priming of impossible objects in the loud–soft condition. Overall, the improvement of object decision accuracy as a consequence of study-list exposure to an object was similar in the two encoding conditions.

Analysis of variance revealed a significant main effect of item type, $F(1, 38) = 6.67$, $p < .02$, $MS_e = .027$, which showed that object decision performance was significantly more accurate for studied than for nonstudied objects. There was also a significant Item Type × Object Type interaction, $F(1, 38) = 9.28$, $p < .01$, $MS_e = .021$, which indicated that there was significant priming of possible but not of impossible objects. Neither the main effect of encoding task nor any interactions involving encoding task were significant, all Fs < 2.67.

Recognition. As indicated by the findings displayed in Table 6, there was some evidence for more accurate recognition in the loud–soft condition than in the store–put condition. However, an ANOVA that was performed on corrected recognition scores revealed that the effect of encoding task was not statistically significant, $F(1, 38) = 2.23$, $p = .14$, $MS_e = .047$. Possible objects were recognized more accurately than were impossible objects, as indicated by a significant main effect of encoding task, $F(1, 38) = 5.31$, $p < .03$, $MS_e = .021$. The Encoding Task × Object Type interaction was nonsignificant, $F < 1$.

Table 5
Object Decision Performance (Mean Proportions Correct) in Experiment 3

Type of object	Type of study task: Constrained	Unconstrained	*M*
Possible			
Studied	.74	.78	.76
Nonstudied	.63	.62	.63
Impossible			
Studied	.64	.60	.62
Nonstudied	.59	.65	.62
M			
Studied	.69	.69	.69
Nonstudied	.61	.63	.62

Note. Subjects in the constrained condition were given 5 s to make a store–put judgment; subjects in the unconstrained condition were given 5 s to make a loud–soft judgment.

Table 6
Recognition Performance (Mean Proportions of Hits and False Alarms) in Experiment 3

Type of object	Type of study task: Constrained	Unconstrained	*M*
Possible			
Studied	.71	.79	.75
Nonstudied	.17	.15	.16
Impossible			
Studied	.69	.67	.68
Nonstudied	.26	.27	.27
M			
Studied	.70	.73	.72
Nonstudied	.22	.21	.22

Note. Studied = proportion of studied items called *old* (hit rate); nonstudied = proportion of nonstudied items called *old* (false-alarm rate). Subjects in the constrained condition were given 5 s to make a store–put judgment; subjects in the unconstrained condition were given 5 s to make a loud–soft judgment.

Discussion

The main result of Experiment 3 is that priming occurred after both the store–put and the loud–soft functional encoding tasks. To the extent that the former task involves a direct constraint between object structure and function whereas the latter task does not, it appears that priming does not depend on the existence of a direct constraint between the structure and function of a novel object. This result is consistent with our structural description system hypothesis, which holds (a) that priming is observed following a functional encoding task because making a judgment about functions of a novel object necessarily involves an analysis of its structure and (b) that the exact relation between structure and function is unimportant because it involves mappings or processes outside of the structural description system.

It is possible, however, that the priming observed in the loud–soft condition is not attributable to structural analyses that are a necessary basis of functional judgments. Rather, priming may occur because subjects make the loud–soft judgment by relating the novel target objects to familiar objects from everyday life and by thinking about the sounds that those objects would make. Indeed, the loud–soft task instructions included examples of everyday objects to illustrate the kinds of sounds that subjects should be imagining; the inclusion of the examples may have encouraged subjects to perform the task by accessing their real-world knowledge of objects. If so, then the priming observed following the loud–soft task may be attributable to semantic rather than to structural encoding processes and hence may not bear directly on the question of whether presemantic object decision priming can occur without direct constraint between the structure and function of a novel object.

Although we cannot rule out the possibility that subjects performed the loud–soft task by calling on semantic knowledge of real-world objects, results from a previous experiment cast doubt on the viability of this idea. Specifically, Schacter et al., (1990) found that when subjects were given an encoding task that explicitly required them to think of an object from the real world that each target drawing reminded them of most, no priming was observed on a later object decision test. A subsequent experiment suggested that the absence of priming following this elaborative task was attributable to the failure of subjects in this condition to focus on three-dimensional aspects of object structure. Thus, if subjects in the loud–soft condition had indeed made their judgments by accessing their semantic knowledge of the sounds made by real-world objects, we would not have expected to observe robust priming, but we did.

To examine the issue more directly, in Experiment 4 we compared two variants of the loud–soft encoding task: an elaborative version in which subjects were specifically instructed to perform the task by thinking of sounds made by real-world objects of which the target drawings reminded them and a structural version in which subjects were instructed to make their judgments without reference to real-world objects by focusing on each drawing's visual–structural properties. If the priming effects from the loud–soft task in Experiment 3 are attributable to semantic encoding processes, then more priming should be observed in the elaborative condition than in the structural condition. If, however, our previous finding of little or no object decision priming from a semantic encoding task extends to the present paradigm, and if priming in the loud–soft condition is attributable to visual–structural analyses that are carried out in the course of making a loud–soft judgment, then the opposite pattern of results should be expected, that is, more priming in the structural condition than in the elaborative condition.

Experiment 4

Method

Subjects. Eighty University of Arizona undergraduates participated in the experiment either in exchange for course credits or for a payment of $5.00. They were assigned randomly to one of four groups.

Design, materials, and procedure. The basic design was a 2 × 2 × 2 × 2 mixed factorial, with encoding task and type of test as between-subjects factors and item type and object type as within-subjects factors. All aspects of design, materials, and procedure were identical to Experiment 3 except for the encoding task instructions. In the elaborative condition, subjects were told that they would be performing a task that involved using their imaginations to think about novel objects that they had never before seen. For each drawing they were told that they should try to imagine the kind of sound the object would make—either a loud, jolting noise like a car horn, a fire alarm, or a police siren or a soft, ringing sound like a telephone, a doctor's beeper, or a microwave oven. To help them perform the task, we told the subjects to think first of a familiar real-world object of which each drawing most reminded them and then to focus on imagining the kind of sound that the familiar object would make. In the nonelaborative condition, task instructions were the same except that subjects were told not to attempt to relate the objects on the screen to familiar objects from everyday life but instead to treat them as novel objects and to focus on imagining what kind of sound the object might make by paying careful attention to the object. Objects remained on the screen for 5 s in both encoding tasks.

After the conclusion of the task, half of the subjects in each encoding condition were given an object decision test, and the other half were given a recognition test in the manner described for Experiment 3.

Results

Object decision. Consider first the results from the nonelaborative encoding task, which are displayed in Table 7. The data indicate a large priming effect for possible objects, as well as a weaker trend for priming of impossible objects. Combined across object type, object decision accuracy was considerably higher for studied objects (.71) than for nonstudied objects (.60). In contrast, in the elaborative encoding condition there was only a modest trend for priming of possible objects, together with similar amounts of negative priming for impossible objects. Combined across object type, object decision accuracy was nearly identical for studied objects (.59) and nonstudied objects (.58) in the elaborative condition.

Analysis of variance confirmed this description of results by showing significant main effects of item type, $F(1, 38) = 8.64$, $p < .01$, $MS_e = .020$, which indicated that priming occurred, and object type, $F(1, 38) = 4.42$, $p < .05$, $MS_e = .039$, which indicated higher levels of performance for possible than for impossible objects. The Item Type × Object Type interaction was also significant, $F(1, 38) = 6.73$, $p < .02$, $MS_e = .014$. Most important, there was a significant interaction between encoding task and item type, $F(1, 38)$, $p < .03$, $MS_e = .020$, which confirmed that more priming occurred in the nonelaborative condition than in the elaborative condition. Indeed, a planned comparison revealed that, in the elaborative condition, overall object decision accuracy was not significantly higher for studied items than for nonstudied items ($t < 1$). Note that these results may be in part attributable to a trend for negative priming of impossible objects in the elaborative condition (Table 7). Focusing solely on the possible objects, we found that the priming

Table 7
Object Decision Performance (Mean Proportions Correct) in Experiment 4

Type of object	Type of study task: Nonelaborative	Elaborative	*M*
Possible			
Studied	.77	.65	.71
Nonstudied	.62	.57	.60
Impossible			
Studied	.65	.53	.59
Nonstudied	.57	.58	.58
M			
Studied	.71	.59	.65
Nonstudied	.60	.58	.59

Note. Subjects in the nonelaborative condition were given 5 s to make a loud–soft judgment; subjects in the elaborative condition were given 5 s to make a loud–soft judgment and were also instructed to base their judgments on knowledge of sounds made by a real-world object that each drawing resembled.

effect in the nonelaborative condition was statistically significant, $t(19) = 4.08$, $p < .001$, for studied (.77) versus nonstudied (.62) possible objects, whereas the priming effect in the elaborative condition was not statistically significant, $t(19) = 1.63$, $p > .10$, for studied (.65) versus nonstudied (.57) possible objects. However, a direct comparison of the priming scores (i.e., studied minus nonstudied objects) from the two conditions did not achieve statistical significance, $t(38) = 1.14$.

Recognition memory. Table 8 presents data from the recognition memory task. In contrast to the object decision task, recognition performance was numerically higher in the elaborative condition than in the nonelaborative condition. However, an ANOVA performed on the corrected recognition scores indicated that the main effect of encoding task did not achieve statistical significance, $F(1, 38) = 2.41$, $p = .129$, $MS_e = .047$. There was a significant effect of object type, $F(1, 38) = 21.22$, $p < .001$, $MS_e = .029$, and a nonsignificant Encoding Task × Object Type interaction, $F(1, 38) = 1.40$, $MS_e = .029$.

To examine the relation between object decision and recognition performance more directly, we performed a combined ANOVA in which priming scores and corrected recognition scores were the dependent measures. The critical outcome of the ANOVA was a significant Encoding Task × Type of Test interaction, $F(1, 76) = 7.21$, $p < .01$, $MS_e = .044$.

Discussion

Experiment 4 has provided evidence against the idea that priming in the loud–soft condition can be attributed to subjects' accessing semantic knowledge of the sounds made by familiar, real-world objects: When they were specifically instructed to do so, we failed to observe a significant priming effect. We assume that the low level of priming in the elaborative condition can be explained in the same manner as a previous, similar finding by Schacter et al. (1990): Subjects failed to carry out the extensive analyses of three-dimensional object structure that are necessary to support object decision priming and instead focused their attention on generating semantic attributes of familiar objects. This semantic elaboration did not produce significant priming of possible objects, nor did it increase overall object decision accuracy for studied objects compared with nonstudied objects; it yielded only a modest response bias to call previously studied possible and impossible objects *possible* more often than nonstudied objects. The fact that significant priming was observed when subjects were instructed to focus on the visual–structural properties of the objects and were told not to think of familiar objects provides further support for this interpretation.

Table 8
Recognition Performance (Mean Proportions of Hits and False Alarms) in Experiment 4

Type of object	Type of study task: Nonelaborative	Elaborative	*M*
Possible			
Studied	.79	.86	.83
Nonstudied	.21	.16	.19
Impossible			
Studied	.74	.77	.76
Nonstudied	.30	.30	.30
M			
Studied	.77	.82	.80
Nonstudied	.26	.23	.25

Note. Studied = proportion of studied items called *old* (hit rate); nonstudied = proportion of nonstudied items called *old* (false-alarm rate). Subjects in the nonelaborative condition were given 5 s to make a loud–soft judgment; subjects in the elaborative condition were given 5 s to make a loud–soft judgment and were also instructed to base their judgments on knowledge of sounds made by a real-world object that each drawing resembled.

Overall, then, these data support the idea that functional encoding tasks produce priming on the object decision test because making a judgment about the function of a novel object necessarily entails an analysis of its structure, whether the structure directly constrains function or not (unless task instructions interfere with appropriate structural analysis, as in the elaborative encoding condition). It is this analysis of object structure that supports priming after functional encoding tasks, and we assume that the priming occurs entirely within the structural description system.

Another way to obtain information that bears on this idea would be to examine the effects of combining structural and functional encoding tasks on object decision performance. If the object decision priming effects that are observed following structural and functional encoding tasks are based on different and perhaps independent sources of information, then we would expect priming to be larger when subjects perform both structural and functional encoding tasks with respect to the same object than when they perform a structural task twice or a functional task twice. Previous research has shown that multiple repetitions of a structural encoding task (left–right judgment) did not produce significantly more priming than did a single exposure, which suggests that repeating the same encoding task yields redundant information about object structure (Schacter, Cooper, Delaney, Peterson, & Tharan, 1991). The question is whether performing both structural and functional tasks would yield nonredundant information and hence increase the magnitude of priming.

To examine the issue, we used the left–right (structural) encoding task and the tool–support (functional) encoding task. One group of subjects made left–right judgments on each of two exposures to an object (structural condition), a second group made tool–support judgments on each of two exposures to the same objects (functional condition), and a third group made a left–right judgment on one exposure to an object and a tool–support judgment on a second exposure (structural–functional condition). If the left–right and tool–support tasks yielded distinct representations that supported object decision priming, then combining the two tasks should have produced more priming than repetition of either task. In contrast, we expected explicit memory performance to be highest in the group that performed the tool–support task twice, because these subjects would have had greater opportunity for elaborative encoding than would subjects in the other two groups.

Experiment 5

Method

Subjects. Forty-eight Harvard University undergraduates participated in the experiment in exchange for a payment of $5.00.

Design, materials, and procedure. A 3 × 2 × 2 × 2 mixed factorial design was used, with encoding task as the between-subjects variable and object type, item type, and type of test as within-subjects variables; items were completely counterbalanced across conditions. The basic design, materials, and procedure were identical to those of Experiment 2, with two exceptions. First, all three encoding groups were given two 5-s exposures to the target objects; they were shown the entire list once and were then exposed again to the same objects in a different random order. The first group of subjects was given left–right encoding instructions for both list exposures; a second group was given tool–support encoding instructions for both exposures; and a third group was given either left–right or tool–support encoding instructions prior to the first exposure and was then given instructions for the other task prior to the second exposure. In the third group, half of the subjects were given the left–right task first, and the other half were given the tool–support task first.

The second main change from Experiment 2 (and all other preceding experiments) is that drawings were presented on a Macintosh IIsi computer instead of a Compaq Deskpro. However, the drawings subtended the same degree of visual angle as did the drawings used in previous experiments, and the drawings were exposed for 50 ms, as in Experiments 2–4.

Results

Object decision. As indicated by the data shown in Table 9, there was substantial priming of possible objects in all three encoding conditions and no priming of impossible objects in any of them. However, the magnitude of the priming effect was not notably greater in the structural–functional group than in either of the other two groups. The structural–functional group and the functional group exhibited virtually identical levels of priming, and the structural group showed slightly less priming of possible objects and a weak trend for negative priming of impossible objects. An ANOVA revealed significant main effects of item type, $F(1, 45) = 20.07$, $p < .001$, $MS_e = .018$, and object type, $F(1, 45) = 23.10$, $p < .001$, $MS_e = .032$, as well as a significant Item Type × Object Type interaction, $F(1, 45) = 24.31$, $p < .001$, $MS_e = .022$. As in previous experiments, these results indicate that object decision performance overall was more accurate for studied than for nonstudied objects and that priming occurred for possible but not for impossible objects. However, the effect of encoding task was negligible, $F(2, 45) = 1.11$, $MS_e = .059$, and no interactions involving encoding task approached significance (all Fs < 1.45).

Table 9
Object Decision Performance (Mean Proportions Correct) in Experiment 5

	Type of study task			
Type of object	Structural	Functional	Structural–functional	*M*
Possible				
Studied	.81	.86	.88	.85
Nonstudied	.65	.65	.67	.66
Impossible				
Studied	.57	.69	.60	.62
Nonstudied	.62	.69	.61	.64
M				
Studied	.69	.77	.74	.73
Nonstudied	.64	.67	.64	.65

Note. Subjects in the structural condition were given 5 s to make each of two left–right judgments; subjects in the functional condition were given 5 s to make each of two tool–support judgments; subjects in the structural–functional condition were given 5 s to make a structural judgment and 5 s to make a functional judgment.

Table 10
Recognition Performance (Mean Proportions of Hits and False Alarms) in Experiment 5

	Type of study task			
Type of object	Structural	Functional	Structural–functional	*M*
Possible				
Studied	.83	.83	.81	.82
Nonstudied	.28	.16	.31	.25
Impossible				
Studied	.61	.67	.64	.64
Nonstudied	.25	.13	.30	.23
M				
Studied	.72	.75	.73	.73
Nonstudied	.27	.14	.31	.24

Note. Studied = proportion of studied items called *old* (hit rate); nonstudied = proportion of nonstudied items called *old* (false-alarm rate). Subjects in the structural condition were given 5 s to make each of two left–right judgments; subjects in the functional condition were given 5 s to make each of two tool–support judgments; subjects in the structural–functional condition were given 5 s to make a structural judgment and 5 s to make a functional judgment.

Recognition. A different pattern of results was observed in the recognition task than in the object decision task (see Table 10). As expected, corrected recognition scores were higher in the functional condition (.61) than in either the structural–functional condition (.41) or the structural condition (.47). Recognition memory was higher for possible objects than for impossible objects in all three conditions. An ANOVA that was performed on the corrected recognition scores yielded main effects of encoding task, $F(2, 45) = 3.10$, $p = .054$, $MS_e = .096$, and object type, $F(1, 45) = 13.19$, $p < .001$, $MS_e = .047$, and a nonsignificant interaction between these two variables ($F < 1$). Planned comparisons revealed that recognition accuracy was significantly higher in the functional group than in the structural–functional group or the structural group, both $ts(14) > 2.31$, $p < .05$, whereas performance in the structural–functional and structural groups did not differ significantly, $t(14) < 1$.

To compare more directly the effects of the encoding tasks on object decision and recognition performance, we performed a combined ANOVA on priming scores and corrected recognition scores, with type of test as a within-subjects variable. The Encoding Task × Type of Test interaction was marginally significant, $F(2, 45) = 2.73$, $p = .076$, $MS_e = .049$.

Discussion

Experiment 5 did not yield any evidence that combining structural and functional encoding tasks produced greater levels of priming than did performing the same structural task twice or the same functional task twice; the levels of priming observed after each task were indistinguishable statistically. By contrast, and in accordance with our expectations, performing a functional encoding task twice produced significantly higher levels of recognition memory than did either the structural–functional or structural tasks, presumably because subjects engaged in the most extensive elaborative processing in the functional condition. It is perhaps surprising that recognition performance was no higher in the structural–functional condition than in the structural condition (it was nonsignificantly lower) because the former condition allowed the opportunity for more elaborative processing than did the latter. We have no ready explanation for this apparent anomaly.

The fact that the structural–functional task yielded levels of priming similar to those of both the structural and functional tasks fails to support the idea that structural and functional encoding judgments yield different kinds of information that can support priming on the object decision task independently. However, we must be cautious about accepting this conclusion because it involves acceptance of the null hypothesis. Moreover, the levels of object decision performance in Experiment 5 were quite high, with performance for studied possible objects exceeding 80% correct in all conditions and approaching 90% correct in the functional condition. Thus, the possibility that between-tasks differences have been obscured by ceiling effects must be considered seriously. We faced a similar problem in Experiment 1, and we addressed it by lowering baseline levels of performance with a faster exposure duration on the object decision test. In Experiment 5, we used the 50-ms exposure rate from Experiment 2, yet we nevertheless obtained considerably higher levels of baseline performance; these differences may be attributable to the different subject groups or computer displays used in the two experiments.

To investigate further the potential role of ceiling effects in the outcome of Experiment 5, we performed a partial replication of it, comparing performance in the structural–functional and functional groups and using a much briefer (17-ms) exposure rate on the object decision task. The question was whether differences between encoding tasks would begin to emerge with lower levels of baseline performance and with correspondingly reduced possibilities of artifacts attributable to ceiling effects.

Experiment 6

Method

Subjects. Forty Harvard University undergraduates participated in the experiment in exchange for a payment of $5.00.

Design, materials, and procedure. All aspects of the experiment were identical to Experiment 5, except that (a) the object decision exposure rate was 17 ms, (b) only the structural–functional and functional encoding tasks were used, and (c) the recognition task was not included. Thus, the design consisted of a 2 × 2 × 2 factorial, with encoding task as the between-subjects variable and item type and object type as the within-subjects variables; there were 20 subjects in each encoding condition.

Results and Discussion

As indicated by the data shown in Table 11, the faster exposure rate produced a dramatic drop in baseline levels of performance, which varied around the chance level of 50% correct. Nevertheless, large priming effects were observed for possible objects, and performance for studied possible objects did not exceed 75% correct in either condition, which thus removed any concerns about ceiling effects. Nevertheless, there was no evidence for more priming in the structural–functional condition than in the functional condition; if anything, a weak trend in the opposite direction was observed. An ANOVA revealed main effects of item type, $F(1, 38) = 46.08$, $p < .001$, $MS_e = .023$, and object type, $F(1, 38) = 8.72$, $p < .01$, $MS_e = .022$, together with a significant Item Type × Object Type interaction, $F(1, 38) = 36.07$, $p < .001$, $MS_e = .028$. The main effect of encoding task was nonsignificant, $F(1, 38) = 1.82$, $MS_e = .042$, and no interactions involving encoding task approached significance (all Fs < 1.4).

Combined with the results of Experiment 5, then, these results fail to support the idea that object decision priming that follows structural and functional encoding tasks is supported by independent sources of information. The data are, however, consistent with our suggestion that priming effects

Table 11
Object Decision Performance (Mean Proportions Correct) in Experiment 6

Type of object	Type of study task: Functional	Structural–functional	*M*
Possible			
Studied	.75	.71	.73
Nonstudied	.44	.43	.44
Impossible			
Studied	.55	.45	.50
Nonstudied	.54	.51	.53
M			
Studied	.65	.58	.62
Nonstudied	.49	.47	.48

Note. Subjects in the functional condition were given 5 s to make each of two tool–support judgments; subjects in the structural–functional condition were given 5 s to make a structural judgment and 5 s to make a functional judgment.

occur after functional encoding tasks because making judgments about the functions that might be performed by novel objects necessarily entails an analysis of their structure.

General Discussion

The present experiments have provided new information about the effects of structural and functional encoding tasks on implicit and explicit memory for novel visual objects and have also provided empirical support for our structural description system account of object decision priming. Experiments 1 and 2 showed that structural and functional encoding tasks produce similar amounts of priming even though functional encoding tasks yield significantly higher levels of explicit memory than do structural encoding tasks. Experiments 3 and 4 indicated that the priming effects that are observed after functional encoding do not depend on a direct constraint between structure and function. Experiments 5 and 6 revealed significant and comparable amounts of priming when structural and functional encoding tasks are combined or when the same structural or functional encoding tasks are performed twice. The data are consistent with the idea that priming effects on the object decision task in both structural and functional encoding conditions depend on a presemantic representation that is computed by the structural description system. Explicit memory, on the other hand, is enhanced by the additional semantic elaborations that are promoted by functional encoding tasks.

It is perhaps worth noting that the dissociative effects of structural and functional encoding tasks on implicit and explicit memory were observed under conditions in which an extremely brief exposure duration was used on the object decision task (ranging from 17 to 100 ms) and a longer exposure duration was used on the recognition task (6 s). Accordingly, the observed dissociations may be in part attributable to these exposure time differences. For example, it is conceivable that recognition memory (like object decision) would be no higher after functional than after structural encoding tasks if the same brief exposure duration had been used for recognition and object decision. More generally, when making implicit–explicit memory comparisons, it is desirable to hold cue features constant across conditions and to vary only test instructions (see Schacter, Bowers, & Booker, 1989, for discussion).

To provide information concerning the issue, we gave a revised recognition memory test to two additional subject groups, each composed of 10 subjects (Harvard University undergraduates). Studied and nonstudied drawings were exposed for 50 ms, just as in several of the object decision tests described earlier, and subjects made yes–no recognition judgments. One group of subjects performed the left–right encoding task prior to the recognition test, and the other group performed the tool–support encoding task; the same set of objects described in previous experiments was used. As in Experiments 1 and 2, corrected recognition scores were higher after the tool–support task (.53) than after the left–right task (.45), $t(18) = 1.96, p < .05$, although the absolute magnitude of the difference was somewhat attenuated. Thus, while it seems clear that the dissociations that we have reported are not entirely attributable to the exposure time differences, the longer exposure time on the recognition test may enable subjects to make more effective use of explicit retrieval processes and hence benefit more from an elaborative study task.

A further feature of the data that warrants brief commentary is that the priming effects observed in Experiments 5 and 6 were larger than those obtained in the earlier experiments. Experiments 5 and 6 differed from the others in several ways, including subject groups (University of Arizona undergraduates vs. Harvard University undergraduates), computer systems (Compaq vs. Macintosh), and number of study-list exposures (one vs. two). It is conceivable that one, some, or all of these differences conspired to produce larger priming effects in Experiments 5 and 6 than in Experiments 1–4 (note, however, that our previous research suggests that the sheer number of repetitions is not likely to be a major factor; Schacter, Cooper, Delaney, Peterson, & Tharan, 1991). Whatever the reasons for the differences in absolute magnitude of priming across experiments, the important point is that the pattern of results was generally in line with our predictions in both the earlier and later experiments.

We began by noting evidence for structure–function dissociations in neuropsychological studies of patients with object-processing deficits (Riddoch & Humphreys, 1987; Warrington, 1975, 1982; Warrington & Taylor, 1978), and it is useful to consider our data in light of these observations. On the one hand, the neuropsychological evidence for structure–function dissociation is entirely consistent with our data indicating that structural and functional encoding tasks produce different effects on object decision and recognition tests, respectively. That is, the neuropsychological data showing relatively preserved access to structural knowledge of objects despite impaired functional knowledge provided one basis for postulating a presemantic system dedicated to representing object structure (e.g., Warrington, 1982). Likewise, our data showing that recognition but not object decision performance is enhanced by functional encoding tasks suggest the involvement of a presemantic system in priming of visual objects. Thus, we have converging evidence from independent sources of research for a presemantic structural description system (cf. Schacter, 1992b).

On the other hand, careful consideration of our results and ideas with respect to the neuropsychological data suggests a more paradoxical state of affairs. We have argued that priming effects that follow functional encoding tasks can be attributed to perceptual operations within the structural description system that are an obligatory component of judgments about potential functions of novel objects. That is, subjects base their judgments of function, at least to some extent, on structural analysis of an object. Considered in light of this idea, the structure–function dissociation observed in neuropsychological research presents a puzzle. If, as suggested by our analysis, a preserved ability to analyze the structure of an object provides a basis for making adequate functional judgments, then it is not clear why patients who exhibit relatively intact access to knowledge of object structure show impaired access to knowledge of object function.

We refer to this state of affairs as the *structure–function paradox*: If judgments about function are made on the basis of structure, how can we account for neuropsychological evidence of structure–function dissociation?

We suggest a possible resolution to this paradox that turns on a distinction between two different bases for deriving knowledge of object function. The first, which we have emphasized in this article, involves perceptual analysis of object structure. In Gibson's (1977) terminology, the structure of an object may specify or "afford" certain functions, and when it does, knowledge of function may be based on structural analysis of object *affordances* (e.g., Runeson & Frykholm, 1981; Warren, 1984). However, as Norman (1988) has discussed at length, structure does not readily afford function in the case of many everyday objects, particularly man-made ones. For example, the functions of a video cassette recorder are not easily discernible on the basis of structural analysis alone. With these kinds of objects, functional knowledge depends on semantic learning of rules or propositions that relate structure to function.

If we accept the distinction between structurally based and semantically based knowledge of object function, we can suggest a relatively straightforward resolution to the structure–function paradox: Impaired functional knowledge in patients who exhibit relatively intact structural processing may be attributable to the use of tests that include objects whose function is not afforded by their structure and therefore must be represented in semantic–propositional form (cf. Riddoch, Humphreys, Coltheart, & Funnell, 1988; Shallice, 1988; Warrington, 1982). Thus, patients may be unable to gain access to the semantic–propositional knowledge that is required for successful task performance. This idea could be tested by developing tests of functional knowledge in which the degree to which the structure of an object specifies its function is manipulated systematically.

Returning to our results, we have argued that with novel objects, functional judgments must involve some structural analysis—whether or not object structure directly constrains or affords function—because subjects have no basis for making functional judgments other than an analysis of structure; there are no stored propositions about functions of novel objects that subjects can retrieve. Consistent with this account, when we instructed subjects in Experiment 4 to make functional judgments by accessing stored semantic knowledge of familiar objects, we failed to observe significant priming. These observations support the idea that priming in our experiments occurred entirely within the structural description system. Note, however, that we have also suggested that higher levels of recognition memory after functional than after structural tasks can be attributed to enhanced elaboration in the functional condition. Although this assertion could be seen as contradictory to the idea that priming in the functional encoding condition depends on structural analysis, the inconsistency is more apparent than real. As long as we assume that functional judgments, although requiring some structural analysis, also involve additional elaborative–semantic processing that does not occur in structural encoding tasks, then both the object decision and recognition data can be accommodated.

The suggestion that priming in our experiments occurred entirely within the structural description system suggests a role for priming in everyday object perception: It may enhance an organism's ability to pick up the useful affordances of an object. If we assume that not all potential affordances are immediately perceptible on an initial encounter with an object (cf. Gibson, 1977; Norman, 1988), then we can hypothesize that acquiring information about object structure might facilitate subsequent perception of those affordances. Viewed in this context, priming in the structural description system may constitute one basis for linking knowledge of object structure and function and thus serve as a bridge between perception and action.

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Received September 8, 1992
Revision received December 17, 1992
Accepted December 18, 1992 ■