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Implicit Memory for Unfamiliar Objects Depends on Access to Structural Descriptions

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We investigated implicit memory for unfamiliar objects with a task in which subjects decided whether structurally possible and impossible line drawings could exist in three-dimensional space. In Experiment 1, significant priming effects on object decision performance were observed after encoding of global, three-dimensional object structure but not local, two-dimensional object features. Explicit memory did not differ significantly as a function of global vs. local study processing. In Experiments 2 and 3, elaborative encoding had different effects on object decision and recognition performance, thus providing evidence for functional dissociation between implicit and explicit memory. Stochastic independence between object decision and recognition performance was also observed. Results were consistent with the hypothesis that implicit memory, as indexed by priming on the object decision task, depends on encoding of and access to structural descriptions of objects.

Overview

Explicit memory refers to conscious or intentional recollection of previous experiences, whereas *implicit memory* refers to unintentional retrieval of previously acquired information on tests that do not require intentional recollection of a specific prior episode. Dissociations between explicit and implicit memory have been documented in a variety of tasks and subject populations. Our experiments extend implicit memory research into a novel domain: the representation and retrieval of information about unfamiliar three-dimensional objects. Subjects studied line drawings that depicted unfamiliar *possible* objects that could exist in three-dimensional space and *impossible* objects that contain subtle surface and edge violations that would prohibit them from actually existing. Implicit memory was assessed with an *object decision task* in which subjects were given 100-ms exposures to old and new possible and impossible objects and had to decide whether each object could exist in the real world. Accurate performance on this task requires access to information about the global, three-dimensional structural relations that define an object. Therefore, in accordance with the principle of transfer-appropriate processing, we expected study tasks that promote the acquisition of information about global object structure—a *structural description* of the object—to produce priming effects on the object decision test, whereas study tasks that do not require encoding a structural description would not produce priming. Results from three experiments that entailed a variety of structural and nonstructural encoding tasks were consistent with this hypothesis: Significant priming was observed after encoding of global or three-dimensional object structure but not local or two-dimensional object features. Explicit memory for the objects was assessed with a yes/no recognition test. The experiments revealed two types of dissociation between implicit and explicit memory. First, study tasks that required elaborative encoding of target objects produced different and even opposite effects on object decision and recognition performance, which thus revealed functional independence between the two tasks. Second, probability of a correct classification on the object decision test was uncorrelated with probability of recognition in each experiment, which thus revealed stochastic independence between the two tasks. In addition, appearance of studied and nonstudied objects on the recognition test failed to produce priming in a subsequent object decision test, which indicates that implicit memory depends specifically on a structural encoding of target objects. The results were interpreted in light of recent neuropsychological research suggesting the existence of a structural description system—distinct from episodic memory—that is specialized for representation and retrieval of information concerning object form and structure.

Introduction

Considerable current research is devoted to examining the relation between explicit and implicit forms of memory. *Explicit memory* refers to intentional or conscious recollection of recent experiences, as expressed on standard recall and

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recognition tests; *implicit memory*, in contrast, refers to unintentional retrieval of previously acquired information in tasks that do not require conscious recollection of a specific previous experience, such as word stem and fragment completion, lexical decision, and word identification (Graf & Schacter, 1985; Schacter, 1987).

Recent studies have revealed striking dissociations between tasks that tap explicit and implicit memory. For example, researchers have demonstrated that implicit and explicit memory are differentially affected by such variables as level and type of study processing (e.g., Graf & Mandler, 1984; Graf & Schacter, 1989; Jacoby, 1983; Jacoby & Dallas, 1981; Schacter & Graf, 1986; Schacter & McGlynn, 1989; Winnick & Daniel, 1970), study/test modality shifts (e.g., Graf, Shimamura, & Squire, 1985; Jacoby & Dallas, 1981; Kirsner, Milech, & Standen, 1983; Roediger & Blaxton, 1987a, 1987b; Schacter & Graf, 1989), and various other manipulations (e.g., Graf & Schacter, 1987; Hayman & Tulving, 1989a, 1989b; Masson, 1984; Mitchell & Brown, 1988; Tulving, Schacter, & Stark, 1982; Weldon & Roediger, 1987). In addition, subject populations that exhibit poor memory performance on explicit tests, such as amnesic patients and elderly adults, have shown robust and frequently normal retention on a number of implicit memory tests (e.g., Cohen & Squire, 1980; Graf, Squire, & Mandler, 1984; Light, Singh, & Capps, 1986; Moscovitch, Winocur, & McLachlan, 1986; Schacter, 1985b; Warrington & Weiskrantz, 1974). Dissociations between implicit and explicit memory represent an intriguing theoretical puzzle that has been approached from a variety of perspectives (for review and discussion, see Richardson-Klavehn & Bjork, 1988; Schacter, 1987).

Most implicit memory research has relied heavily on verbal materials: words, nonwords, paired associates, linguistic idioms, and the like; relatively less attention has been paid to implicit memory for nonverbal information. This circumstance is not entirely surprising because much contemporary research in implicit memory grew out of earlier studies concerning lexical representation, access, and priming (see Schacter, 1987, for historical considerations). To the extent that implicit memory research has extended beyond the bounds of verbal materials, it has been focused largely on priming effects in naming and identifying pictures of familiar objects and faces, tasks that include a strong verbal component (e.g., Bruce & Valentine, 1985; Durso & Johnson, 1979; Kirsner, Milech, & Stumpfel, 1986; Milner, Corkin, & Teuber, 1968; Mitchell & Brown, 1988; Warrington & Weiskrantz, 1968; Weldon & Roediger, 1987; Winnick & Daniel, 1970; for review, see Schacter, Delaney, & Merikle, in press).

Several researchers, however, have examined implicit memory for nonverbal materials other than pictures of nameable items. Bentin and Moscovitch (1988), for instance, examined whether repetition priming could be observed on a task that required subjects to discriminate real, though unfamiliar, faces from nonfaces (i.e., "faces" with jumbled features); they failed to observe repetition effects except in a zero-lag condition in which an item was repeated immediately after initial presentation (but see Tulving, 1985). Kroll and Potter (1984), in contrast, found significant repetition effects at long lags in a task in which subjects decided whether pictures of nonsense objects (and actual objects) were real or not. Kunst-Wilson and Zajonc (1980) reported that brief exposures to geometric shapes affected subsequent preference judgments about the shapes, and Mandler, Nakamura, and Van Zandt (1987) extended this phenomenon to brightness and other judgments (cf. Johnson, Kim, & Risse, 1985). In an experiment by Musen and Treisman (in press), subjects studied dot patterns and were then given an identification test in which they attempted to copy old and new patterns from a brief exposure; substantial priming effects were observed in this task. Gabrieli, Milberg, Keane, and Corkin (in press) reported evidence of robust priming on a similar task in a study of the amnesic patient H.M. These studies suggest that implicit memory can be observed for nonverbal materials other than nameable pictures (see also Humphreys & Quinlan, 1987, 1988).

In this article, we extend implicit memory research into a previously unexplored domain: the representation and retrieval of information about unfamiliar three-dimensional objects. Questions concerning the mental representation of objects are fundamental to an understanding of both perception and memory, and considerable research on perceptual processing of unfamiliar objects has been reported (cf. Biederman, 1987; Cooper, 1989b; Humphreys & Quinlan, 1987; Marr, 1982; Shepard & Cooper, 1982). However, there has been little research on episodic memory for unfamiliar objects, and in the few reported studies, the researchers all assessed memory with explicit tests such as forced-choice recognition (e.g., Attneave, 1957; Bahrick & Boucher, 1968; Cooper, 1989a, 1989b; Rock, 1973; Rock & DiVita, 1987).

What sort of task could be used to assess implicit memory for unfamiliar three-dimensional objects? One promising candidate—promising from a number of research perspectives—is the *object decision task*, in which a line drawing must be classified as to whether it depicts a three-dimensional object. Such a task has been used in previous investigations of memory for familiar objects (Kroll & Potter, 1984; Riddoch & Humphreys, 1987a, 1987b). In these studies, subjects were presented with line drawings of real objects (e.g., a car or a dog) and nonobjects that were created by the rearranging of features of actual objects; they were required to decide whether each drawing represented a real object or a nonobject. Repetition priming effects have been observed in this object decision task (Kroll & Potter, 1984; Riddoch & Humphreys, 1987b). In quite a different line of research on object recognition, Cooper (1988, 1989a, 1989b) used a modified version of an object decision task to study encoding of, and memory for, unfamiliar three-dimensional objects. In these experiments, subjects initially decided whether sets of two-dimensional views of object sides could combine to form a possible three-dimensional object. A subsequent forced-choice recognition test revealed considerable explicit memory for drawings of three-dimensional objects that could have been formed from the sets of two-dimensional views.

For our research, we designed an object decision test to serve as an index of implicit memory for unfamiliar objects. The task required subjects to distinguish between representations of possible (but unfamiliar) structures that could exist in the three-dimensional world and representations of impossible structures that are not physically realizable in three dimensions. In our experiments, subjects studied drawings of novel three-dimensional constructions like those displayed in Figure 1. Some of the drawings depict *possible objects*: objects whose surfaces and edges are connected in such a way that they could potentially exist in the real world. Other drawings represent *impossible objects*: objects that contain subtle surface, edge, or contour violations that would make it impossible for them to exist as actual three-dimensional objects (e.g., Cowan, 1977; Draper, 1978; Penrose & Penrose, 1958; Sugihara, 1982).

In order to assess implicit memory for these unfamiliar objects, subjects were given 100-ms exposures to drawings of studied and nonstudied possible and impossible objects; their task was to decide whether each object was possible or impossible. This object decision task can be thought of as an implicit memory test in the sense that it does not make explicit reference to, or require conscious recollection of, any specific previous encounter with a presented object. If, therefore, object decision performance is facilitated by prior study of the test objects, there would be some evidence of implicit memory for unfamiliar, three-dimensional objects.

In the next section, we outline the major issues that we addressed experimentally by using the object decision task as an index of implicit memory.

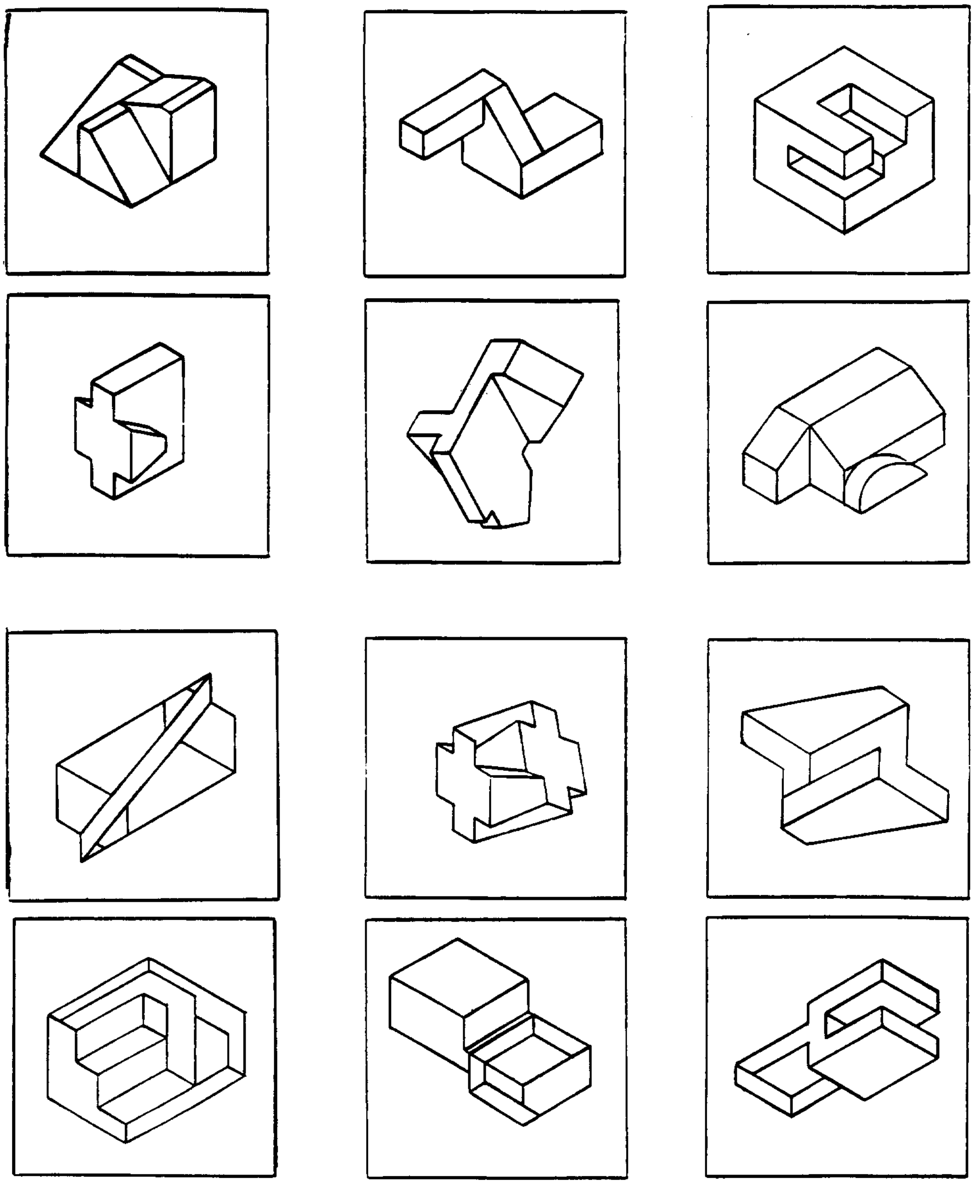

Figure 1. Sample objects used in our experiments. (The drawings in the upper two rows depict *possible* objects that could exist in three-dimensional form; the drawings in the lower two rows depict *impossible* objects that contain structural violations that would prohibit them from actually existing in three-dimensional form. See text for further explanation.)

Implicit Memory for Unfamiliar Objects: Four Issues

We now consider in turn the issues that are of primary concern in our research: the generality of the implicit/explicit distinction, the role of preexisting representations in implicit memory, the principle of transfer-appropriate processing, and the contribution of structural descriptions.

Generality of the Implicit/Explicit Distinction

The first and most general issue concerns whether the implicit/explicit distinction holds within the domain that we are exploring: Can implicit memory for unfamiliar objects be documented, and if so, can it be dissociated from explicit remembering of the objects? Answers to these questions will help to assess the general applicability and utility of the distinction between implicit and explicit forms of memory. If positive answers to these questions are obtained, our research could have important implications for the understanding of object recognition. Because previous studies entailing implicit measures have provided new information about memory function within the verbal domain, use of an implicit test may yield novel insights into the processes underlying the representation of and memory for unfamiliar objects—insights that might not be revealed by standard explicit tasks.

Role of Preexisting Representations

A second issue that we hope to illuminate concerns whether implicit memory depends on, or reflects the activation of, preexisting memory representations, nodes, or units. Several investigators have maintained that implicit memory effects can be attributed to activation of preexisting memory representations at the time of study (e.g., Diamond & Rozin, 1984; Graf et al., 1984; Mandler, 1980; Morton, 1979) or at least depend crucially in some way on their existence (e.g., Bentin & Moscovitch, 1988; Schacter, 1985b). Nevertheless, a number of studies have shown that performance on various implicit tests can be influenced by newly acquired information and associations that are not represented in memory as a single node or unit before the experiment (e.g., Feustal, Shiffrin, & Salasoo, 1983; Graf & Schacter, 1985, 1987, 1989; Schacter & Graf, 1986, 1989). In these studies, however, the stimulus materials were either (a) unrelated paired associates, in which the individual words do have a preexisting, unitized representation in memory, or (b) nonwords, which consist of familiar letters that have preexisting memory representations. There have been only a few reports of implicit memory for materials that do not have any preexisting representation as a unit in memory (cf. Gabrieli et al., in press; Kroll & Potter, 1984; Kunst-Wilson & Zajonc, 1980; Musen & Treisman, in press; Tulving, 1985).

The objects that we used as target materials in our experiments were entirely novel and frequently unusual constructions that had no preexisting memory representations (Figure 1). Therefore, to the extent that we could demonstrate that a study trial exposure to these unfamiliar objects influences performance on an implicit test, we would have evidence that within the domain of three-dimensional objects, implicit memory need not involve the activation or even existence of some preexisting representation of the target item.

Transfer-Appropriate Processing

A third issue that we address concerns the general applicability and utility of a transfer-appropriate processing account of implicit memory phenomena. The principle of transfer-appropriate processing holds that memory performance is successful to the extent that a test reinstates the specific processing operations that were used to encode a target stimulus (Morris, Bransford, & Franks, 1977). Roediger and his colleagues have argued that this principle can be usefully applied to the understanding of implicit/explicit dissociations (e.g., Roediger & Blaxton, 1987a, 1987b; Roediger, Weldon, & Challis, 1989). Specifically, they have endorsed Jacoby's (1983) suggestion that such implicit tests as stem completion, fragment completion, and perceptual identification typically rely on sensory/perceptual or data-driven processing, whereas standard tests of explicit recall and recognition typically rely on semantic or conceptually driven processing. This general notion—although not free of difficulties—can accommodate the finding of differential effects of semantic and nonsemantic study processing on performance of implicit and explicit tests, as well as a number of other implicit/explicit dissociations reported in the literature (for discussion, see Hayman & Tulving, 1989b; Richardson-Klavehn & Bjork, 1988; Roediger et al., 1989; Schacter, 1987).

The relation between transfer-appropriate processing and our research is straightforward. To perform our object decision task accurately, subjects needed to extract information about the three-dimensional structure of the object: We hypothesized that an object can be deemed "possible" only after an analysis of the structural relations among the various parts of the object. Therefore, in conformity with the transfer-appropriate processing view, we reasoned that facilitation of object decision performance should be observed after study tasks that induce encoding of information about global, three-dimensional object structure. In contrast, study tasks that do not permit acquisition of information about three-dimensional structure should not facilitate subsequent object decision performance. Our experiments were designed to evaluate these hypotheses.

The notion that implicit memory will be observed on the object decision task only after encoding of three-dimensional object structure is consistent with previous findings that priming effects on various implicit tests are extremely specific and can be disrupted by various study/test changes that have relatively little effect on explicit remembering (cf. Gardiner, Dawson, & Sutton, 1989; Hayman & Tulving, 1989b; Roediger & Blaxton, 1987a, 1987b). Explicit memory, though itself characterized by some specificity (Tulving & Thomson, 1973), also shows a good deal of flexibility; various kinds of information can be used to guide reconstruction of a target item (e.g., D. L. Nelson & Friedrich, 1980). These considerations have led Hayman and Tulving to propose that priming effects exhibit greater specificity than do explicit memory effects and are thus in some sense hyperspecific (e.g., Glisky, Schacter, & Tulving, 1986; Schacter, 1985a).

To investigate the relative specificity of implicit memory for unfamiliar objects, we compared priming effects on the object decision task with explicit remembering of target objects, assessed in a yes/no recognition test. In accordance with the transfer-appropriate processing notion, we expected that subjects would show considerable amounts of recognition memory after various kinds of study tasks, as long as the tasks enabled them to acquire distinctive information about each object (see the following section). However, although recognition memory can make use of different types of information, we expect that implicit memory will be observed only when subjects have acquired information about three-dimensional object structure.

Contribution of Structural Descriptions

Recent research and theorizing in artificial intelligence, cognitive psychology, and neuropsychology have addressed the role of structural descriptions in object recognition. A *structural description* refers to a mental representation of relations among components of an object that specifies its global form and structure; a variety of schemes for representing structural descriptions have been presented (cf. Hinton, 1979; Marr, 1982; Marr & Nishihara, 1978; Riddoch & Humphreys, 1987a, 1987b; Winston, 1975). Recent neuropsychological research suggests that structural descriptions of objects can be represented independently of semantic information concerning object function or meaning. For example, Riddoch and Humphreys (1987a) described a patient who showed severe impairment on tests that required access to semantic knowledge about objects from visual input, but who retained normal access to structural knowledge from vision: The patient showed no impairment on an object decision task that required him to discriminate common objects from structurally anomolous nonobjects (as well as other tests that tapped knowledge of object structure), yet he could neither name the common objects nor answer questions about their functional or associative properties (see also Sartori & Job, 1988; Warrington, 1982; Warrington & Taylor, 1978).

We suggest that performance on our object decision task would be facilitated by access to structural descriptions of target objects. As stated earlier, we designed the object decision test to require analysis of information about global, three-dimensional object structure. Therefore, if a study task promotes the acquisition of a three-dimensional structural description of a target object, the availability of such knowledge at the time of test should facilitate object decision performance. This hypothesis is entirely consistent with the predictions derived from the transfer-appropriate processing idea; in addition, however, it suggests an underlying structural *basis* of transfer-appropriate processing in our paradigm and suggests testable hypotheses concerning the relation between structural descriptions and semantic representations that we explored empirically in Experiments 2 and 3.

To initiate investigation of these issues, we conducted Experiment 1 to compare object decision and recognition performance after study tasks that required the encoding of global, three-dimensional object structure or local, two-dimensional object features, respectively. We hypothesized that facilitation of object decision performance would be observed only after the former study task, whereas comparable levels of recognition memory would be observed after both study tasks.

Experiment 1

Two types of encoding tasks were used in Experiment 1. The purpose of the first task was to promote encoding of three-dimensional object structure by requiring subjects to decide whether each presented object faced primarily to the left or to the right. To make the left/right judgment, subjects had to consider the object as a unified three-dimensional entity and encode relations among its structural components. For most of the target drawings, it was not immediately obvious which way the object was facing, and so the task required a careful structural analysis. In the second encoding task, we focused subjects' attention on local two-dimensional features of the objects by having them decide whether an object had more horizontal lines or vertical lines. Accurate performance on this task required extensive processing of each object's components but did not involve processing of the structural relations among them or viewing the object as a three-dimensional whole. Type of encoding task was manipulated as a between-subjects variable. All subjects studied both possible and impossible objects; no mention was made of the possible/impossible nature of the objects during study.

After completing the respective encoding tasks, half of the subjects were given the object decision test, which was composed of possible and impossible objects, of which half were studied and half were nonstudied. Implicit memory was inferred if object decision accuracy was higher for studied than for nonstudied items. The other half of the subjects were given a yes/no recognition test that included the identical items but required subjects to remember explicitly whether they had studied them. In addition, immediately after the recognition test, these subjects were given an object decision test on the same items that had just been tested for recognition memory. In previous studies of implicit memory entailing fragment completion tasks, researchers have reported that presentation of an item on a recognition test facilitates completion of that item on a subsequent completion test (e.g., Hayman & Tulving, 1989a; Schacter, McLachlan, Moscovitch, & Tulving, 1984; Tulving et al., 1982). It has also been shown that performance on an explicit recognition test is statistically independent of performance on various implicit tests (e.g., Eich, 1984; Hayman & Tulving, 1989a; Jacoby & Witherspoon, 1982; Light et al., 1986; Schacter et al., 1984; Tulving, 1985; Tulving et al., 1982). By testing object decision performance after the recognition test, we could examine whether presentation of an item on the recognition test facilitated a subsequent object decision about that item, and we could also determine whether object decision performance was independent of recognition memory.

In summary, our main hypotheses concerning Experiment 1 were that (a) encoding the global three-dimensional structure of an object by making the left/right judgment would facilitate subsequent object decision performance, whereas encoding local two-dimensional features by making the horizontal/vertical lines judgment would not produce any significant facilitation, and (b) recognition memory performance should be similar after the left/right and horizontal/vertical tasks because subjects acquire distinctive information about each object in both study tasks.

Method

Subjects. Seventy-two University of Arizona undergraduates participated in the experiment for course credits. They were randomly assigned to experimental conditions.

Design and materials. The main experimental design consisted of a 2 × 2 × 2 × 2 (Left/Right vs. Horizontal/Vertical Study Task × Object Decision vs. Recognition Test × Possible vs. Impossible Object × Studied vs. Nonstudied Object) mixed factorial. The first two factors were manipulated as between-subject variables, and the latter two were manipulated as within-subject variables. In addition, the object decision task was given either before or after the recognition test, which thereby created a test order variable for the object decision analysis.

The experimental materials consisted of a total of 40 line drawings, 20 representing possible objects and 20 representing impossible objects (see Figure 1). Subjects studied 10 possible and 10 impossible objects. The remaining 10 possible and 10 impossible objects were not studied; they were included on the object decision task in order to determine baseline levels of performance and on the recognition test as distractor items. The object decision and recognition tests thus consisted of 40 critical items: 20 studied objects (10 possible and 10 impossible) and 20 nonstudied objects (10 possible and 10 impossible). The presentation order of objects on both tests was determined randomly for each subject. For those subjects who received an object decision test after the recognition test, the identical 40 items were presented on both tests, although in a different random order for each test. Possible and impossible objects were randomly assigned to one of two material sets that were rotated through all experimental conditions. This procedure yielded a fully counterbalanced design in which each possible and impossible object appeared equally often in the left/right or horizontal/vertical study tasks, as a studied or nonstudied item, and on the object decision and recognition tests.

The possible and impossible objects were derived from two sources. All 20 possible objects were adopted from a set of materials used in previous research (Cooper, 1988, 1989a, 1989b). The impossible objects, drawn by Suzanne M. Delaney, were variations of structures similar to those illustrated in Figure 1. The general strategy in selecting and creating experimental materials was to include objects that satisfied two constraints: (a) There were, among an independent group of subjects, high levels of agreement concerning the possible/impossible nature of each object on a task in which they were given unlimited time to inspect the objects and make a possible/impossible judgment about them; and (b) determining the possible/impossible nature of each object was sufficiently difficult that subjects would perform well below ceiling levels when given a brief exposure to the items under baseline conditions (i.e., no prior exposure) on the object decision test.

The impossible objects selected for the study were constructed to be roughly as complex and unusual as the possible objects. All had subtle line, surface, or edge violations that rendered them impossible: ambiguous lines and planes that create impossible relations between surfaces and edges within the figure. The possible objects that were selected, though also complex and unusual, did not have any ambiguities that suggested impossible relations among surfaces and edges. Each plane in the drawing depicted a surface, and each line depicted an edge; all possible objects appeared to be solid and to have volume.

Computer-generated line drawings of candidate objects were shown to 20 subjects who had unlimited time to classify each object. They were told that some of the objects could actually exist in the real world, whereas others could not, and were given several examples of possible and impossible objects. Subjects classified 97% of the possible objects correctly; the lowest mean percent agreement for any individual possible object was 80 for one object. There was less agreement on the impossible objects: 87% of them were classified correctly, and the lowest mean percent agreement for an individual object was 70. Although the overall level of agreement concerning impossible objects was high, the fact that it was lower than for the possible object means that any comparisons between the two must be treated with caution, as will become apparent in subsequent discussion. However, because our main focus was on whether subjects showed implicit memory for unfamiliar possible objects, the fact that there was some disagreement about the impossible objects is not crucial. The major purpose of the impossible objects was to make it plausible for subjects to give either a "possible" or an "impossible" response on the object decision test.

To determine an appropriate exposure time for the object decision test, we conducted a pilot study in which the selected objects were presented to subjects on the monitor of an IBM microprocessor for 100 ms and were followed by a darkened screen. The objects subtended a mean visual angle of 18.4° when viewed from 45 cm. The drawings were presented in medium resolution, and they appeared amber against a uniform blue-grey background. On each object decision trial, a fixation point appeared in the middle of the screen, and an instruction prompt lower on the screen instructed the subject to press a key to begin the trial; the subject initiated the presentation of the object by pressing the designated key. Once the item appeared, subjects pressed one response key to indicate that the object was possible and another, adjacent key to indicate that the object was impossible. Subjects were given extensive instructions describing what constitutes a possible or an impossible object, respectively, and were shown several examples of each. They were told that both possible and impossible items would be presented briefly to them on the computer screen, and because the presentation rate was so brief, it was important to look closely at the fixation point before object exposure. Ten practice items were presented at the 100-ms rate before presentation of the first of the 40 critical items.

Results from 22 college students indicated that 67% of possible objects and 64% of impossible objects were classified correctly; thus the overall baseline level was 66% (item-by-item analyses of responses to individual objects revealed a roughly normal distribution of baseline classification rates). With a chance performance level of 50%, these results indicate that subjects can perform the object decision task at above-chance accuracy levels for both object types, but this level leaves considerable room for detecting any improvements attributable to a prior exposure to the objects. The 100-ms exposure rate was therefore adopted for the object decision test in all experiments reported here.

Procedure. All subjects were tested individually. Each experiment was conducted under conditions of incidental encoding: Subjects were told that they were participating in an experiment on object perception, and no mention of a later memory test was made. In the left/right study condition, subjects were informed that a series of drawings would appear on the computer monitor for 5 s and that their task was to determine whether each object appeared to be facing to the left or to the right. They were further instructed to use the entire 5 s to inspect each object carefully, because the objects were not as simple as they might first appear, and were told that it was important for them to make an accurate left/right judgment. Similar instructions were given in the horizontal/vertical condition, except that subjects were asked to judge whether each object had more horizontal or vertical lines. The study phase then began with five practice items, followed by presentation of the 20 critical objects in random order at a 5-s rate.

Immediately after study presentation, half of the subjects were given instructions for the object decision test intermixed with examples of possible and impossible objects. Subjects were told that figures would flash on the screen very quickly and that their task was to decide whether each drawing could actually exist in the three-dimensional world. The possible/impossible nature of the objects was then explained and appropriate examples were provided. Subjects were instructed to press the one key (on the left) if the drawing could be a possible three-dimensional object and another key (on the right) if it could not be a possible object.

Administration of the instructions took about 2 min. The test then began with 10 practice items; 5 had appeared as practice items at study, and 5 were new. The 40 critical items were then presented at a 100-ms rate under the conditions described for the pilot study. The other half of the subjects were given a surprise yes/no recognition test. They were told that they would be shown a series of objects, some of which had just been presented during the encoding task (left/right or horizontal/vertical) and some of which had not been exposed previously. Subjects were instructed to press the left response key if they remembered seeing the object during the prior encoding task and the right response key if they did not remember seeing the object.

Ten practice items (five old and five new) were presented before the 40 critical items. As in the object decision task, about 2 min elapsed between the conclusion of the study task and the appearance of the first critical item on the recognition test. Objects remained on the computer screen for 6 s until subjects made their recognition response. The exact length of time to complete the recognition test varied from subject to subject, but it generally took about 3–4 min. After conclusion of the recognition test, subjects in this group were given object decision instructions, followed by presentation of the same 10 practice items and 40 critical items under the conditions described earlier. Approximately 6–7 min elapsed between the end of the study task and the appearance of the first critical item on this second-test object decision task. On both the object decision and recognition tasks, subjects initiated each test trial when the fixation point appeared.

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

Results

The results of the object decision and recognition tests are first considered separately and then followed by a contingency analysis of the relation between them.

Object decision. Four important points should be noted about the results of the object decision test (see Table 1). First, for the possible objects, there was clear evidence that object decision performance was facilitated by a prior left/right judgment: Studied items were classified more accurately than were nonstudied items both when the object decision test was given first and when it was given second. Second, the evidence for facilitation of object decision performance after the horizontal/vertical task was weak: Although there was some advantage for studied items (72% judged correctly) over nonstudied items (64% judged correctly) when the object decision test was given first, there was no difference between studied items (63% judged correctly) and nonstudied items (64% judged correctly) when the object decision test was given second. Third, no evidence of facilitation for impossible objects was observed after either encoding task. Fourth, when the object decision test was given after a recognition test (second test condition), performance was no more accurate than when the object decision test was given alone, without a prior recognition test. Although some fluctuation across conditions did occur, there was no consistent trend for the appearance of either studied or nonstudied items on the recognition test to enhance subsequent object decision performance.

Table 1
Object Decision Performance: Experiment 1

	Encoding condition/test order					
	Left/right			Horizontal/vertical		
Item type	First	Second	*M*	First	Second	*M*
	Possible objects					
Studied	.81	.81	.81	.72	.63	.67
Nonstudied	.63	.71	.67	.64	.64	.64
M	.72	.76		.68	.64	
	Impossible objects					
Studied	.67	.66	.67	.59	.61	.60
Nonstudied	.68	.66	.67	.64	.62	.63
M	.68	.66		.61	.62	

Analysis of variance (ANOVA) confirmed this description of the results. A significant Type of Study Processing × Studied/Nonstudied Object interaction, $F(1, 68) = 4.31$, $MS_e = 2.18$, $p < .05$, indicated that object decision performance was facilitated in relation to baseline in the left/right but not the horizontal/vertical condition. In addition, however, a significant Object Type × Studied/Nonstudied Object interaction, $F(1, 68) = 11.18$, $MS_e = 1.70$, $p < .001$, indicated that possible but not impossible objects were facilitated by prior study list exposure.

Because object decision performance was facilitated only for the possible objects, we carried out a separate analysis that was restricted to these objects. The analysis revealed main effects of type of study processing, $F(1, 68) = 4.39$, $MS_e = 5.51$, $p < .05$, and studied/nonstudied object, $F(1, 68) = 15.24$, $MS_e = 1.70$, $p < .001$. It also revealed a significant Type of Study Processing × Studied/Nonstudied object interaction, $F(1, 68) = 6.88$, $p = .01$, thus confirming that object decision performance for possible objects was facilitated more by the left/right study task than by the horizontal/vertical task. Planned comparisons revealed that in the left/right condition, overall performance was significantly ($p < .001$) more accurate for studied than for nonstudied possible objects, $t(35) = 5.59$. In the horizontal/vertical condition, in contrast, no overall difference was observed between studied and nonstudied possible objects, $t(35) < 1$.

Analyses of object decision performance as a function of whether it was the first or second test yielded no significant main effect of test order, both when the analysis included possible and impossible objects, $F(1, 68) < 1$, $MS_e = 4.55$, and when it was restricted to possible objects, $F(1, 68) < 1$, $MS_e = 5.51$. Test order did not enter into any significant interactions in either analysis, except for an interaction with studied/nonstudied object when analysis was restricted to possible objects, $F(1, 68) = 3.94$, $MS_e = 1.70$, $p = .048$. This finding reflects a trend for somewhat less facilitation of object decision performance when this test was given after the recognition test than when it was given first. Because the finding was not replicated in any of the subsequent experiments, we do not consider it further. No other effects or interactions were significant.

Recognition memory. Data concerning recognition performance are displayed in Table 2 in terms of the proportions of hits and false alarms in the various experimental conditions. Recognition memory was slightly more accurate in the left/right than in the horizontal/vertical study condition and for possible than for impossible objects. For purposes of statistical analysis, two different measures of recognition were subjected to an ANOVA: hit rate and hit rate minus false alarm rate. Both analyses led to identical conclusions. We report only the results of the hit rate analysis in this and subsequent experiments because in no case did the alternative analyses suggest a different conclusion; this simply reflects the fact that false alarm rates were relatively constant across conditions.

An overall ANOVA revealed a marginally significant effect of object type, $F(1, 34) = 3.84$, $MS_e = 2.08$, $p = .055$. The main effect of type of study processing was not significant, $F(1, 34) < 1$, $MS_e = 3.74$, nor was the interaction between type of study processing and object type, $F(1, 34) < 1$, $MS_e = 2.08$). When analysis was restricted to the possible objects, the difference between the left/right and horizontal/vertical conditions did not approach significance, $t(34) < 1$.

The preceding analysis indicates that whereas object decision performance for possible objects was higher after left/right encoding than after horizontal/vertical encoding, explicit recognition of these objects was not significantly affected by this manipulation. However, an ANOVA that included type of test as a factor did not reveal a significant Type of Study Processing × Type of Test interaction. Two such analyses were performed. In the first, recognition and second test object decision performance were compared, and type of test was a within-subjects variable. The study/test interaction approached but did not attain significance, $F(1, 34) = 3.03$, $MS_e = 2.43$, $p = .087$. In the second analysis, in which recognition and first-test object decision performance were compared (and type of test was a between-subjects factor), no evidence of interaction was observed, $F(1, 34) < 1$, $MS_e = 2.67$.

Table 2
Recognition Performance: Experiment 1

Item type	Encoding condition		
	Left/ right	Horizontal/ vertical	*M*
	Possible objects		
Studied	.67	.61	.64
Nonstudied	.26	.26	.26
	Impossible objects		
Studied	.59	.56	.58
Nonstudied	.30	.35	.32

Note. Studied = proportion of studied items called "old" (hit rate). Nonstudied = proportion of nonstudied items called "old" (false alarm rate).

Contingency analysis of object decision and recognition performance. The purpose of the contingency analysis was to determine whether priming effects on object decision performance are dependent on, or independent of, recognition memory. Therefore, our contingency analysis focused on studied possible objects in the left/right task because this is the sole condition in which significant facilitation was observed. The analysis was also restricted to second-test object decision performance because only subjects in this condition had been given the recognition test before the object decision test. For these subjects, we constructed a 2 × 2 contingency table in which each of the cells corresponded to one of the four possible joint outcomes for studied items on the two tests. Specifically, subjects' responses concerning individual objects were classified into one of four mutually exclusive categories, each of which represents the joint probability of a particular outcome: (a) correct on both tasks (RN+OD+), (b) correct on recognition and incorrect on object decision (RN+OD−), (c) incorrect on recognition and correct on object decision (RN−OD+), or (d) incorrect on both tasks (RN−OD−).

If recognition and object decision performance are statistically independent of one another, then RN+OD+ should be similar to the product of the simple probabilities of recognition and object decision (RN × OD). In our experiment, RN+OD+ was .55 and RN × OD was .54, which suggested independence. In addition, we compared the simple probability of a correct object decision, P(OD), to the conditional probability of a correct object decision given a correct recognition response, P(OD/RN). P(OD) was .81, whereas P(OD/RN) was .83. These two probabilities did not differ significantly from one another, $t(17) < 1$, which provided further evidence of independence. Last, to evaluate the relation between recognition and object decision more formally, we used the Yule *Q* statistic, a special case of Goodman and Kruskal's (1954) gamma correlation that applies to the analysis of data from 2 × 2 contingency tables. *Q* is a measure of the strength of relation between two variables that can vary from −1 (negative association) to +1 (positive association); 0 reflects complete independence (see Hayman & Tulving, 1989a, and T. O. Nelson, 1984, for more detailed discussion; because there is a slight bias in *Q* values computed from 2 × 2 tables, we used the correction procedure described by T. O. Nelson, 1984, p. 124). For our data, $Q = +0.14$, and this value did not differ significantly from zero; significance was assessed with a chi-square test suggested by Hayman and Tulving, $\chi^2(1, N = 180) = 0.45$. The contingency analysis thus demonstrates stochastic independence between recognition and object decision performance.

Discussion

The results of Experiment 1 indicate that performance on the object decision task was facilitated by prior encoding of the global structure of an unfamiliar object but not by encoding of local features. However, evidence for priming or facilitation of object decision performance was observed only for possible objects. Classification of impossible objects was not facilitated by either study task: Object decision performances for studied and nonstudied impossible objects were virtually identical after both the left/right and horizontal/vertical tasks.

As noted in the Method section, however, there was among subjects somewhat less agreement concerning the impossible objects than concerning possible objects, and we did not attempt to rigorously equate possible and impossible objects on various relevant dimensions; these factors may be related to the failure to observe priming of impossible objects in Experiment 1. Nevertheless, the lack of facilitation for impossible objects was observed even though baseline levels of classification accuracy were about the same for possible and impossible objects. This basic finding—failure to observe priming of object decision performance for impossible objects—was replicated repeatedly throughout this series of experiments. We therefore postpone further consideration of the impossible objects until the General Discussion section, and we focus our analyses and discussion exclusively on the possible objects.

Experiment 1 provides empirical support for the main hypotheses outlined earlier. The finding that object decision performance was facilitated only by prior encoding of global object structure is consistent with a transfer-appropriate processing account and supports the notion that object decision performance is facilitated by access to structural descriptions. Recognition memory, by contrast, did not differ significantly in the two encoding conditions, which indicated that different types of information about both global and local object features could be used through explicit retrieval processes to support recognition performance. Although these findings provide some evidence for a dissociation between implicit and explicit memory for unfamiliar objects, the fact that we did not obtain a significant Type of Study Task × Type of Test interaction leads us to interpret the findings cautiously.

Other features of our results, however, suggest that different processes are involved in object decision and recognition performance and provide further evidence that a highly specific kind of information supports object decision performance. We found that subjects who performed the object decision task after a recognition test were no more accurate than were subjects who performed only an object decision task. The recognition test consisted of previously studied objects and nonstudied objects that appeared for the first time on this test (i.e., distractor or lure items). Thus the finding that the appearance of studied and nonstudied items on the recognition test did not facilitate subsequent object decision performance means that (a) when a nonstudied object appeared for the first time as a new distractor item on the recognition test, the processes used to encode that object and to make a recognition decision about it did not produce the kind of representation that is necessary to facilitate object decision performance; (b) when an object that had been studied in the local processing condition appeared as an old item on the recognition test, the processes used to encode that object did not add to the existing representation in such a manner as to produce priming of the object decision performance; and (c) when an object that had been studied in the global processing condition appeared on the recognition test, the processes used to encode that object did not *increase* the amount of priming observed on object decision.

The fact that encoding these various types of items on the recognition test neither produced nor increased facilitation of object decision performance is particularly impressive because previous studies have shown that test priming effects attributable to the appearance of an item on a recognition test are almost ubiquitous, facilitating subsequent performance on explicit tests of recall and recognition (e.g., Bahrick & Phelps, 1988; Donnelly, 1988; Flexser & Tulving, 1978) and on implicit tests such as fragment completion (e.g., Tulving et al., 1982).

These findings underscore the specificity of the priming effects that we have observed. We assume that when subjects made a recognition decision concerning whether they previously studied an object, they encoded the object as a unitary configuration or whole; they were certainly in no way restricted to encoding only local features of the object, as they were in the horizontal/vertical study task. Yet simply encoding the object as a whole was apparently not sufficient to produce facilitation of object decision performance. These data strongly suggest, then, that facilitation of object decision performance requires explicit encoding of, and subsequent access to, a structural description of an object.

This idea gained further support from the finding that object decision and recognition performance exhibited stochastic independence. If priming of object decision performance were based on the same type of information that supports explicit recognition, dependence between the two tasks should have been documented; probability of a correct object decision ought to have been systematically correlated with probability of a correct recognition judgment. The fact that we found stochastic independence is particularly impressive because there was no evidence that object decision performance for previously studied items was facilitated by test-induced priming from the appearance of an item on the recognition test. Shimamura (1985) argued that when independence between recognition and an implicit test is observed, it may be produced artifactually by priming effects that are attributable to the prior appearance of target items on the recognition test. Our results indicate that stochastic independence can be observed even when there is no evidence of test-produced priming effects. However, we recognize that interpreting a finding of stochastic independence is not always straightforward and that it can be clouded by a variety of subtle and complex issues (for discussion, see Hayman & Tulving, 1989a; Hintzman, 1980; Shimamura, 1985). Though we acknowledge the need for some interpretive caution, we view the finding of stochastic independence as a suggestive clue that object decision and recognition performance depend on different underlying processes. In Experiment 2, we obtained a different kind of evidence that converged on the same conclusion.

Experiment 2

The main purposes of Experiment 2 were (a) to examine empirical implications of the idea that facilitation of object decision performance depends on access to structural descriptions and (b) to attempt to dissociate further implicit and explicit memory for unfamiliar objects. To accomplish these objectives, we compared object decision performance after the left/right encoding task from Experiment 1 with a study task that required subjects to generate elaborative encodings of the target objects.

Subjects were instructed to examine each object and to think of something familiar that the object reminded them of most. This task requires relating the objects to preexisting knowledge structures, generating appropriate elaborators, and achieving a meaningful interpretation of each object—in short, coming up with the sort of semantically rich and distinctive encodings that enhance explicit memory performance (e.g., Craik & Tulving, 1975; Jacoby & Craik, 1979; Tulving, 1983). Accordingly, we expected that this elaborative encoding task would yield significantly higher levels of recognition performance than would the left/right encoding task.

A quite different pattern of results was expected for the object decision task. In our analysis, the type of semantic encoding that the elaborative task promoted, though useful for recognition, did not enhance object decision performance in relation to the left/right encoding task: If, as suggested by Riddoch and Humphreys (1987a, 1987b), structural descriptions of objects are represented separately from semantic information about them, then elaborative encoding should not produce a more useful structural description of the object than should left/right encoding.

Two possible outcomes, however, would be consistent with our view. First, elaborative encoding and left/right encoding may produce similar levels of performance on the object decision task. This outcome would be expected if, during performance of the elaborative encoding task, subjects encode structural descriptions of the target objects. Second, because the elaborative encoding task does not specifically require subjects to encode structural descriptions of the objects, no facilitation of object decision performance may be observed in this condition, despite the expected high levels of recognition performance. Although we did not have a firm basis for predicting one or the other of these outcomes, both entailed a dissociation between object decision and recognition performance, inasmuch as we hypothesized that elaborative encoding would improve recognition but not object decision performance.

Method

Subjects. Seventy-two University of Arizona undergraduates participated in the experiment for course credits. They were randomly assigned to experimental conditions.

Design, materials, and procedure. The main design consisted of a 2 × 2 × 2 (Left/Right vs. Elaborative Study Task × Object Decision vs. Recognition Test × Studied vs. Nonstudied Object) mixed factorial in which the first two factors were manipulated as between-subject variables and the third was manipulated as a within-subject variable. As in Experiment 1, the object decision task was given either as the first test or as the second test (i.e., after the recognition test). Test order was thus a between-subjects variable for the object decision analysis.

The same set of objects described in Experiment 1 served as target materials for this experiment. All subjects studied 10 possible and 10 impossible objects and were later tested for recognition or object decision both with these objects and with 10 nonstudied possible and impossible objects; all objects were completely counterbalanced across experimental conditions.

Subjects in the left/right condition were instructed as in Experiment 1 and were given 5 s to perform the task. For the elaborative encoding condition, subjects were told to think of something familiar that each drawing reminded them of most. They were encouraged to be imaginative and were required to provide a different elaboration for each drawing. After 5 s elapsed, they described their elaboration to the experimenter, who wrote a summary of it. As in Experiment 1, both task were performed under incidental study conditions.

After completing the respective encoding tasks, half of the subjects were given object decision instructions, and half were given recognition instructions. The two tests were administered exactly as described in Experiment 1. For subjects in the recognition condition, the object decision test was then given immediately after completion of the recognition test.

Results

Object decision. The object decision data for both possible and impossible objects are presented in Table 3. As in Experiment 1, there was no evidence that performance on impossible objects was facilitated by either study task. All subsequent analyses included only the possible objects.

Consider first the data from the left/right study task. As in Experiment 1, studied items were classified more accurately (78% correct) than nonstudied items (66% correct); similar results were obtained both when object decision was the first test and when it was the second test. In contrast, there was little evidence that object decision performance was facilitated by the elaborative study task. Although the overall levels of performance were relatively high, reflecting an elevated baseline rate in this condition, classification of studied items (76% correct) was only slightly more accurate than classification of nonstudied items (73% correct). When object decision was the first test, probabilities of accurately classifying studied items (.73) and nonstudied items (.72) were virtually identical; when object decision was the second test, there was a trend

Table 3
Object Decision Performance: Experiment 2

	Encoding condition/test order					
	Left/right			Elaborative		
Item type	First	Second	*M*	First	Second	*M*
	Possible objects					
Studied	.80	.76	.78	.73	.80	.76
Nonstudied	.68	.63	.66	.72	.74	.73
M	.74	.70		.73	.77	
	Impossible objects					
Studied	.63	.70	.67	.52	.64	.58
Nonstudied	.68	.70	.69	.58	.68	.63
M	.66	.70		.55	.66	

for more accurate performance on studied items (80% correct) than on nonstudied items (74% correct). As in Experiment 1, however, there was no overall trend for more accurate performance on the object decision task when it followed the recognition test than when it was the first test.

Analysis of variance confirmed that there was neither a main effect of test order nor any significant interactions with this variable (all Fs < 1). The ANOVA did reveal a main effect of studied/nonstudied object, $F(1, 68) = 11.38$, $MS_e = 1.91$, $p < .001$, and a marginally significant Type of Study Task × Studied/Nonstudied Object interaction, $F(1, 68) = 3.72$, $MS_e = 1.91$, $p = .055$. Planned comparisons indicated that after the left/right task, overall object decision performance was significantly more accurate for studied items than for nonstudied items, $t(35) = 3.37$, $p < 001$. In contrast, after elaborative encoding, studied items were not classified more accurately than were nonstudied items, $t(35) = 1.21$. No other effects or interactions were significant.

Recognition memory. The recognition data (presented in Table 4) contrast sharply with the object decision results. As expected, elaborative encoding produced a considerably higher level of recognition accuracy than did left/right encoding. Analysis of the hit rates for possible objects revealed a highly significant difference between the two encoding conditions, $t(34) = 3.91$, $p < .001$.

In order to evaluate the apparent dissociation between recognition and object decision performance, two combined ANOVAS were performed on the studied items. In the first, recognition was compared with second-test object decision performance; type of test was a within-subject variable. This analysis revealed a significant Type of Study Task × Type of Test interaction, $F(1, 34) = 5.98$, $MS_e = 1.57$, $p < .02$. In the second analysis, recognition performance was compared with first-test object decision performance; type of test was a between-subjects variable. Once again, a significant Type of Study Task × Type of Test interaction was observed, $F(1, 68) = 12.49$, $MS_e = 2.46$, $p < .001$.

Contingency analysis of object decision and recognition performance. The contingency analysis focused on studied possible objects in the left/right study task because this was the only condition in which significant priming was observed. Recognition and second test object decision data were entered into a 2 × 2 contingency table and analyzed in the same manner as in Experiment 1. The joint probability RN+OD+ (.55) was comparable, though not identical, to the product of the simple probabilities, RN × OD (.52). A conditional analysis revealed that P(OD/RN) was .79, which did not differ significantly from the P(OD) of .76, $t(17) < 1$. Yule's Q for these data was +.30. Though somewhat larger than the Q value from Experiment 1 (+.14), Q did not differ significantly from zero, $\chi^2(1, N = 180) = 2.91$. Thus recognition and object decision once again exhibited stochastic independence.

Table 4
Recognition Performance: Experiment 2

Item type	Encoding condition		
	Left/ right	Elaborative	*M*
	Possible objects		
Studied	.69	.88	.78
Nonstudied	.21	.19	.26
	Impossible objects		
Studied	.49	.73	.61
Nonstudied	.30	.35	.32

Note. Studied = proportion of studied items called "old" (hit rate). Nonstudied = proportion of nonstudied items called "old" (false alarm rate).

Discussion

The results of Experiment 2 replicated several key outcomes of Experiment 1: Object decision performance was significantly facilitated by the left/right study task; appearance of studied and nonstudied items on the recognition test did not affect subsequent object decision accuracy; and recognition and object decision performance showed stochastic independence. The critical new finding of Experiment 2 was a striking functional dissociation between object decision and recognition performance: Whereas recognition memory was significantly more accurate after elaborative encoding than after left/right encoding, object decision performance was facilitated more by the left/right task than by the elaborative task. Indeed, there was no significant facilitation of object decision performance after elaborative encoding. This interaction is particularly impressive because there are few examples in the literature in which an experimental manipulation that improved explicit memory also impaired implicit memory (e.g., Jacoby, 1983; Weldon & Roediger, 1987; Winnick & Daniel, 1970).

The failure of elaborative encoding to facilitate object decision performance is consistent with the idea that priming effects on this task depended on access to structural descriptions of target objects. It also supports the notion that structural descriptions are represented and/or accessed separately from semantic information about objects. Subjects in the elaborative encoding task, unlike subjects in the horizontal/vertical task of Experiment 1, were not restricted to encoding local features of objects; in fact, the task instructions (to say what each object reminded them of most) encouraged them to consider each object as a unified configuration. But encoding the object as a whole and even meaningful entity is apparently not sufficient to facilitate subsequent object decision performance. This interpretation is entirely consistent with, and supported by, the data from Experiments 1 and 2 indicating that the appearance of an item on the recognition test (a) does not itself *produce* facilitation, either for nonstudied items or for items that were studied in the horizontal/vertical or elaborative encoding tasks, and (b) does not *increase* the amount of facilitation for items studied in the left/right task. Taken together, these data support the idea that facilitation of object decision performance requires prior encodings that establish structural descriptions of studied objects.

There are at least two possible reasons why the elaborative encoding task failed to produce structural descriptions of target objects that could support priming on the object decision task. First, it is possible that subjects in this condition did perform an adequate structural analysis of the objects but somehow "contaminated" this analysis by elaborating on it in terms of their general knowledge of objects from the real world; that is, when subjects generated a real-world object that each drawing reminded them of most, they may have attached "semantic noise" to the structural description that served to distort it. A "distorted" structural description would not provide the kind of precise structural information that may be necessary to facilitate object decision performance. This extra semantic information is, of course, extremely useful for purposes of recognition because it serves to distinguish the encoding of one object from another. However, this "semantic noise" hypothesis is not consistent with the proposal that semantic information about objects is represented separately from structural information. Instead, it suggests that the two kinds of information are represented together as part of a more global representation of the object, in such a way that semantic information can alter and perhaps interfere with structural information.

An alternative possibility is that subjects in the elaboration condition did not in fact achieve an adequate structural analysis of the objects. Specifically, facilitation of object decision performance may depend on encoding of three-dimensional object structure: Access to three-dimensional information at the time of test is crucial for classifying objects accurately, and so subjects who have encoded this information during study may be better at extracting it from a 100-ms test presentation of each object. By this view, if subjects' elaborations were often based on two-dimensional interpretations of the objects, little evidence of facilitation would be expected. Inspection of the written record of subjects' elaborations revealed a mixture of three-dimensional and two-dimensional interpretations. Examples of three-dimensional elaborations are "a set of stairs," "a skyscraper," "a magnet," and so forth. Most of the two-dimensional interpretations involved letters of the alphabet (i.e., "looks like an 'S'"), although other types were also observed (e.g., "looks like the Red Cross symbol" or "shaped like a stop sign"). Because subjects did produce many two-dimensional elaborations, it is plausible that an elaborative encoding task that required subjects to provide three-dimensional elaborations would yield adequate structural descriptions and therefore facilitate subsequent object decision performance. In Experiment 3 we investigated this possibility.

Experiment 3

In Experiment 3, we modified the elaborative encoding task used in Experiment 2 to ensure three-dimensional encoding of target objects. Specifically, we required subjects to indicate whether each object reminded them most of (a) a type or part of a building, (b) a type of furniture, or (c) a household object. Once subjects classified an object into one of these three categories, they were asked to generate a specific example from the category that the object reminded them of most. The logic behind this manipulation was straightforward: Each of the three categories was composed of three-dimensional objects, and so requiring subjects to classify each drawing into one of the categories should have induced three-dimensional encodings. If, as we hypothesized, the lack of facilitation on object decision in the elaborative encoding condition of Experiment 2 was attributable to a failure to consistently achieve three-dimensional encodings, then we would observe significant priming after the elaborative classification task in Experiment 3. On the other hand, this task—like the elaborative encoding task of Experiment 2—required subjects to relate each object to preexisting real-world knowledge and thus may have distorted the structural description of the objects. If the lack of facilitation after elaborative encoding were attributable to distorted structural descriptions, then we would not observe significant facilitation of object decision performance after the elaborative classification task.

We also wanted to determine whether object decision performance could be facilitated by an encoding task other than the left/right task that required specific structural analysis of each object. To accomplish this objective, we devised a task in which subjects judged the relation between the height and width of each object: the extent to which each object is taller than it is wide or wider than it is tall. An appropriate judgment concerning the height and width of each object appears to require that the object is analyzed in depth (i.e., front and rear of the object need to be determined) and that the orientation of the object in space is assessed (see Figure 1). Thus to the extent that the height/width judgment entailed a three-dimensional structural analysis of target objects, it should produce significant facilitation on a subsequent object decision test. We also expected that the height/width task would result in poorer recognition memory performance than would the elaborative classification task because in the latter condition, subjects related the objects to preexisting real-world knowledge, whereas in the former condition, they did not. Accordingly, we anticipated that type of study task would affect recognition but not object decision performance.

Method

Subjects. Seventy-two University of Arizona undergraduates were randomly assigned to experimental conditions.

Design, materials, and procedure. The main experimental design consisted of a 2 × 2 × 2 (Height/Width vs. Elaborative Classification Study Task × Object Decision vs. Recognition Test × Studied vs. Nonstudied Items) mixed factorial in which the former two variables were manipulated between subjects and the latter was manipulated within subjects. In addition, test order was a between-subjects variable for the object decision task.

Subjects in the height/width condition were instructed to judge the magnitude of the disparity between the height and width of each drawing—that is, to judge whether and to what extent an object is taller than it is wide or wider than it is tall. They were instructed to use the following 4-point scale: *No difference between height and width* (1); *A slight difference between height and width* (2); *A fairly large difference between height and width* (3); and *A very large difference between height and width* (4). Subjects were allowed 5 s per object to perform the height/width task.

In the elaborative categorization condition, subjects were instructed to classify each object into one of three categories, according to what the object reminded them of most: a part or type of a building, a type of furniture, or a household object. They were also instructed to generate a specific example from the category that they selected. Five seconds for each object were allowed for performance of this task.

After completing the study task, half of the subjects performed the object decision task and half performed the recognition task in the manner described previously; recognition subjects were given the object decision task after the conclusion of recognition testing. All other aspects of materials and procedure were identical to Experiments 1 and 2.

Results

Object decision. Results from Experiment 3 are summarized in Table 5. In accordance with expectations, object decision performance after the height/width task was higher for studied possible objects (77% correct) than for nonstudied possible objects (68% correct). The advantage of studied over nonstudied items was about the same on the first and second tests, although there was a trend for higher overall object decision performance in the second-test condition than in the first-test condition. Of equal importance, the combined object decision data indicated that similar amounts of priming were observed after the elaborative encoding task (.79 vs. .71 for studied and nonstudied items, respectively) and the height/width task. The evidence for facilitation in the elaborative condition was somewhat stronger on the first than on the second object decision test. As in previous experiments, there was no consistent evidence that performance on the impossible objects was facilitated by either study task; object decision accuracy fluctuated considerably across the various experimental conditions.

An ANOVA performed on the possible object data revealed a highly significant main effect of studied/nonstudied items, $F(1, 68) = 16.91$, $MS_e = 1.38$, $p < .001$. No other main effects or interactions approached significance (all Fs < 1.36). This analysis indicates that comparable amounts of priming were observed after the height/width and elaborative classification study tasks on both the first and second object decision tests. However, even though the main effect of test order was not reliable, and though test order was not involved in any significant interactions, there was a clear trend in the height/width condition for higher object decision performance in the second-test condition than in the first-test condition.

Recognition memory. In contrast with the object decision results, but in accordance with our hypotheses, the data in Table 6 indicate that recognition memory performance for the possible objects was considerably more accurate after the elaborative classification task than after the height/width task, $t(34) = 4.18$, $p < .001$. In order to compare object decision and recognition performance, two ANOVAS were performed on the studied items. When recognition was compared with second-test object decision data, with type of test as a within-subject factor, a significant Type of Study Task × Type of Test interaction was observed, $F(1, 34) = 10.68$, $MS_e = 1.97$, $p < .005$. In contrast, comparison of the recognition data with the first-test object decision data, with type of test as a between-subjects variable, did not reveal a significant Type of Study Task × Type of Test interaction, $F(1,68) = 1.93$, $MS_e = 3.17$. However, this latter outcome derives from the fact that *overall* first-test object decision performance in the height/width condition was lower than *overall* performance in the elaborative classification condition, just as was observed on the recognition test. But the amounts of priming or facilitation on the object decision test—the *difference* between studied and nonstudied items—were of equivalent magnitude in the height/width and elaborative classification conditions, despite the large disparity in recognition performance.

Contingency analysis of object decision and recognition performance. Because significant priming effects were observed in both the height/width and the elaborative classification tasks, data for studied possible objects from each task were entered into separate 2 × 2 contingency tables. For the height/width condition, the joint probability RN+OD+ (.54) was comparable with the product of the simple probabilities RN × OD (.52). The conditional probability of OD/RN was .84, a value that was not reliably different from the simple probability of object decision (.81), $t(17 < 1)$. The value of Yule's Q in this condition was +.32, which did not differ significantly from zero, $\chi^2(1, N = 180) = 2.88$. For the elaborative classification condition, RN+OD+ (.66) was virtually identical to RN × OD (.65), and the conditional probability of OD/RN (.79) was almost the same as the simple

Table 5
Object Decision Performance: Experiment 3

	Encoding condition/test order					
	Height/width			Elaborative classification		
Item type	First	Second	*M*	First	Second	*M*
			Possible objects			
Studied	.72	.81	.77	.79	.78	.79
Nonstudied	.63	.73	.68	.69	.72	.70
M	.68	.77		.74	.75	
			Impossible objects			
Studied	.57	.61	.59	.59	.71	.65
Nonstudied	.59	.67	.63	.66	.60	.63
M	.58	.64		.63	.65	

Table 6
Recognition Performance: Experiment 3

Item type	Height/ width	Elaborative classification	*M*
	Possible objects		
Studied	.64	.83	.73
Nonstudied	.33	.21	.27
	Impossible objects		
Studied	.63	.67	.65
Nonstudied	.39	.21	.30

Note. Studied = proportion of studied items called "old" (hit rate). Nonstudied = proportion of nonstudied items called "old" (false alarm rate).

probability of object decision (.78). The Q value for this condition was +.07; it did not differ reliably from zero, $\chi^2(1, N = 180) = .05$. These analyses indicate that priming effects on object decision were independent of recognition performance for both the height/width and the elaborative classification tasks.

Discussion

The most important result of Experiment 3 is that the elaborative classification task led to significant facilitation of object decision performance. Thus the data were consistent with the hypothesis that significant facilitation after the elaborative study task in Experiment 2 was absent because subjects did not achieve adequate three-dimensional encodings of the objects. When they were specifically required to do so in the elaborative categorization task, significant priming was observed, even though this task, like the elaborative task from Experiment 2, also required subjects to generate meaningful interpretations of target objects. Thus we have no evidence for the idea that "semantic noise" from the generated elaborators somehow distorted structural descriptions of target objects.

Experiment 3 also provided further evidence for functional dissociation between recognition and object decision performance: Elaborative categorization led to much higher levels of explicit recognition than did the height/width task, in contrast to the comparable levels of object decision accuracy that followed the two tasks. Also, the recognition hit rate for the elaborative classification task (.83) was considerably higher than the hit rate for the left/right task of Experiments 2 and 3 (.67 and .69, respectively), even though the former encoding task did not produce more priming than the latter. These observations, together with the finding that recognition and object decision performance exhibited stochastic independence in Experiment 3, provide additional support for the idea that object decision and recognition performance can be dissociated.

General Discussion

This research established a new empirical phenomenon—implicit memory for unfamiliar three-dimensional objects—and delineated several of its characteristics. The experiments provided converging evidence that priming of object decision performance is observed only when encoding tasks require analysis of the three-dimensional structure of target items. Thus significant facilitation on the object decision task was found after the left/right (Experiments 1 and 2), the elaborative classification (Experiment 3), and the height/width (Experiment 3) study tasks, whereas priming was not observed when subjects were induced to encode local two-dimensional features of target items (Experiment 1) or when they were free to generate their own elaborative encodings (Experiment 2). In keeping with the idea that priming depends on specific encoding of three-dimensional object structure, we found in general that the appearance of an object on the recognition test did not produce significant priming effects on subsequent object decision performance, although there was a consistent trend toward test priming in the height/width condition of Experiment 3 (we will consider shortly one possible interpretation of this latter finding).

Each experiment also yielded two types of evidence for independence between implicit and explicit memory. Evidence for *functional* independence was provided by dissociative effects of experimental variables on object decision and recognition performance: The left/right versus horizontal/vertical manipulation (Experiment 1) had no influence on explicit memory and a significant effect on implicit memory; conversely, the height/width versus elaborative classification manipulation (Experiment 3) had no influence on implicit memory and a significant effect on explicit memory; and the left/right versus unconstrained elaboration manipulation (Experiment 2) had opposite effects on implicit and explicit memory. In addition, contingency analyses of the relation between object decision and recognition performance in each of the three experiments revealed *stochastic* independence between implicit and explicit memory. The fact that we observed both functional and stochastic independence provides converging evidence for a dissociation between object decision and recognition performance because obtaining one type of independence need not imply that the other will also be observed (e.g., Tulving, 1985).

Before we consider further the theoretical implications of these results, one additional finding of our research should be discussed: the failure to observe priming of object decision performance for impossible objects in any experiment. The data on impossible objects fluctuated considerably both within and between experiments; baseline rates were variable, as were performance levels for studied impossible objects. A portion of this unstable pattern may be attributable to the fact, discussed earlier, that there was less agreement about the impossible objects than about the possible objects. Moreover, we did not attempt to equate possible and impossible objects on such dimensions as complexity, size, and so forth. It is conceivable that with a set of impossible objects that both yielded high (i.e., close to unity) levels of agreement concerning impossibility and was matched to the possible objects on various physical dimensions, significant priming effects would be observed. In addition, our instructions for the object decision task emphasized detection of the *possible* objects; subjects were told to press one key if an object "could be" a possible object and another if it "could not be" a possible object. If test instructions had emphasized detection of impossible objects, significant priming might have been observed (for discussion of a similar issue concerning lexical decision priming and nonwords, see Feustal et al., 1983).

Despite these caveats, it is intriguing to conjecture that priming was not found because global structural "impossibility" is itself difficult to represent internally; that is, subjects may have had problems generating a mental model of the structural relations that make an object impossible, and they thus relied instead on detection of local surface and edge violations when making the "impossible" decision. Such an account is suggested by experiments on integration of successive views of objects with impossible global structures (e.g., Hochberg, 1968), and it is consistent with our findings. Our data do indicate that *some* aspects of the structure of impossible objects can be represented. For example, substantial recognition memory for the impossible objects, albeit lower than for the possible objects, was obtained. However, explicit memory for the prior occurrence of an impossible object might be based on a stored representation of local object features that does not include the structural relations that render it impossible. An interesting task for future researchers would be to systematically examine the idea that subjects cannot form mental representations of structural impossibility, even under encoding conditions designed to favor the extraction and representation of information about global three-dimensional structure.

An additional issue that is raised by the failure to observe priming for the impossible objects concerns the potential role of response bias in the priming effects that we did observe. In contrast to our hypothesis that priming of possible objects depends on access to newly acquired structural descriptions of studied items, one could argue that exposure to target objects simply produces a bias to say "possible" on the subsequent object decision test. A response bias of this kind could produce priming for possible but not impossible objects.

A serious difficulty that is encountered in attempts to address this issue concerns the extent to which a "possible" response to an impossible object on the object decision test can be considered evidence of response bias. As discussed earlier, there was less agreement concerning the impossible objects (87%) than the possible objects (97%) when subjects were given unlimited time to classify them. This result suggests that some objects that we deemed impossible occasionally gave rise to "possible" interpretations. It is thus unclear whether "possible" responses to impossible objects on the object decision task reflect a response bias produced by the prior study exposure or are attributable to the fact that some impossible objects give rise to "possible" interpretations, even when unlimited inspection time is provided.

With this interpretive caution in mind, we analyzed the combined data for possible and impossible objects with a view toward addressing the response bias issue. Consider, for example, data from the left/right encoding condition of Experiment 1, in which robust priming was observed. When subjects' responses were collapsed across object type (possible/impossible), 57% of responses to previously studied items were "possible" and 43% were "impossible," whereas only 50% of their responses to nonstudied objects were "possible" and 50% were "impossible." By contrast, in the horizontal/vertical condition—in which no priming was observed—52% of subjects' responses to studied items were "possible," whereas 51% of their responses to nonstudied items were "possible." Accordingly, one could argue that priming is produced by a response bias to say "possible" to studied items rather than to the acquisition of structural information about the possible objects. Unfortunately, this sort of analysis is not particularly useful because *any* set of data with the characteristics that we observed—no priming of impossible objects, together with significant priming of possible objects—would yield response patterns that are consistent with such a response bias interpretation. A more telling sign that a degree of response bias is present in some of our data concerns the fact that in several experimental conditions, performance for studied impossible objects was somewhat lower (albeit nonsignificantly) than for nonstudied impossible objects, thereby indicating an enhanced tendency to say "possible" to studied impossible objects. Although this pattern may be attributable to the aforementioned low agreement concerning impossible objects, there remains the question of whether the response bias interpretation of our priming effects can be distinguished from the structural description hypothesis that we have advanced.

One consideration that leads us to doubt the validity of a response bias interpretation concerns the failure to find reliable evidence of priming from the appearance of an item on the recognition test, particularly in Experiments 1 and 2 and in the elaborative classification condition of Experiment 3. If simple exposure to target objects produces a bias to classify them subsequently as "possible," then evidence of significant test priming should have been observed. Also, the strongest response bias to say "possible" in any of the experiments was observed in the elaborative encoding condition of Experiment 3 (59% "possible" responses to studied items). Yet significant priming effects were not observed in this condition, which thus suggests that the presence of response bias need not produce priming.

A more direct test of the response bias hypothesis is to analyze the combined data for possible and impossible objects with a measure that assesses subjects' object decision accuracy independently of response bias. Such an analysis would allow us to determine whether structural encoding tasks increase the accuracy of object decision performance even when response bias is taken into account. As T. O. Nelson (1984) pointed out, a measure that is well suited to this sort of analysis is Yule's Q (as discussed earlier, a special case of the gamma correlation for analyzing association in 2 × 2 contingency tables). We performed an analysis of the kind suggested by T. O. Nelson (1984, pp. 124–125) for studied and nonstudied objects in each experimental condition by creating for each subject 2 × 2 contingency tables in which the four cells were defined by the orthogonal combination of subjects' responses (possible/impossible) and object type (possible/impossible); we then computed Qs according to procedures described by T. O. Nelson (1984) and Reynolds (1977). The larger the Q value for a particular experimental condition was, the stronger the association between subjects' responses and object type was, independent of response bias. Accordingly, if the priming effects that we observed are attributable to increased accuracy of object decision performance and *not* to response bias, then the following pattern of results should be observed: On the one hand, *Q* values for studied items should be higher than *Q* values for nonstudied items in the left/right encoding condition of Experiments 1 and 2 and in the elaborative classification and height/width encoding conditions of Experiment 3—the conditions that yielded significant priming in the earlier analyses of possible objects. On the other hand, *Q* values for studied and nonstudied items should not differ for the horizontal/vertical task of Experiment 1 and the elaborative encoding task of Experiment 2—the conditions that did not yield evidence of priming in the previous analyses.

Results were generally, though not entirely, consistent with these expectations. For the horizontal/vertical condition, the *Q* for studied items (+.51) was virtually identical to the *Q* for nonstudied items (+.52); a similar pattern was observed in the elaborative encoding condition: *Q*s = +.62 for studied items and +.60 for nonstudied items, both *t*s(35) < 1. By contrast, in the left/right encoding conditions of Experiments 1 and 2, the *Q* values for studied items (+.76 and +.74, respectively) were significantly higher than for nonstudied items (+.59 and +.58, respectively), *t*s(35) = 2.36 and 2.23. Similarly, in the elaborative or three-dimensional classification condition of Experiment 3, the *Q* value for studied items (+.73) was significantly higher than for nonstudied items (+.58, *t*(35) = 1.86). In the height/width condition of Experiment 3, however, *Q* for studied items (+.62) was not significantly higher than for nonstudied items (+.59), *t*(35) < 1.

These analyses indicate that we can reject the hypothesis that the priming effects observed in the left/right encoding conditions of Experiments 1 and 2 and in the elaborative classification condition of Experiment 3 are produced by response bias. However, the analysis of the height/width data does not allow us to reject the hypothesis that priming of possible objects observed in this condition is attributable to response bias. Further evidence suggesting that response bias played a role in the priming effects found in the height/width condition is that only here did we observe a consistent trend for priming from the appearance of an item on the recognition test; as noted earlier, such a trend is consistent with a response bias interpretation. In retrospect, there may be good reasons for believing that priming after the height/width task could result from factors other than gaining access to an encoded description of three-dimensional object structure. The height/width assessment—unlike the left/right judgment, which consistently produced robust priming—*could* be performed on the basis of an analysis of the object's two-dimensional pattern; a three-dimensional model may not always be required for making the height/width decision. In any case, it seems clear that the data from the height/width condition must be viewed with interpretive caution. An important task for future researchers will be to analyze more carefully the extent to which the height/width task requires three-dimensional encoding and also to determine whether height/width encoding can produce significant priming effects under conditions in which response bias interpretations can be firmly ruled out.

We turn now to the implications of our results on possible objects for the main issues delineated in the introduction. By demonstrating that implicit memory effects occur within the domain of unfamiliar three-dimensional objects, we have both extended the range of implicit memory phenomena and added to the rather sparse data base concerning memory for unfamiliar objects. However, one can raise questions concerning the basis for referring to the priming effects that we have observed as instances of "implicit memory." Because levels of recognition performance were relatively high in most conditions, it is possible that subjects relied on explicit memory to perform the object decision test; they may have thought back to the study episode and explicitly retrieved information about the objects. Fortunately, the dissociations between object decision and recognition performance that we documented allow us to rule out this possibility. The same objects constituted the critical items on both tests. Therefore, if subjects had been engaging in explicit retrieval on the object decision task, performance should have been consistently influenced by experimental manipulations in the same way that recognition performance was affected, but it was not. It thus seems appropriate to refer to the priming effects that we have observed as manifestations of implicit memory (for more general discussion of this issue, see Schacter, Bowers, & Booker, 1989).

Our results also indicate that implicit memory can occur when there is no preexisting, unitized memory representation of target items, a finding that confirms and extends similar observations in other domains (cf. Feustal et al., 1983; Graf & Schacter, 1985; Johnson et al., 1985; Kunst-Wilson & Zajonc, 1980; Mandler et al., 1987; Musen & Treisman, in press; Schacter & Graf, 1986, 1989). One could argue that subjects encoded these unfamiliar target objects by relating them to familiar, well-known objects: Although the objects are nominally "novel," they may be encoded in such a way that they become functionally "familiar." One reason to doubt this possibility is that all of our experiments were carried out under conditions of incidental learning, and there is no obvious reason why subjects should attempt to transform the targets into familiar objects unless instructed to do so. More important, the data clearly contradict this possibility: When subjects were specifically instructed to encode the drawings in terms of whatever familiar objects they were reminded of most, no priming effects were observed (Experiment 2). Alternatively, one could argue that the reason why we observed priming for possible but not impossible objects is that possible objects contain more familiar structural components or parts than do impossible objects. Although this may be so, it is still the case that our possible objects have no preexisting memory representations as *unitized*, *whole* objects in the same sense that familiar objects do (e.g., a cup or a lamp). Our findings therefore add to other evidence indicating that implicit memory phenomena cannot be accounted for adequately in terms of automatic activation of preexisting memory representations (for further discussion, see Feustal et al., 1983; Graf & Schacter, 1985; Jacoby, 1983; Roediger & Blaxton, 1987a, 1987b; Schacter, 1985b, 1987, in press).

Our results are also broadly consistent with our hypotheses concerning transfer-appropriate processing. Because accurate performance on the object decision task requires analysis of structural relations, it follows from the transfer-appropriate processing view that encoding tasks that permit acquisition of information about global object structure will facilitate object decision performance, whereas tasks that allow acquisition of other kinds of information about target objects will not produce priming. In contrast to this pattern of results, there was considerable evidence of recognition memory after *all* study tasks, although some tasks led to higher levels of recognition than did others. This result indicates that different types of information can support recognition memory. Priming of object decision performance, however, was observed only after study tasks that required analysis of three-dimensional object structure; there was *no* evidence of implicit memory in the other conditions. This relative inflexibility of implicit memory leads us to conclude that the priming effects that we observed were highly specific (e.g., Hayman & Tulving, 1989b).

The ideas of transfer-appropriate processing and specificity of priming effects, though useful descriptively, do not provide much insight into the mechanisms underlying implicit memory for unfamiliar objects. In this respect, we find the concept of a structural description particularly useful. Our data lend support to the notion that priming effects on the object decision task depend on encoding of, and access to, structural descriptions of target objects. Moreover, the results of Experiments 2 and 3, which indicate that elaborative encoding of target objects does not increase—and can even eliminate—priming effects, are consistent with the proposal that structural descriptions are represented independently of semantic information about objects (Riddoch & Humphreys, 1987a, 1987b; Warrington, 1975, 1982).

On the basis of their finding that patients with certain forms of visual agnosia possess intact structural knowledge of objects that they can neither name nor recognize, Riddoch and Humphreys (1987a, 1987b) proposed further that knowledge about object form and structure depends on a structural description *system* that is separate from, but interacts with, a semantic system that represents associative and functional information about objects (Humphreys, Riddoch, & Quinlan, 1988; Riddoch & Humphreys, 1987a, 1987b; Riddoch, Humphreys, Coltheart, & Funnell, 1988; see Shallice, 1988, for an alternative view). There are several reasons to hypothesize that the structural description system described by Riddoch and Humphreys constitutes the source of the priming effects that we observed. Specifically, we suggest that when subjects performed study tasks that required encoding of global, three-dimensional object structure, a new representation was created by the structural description system; we hypothesize further that this system was engaged when subjects performed the object decision task. When a newly created structural description of a target object was activated by presentation of the target on the object decision test, subjects were able to gain access to information that was useful for making a correct object decision; it thus follows that priming effects were observed.

These latter ideas were put forward by Schacter (in press) in the context of a more general discussion of the underlying bases of implicit memory phenomena. Schacter suggested that a class of systems identified in recent neuropsychological research, referred to as *perceptual representation systems*, plays a crucial role in implicit memory (see also Tulving & Schacter, in press). Perceptual representation systems are concerned with knowledge of form and structure—but not semantics—in various input domains. The structural description system for objects provides one example of a perceptual representation system. Another such system discussed by Schacter is the *word form system* (Warrington & Shallice, 1980), which has been delineated in research on acquired reading disorders. This system represents knowledge about the visual form of words but not their meaning (cf. Ellis & Young, 1988; Sartori, Masterson, & Job, 1987; Schwartz, Marin, & Saffran, 1979; Warrington & Shallice, 1980). Schacter proposed that the word form system plays an important role in many of the priming effects that are observed with lexical items on various implicit memory tests. Such effects are typically independent of semantic study processing and dependent on the processing of structural and other surface features of words, which is consistent with the characteristics of the word form system that have been delineated in dyslexia research (see Schacter, in press, for more detailed discussion).

The structural description system, then, can be thought of as a perceptual representation system that performs functions in the object domain that are similar to those carried out by the word form system in the lexical domain. Though we suggest that the structural description system is involved in implicit memory for unfamiliar objects, we think that it plays a limited role in explicit remembering. This is because access to a newly formed structural description alone does not supply the kinds of information that are useful for explicit recollection of a prior encounter with an object: contextual information concerning the time and place in which an object was encountered, internally generated thoughts that accompany encoding of an object, or elaborations that render an object meaningful, distinctive, and thus highly memorable. Our data showing functional and stochastic independence between object decision and recognition performance are consistent with this idea. It is therefore reasonable to postulate that explicit remembering of target objects requires the involvement of an episodic memory system (Tulving, 1972, 1983) that provides access to contextual, elaborative, and other sorts of information lying outside the domain of the structural description system (see Schacter, in press). Nevertheless, the role of the structural description system in explicit remembering needs to be elucidated further, perhaps by means of explicit memory tasks that require access to structural information.

We emphasize that our ideas are complementary to, rather than in conflict with, the transfer-appropriate processing view expressed by Roediger (Roediger & Blaxton, 1987a, 1987b; Roediger et al., 1989) and others (e.g., Bentin & Moscovitch, 1988; Jacoby, 1983; Masson, 1989; Witherspoon & Moscovitch, 1989). Our approach is thus very much in the spirit of Hayman and Tulving's (1989a, 1989b) attempt to integrate processing and multiple system accounts of implicit memory phenomena. The differential involvement of the structural description system in implicit and explicit memory for unfamiliar objects can be thought of as the underlying basis of the transfer-appropriate processing that we observed. As pointed out by Schacter (in press), this sort of conceptualization represents an attempt to place some structural *constraints* on a processing account; without such constraints, processing views can be somewhat vague and perhaps circular (e.g., Roediger et al., 1989).

Our formulation also has some heuristic merit. For example, severely amnesic patients, who show intact priming effects on various implicit tests (e.g., Schacter, 1987; Shimamura, 1986), typically do not have impairments in perceptual representation systems. By our view, then, amnesic patients should perform normally on implicit tasks that tap various perceptual representation systems and poorly on explicit tasks that tap episodic memory (see Schacter, 1989, in press). Accordingly, we would expect them to show robust priming effects on the object decision test. In addition, our formulation points to a previously unexplored link between implicit memory research and neuropsychological studies of agnosia, dyslexia, and other syndromes in which perceptual representation systems are selectively impaired or preserved.

Last, we like the idea that implicit and explicit memory for unfamiliar objects depend on structural description and episodic systems, respectively, because it makes good *functional* sense. Sherry and Schacter (1987) argued on evolutionary grounds that it is useful to talk about multiple memory systems only when one can make a case that the putative systems perform distinct functions. Simply postulating the existence of multiple systems on the basis of empirical dissociations between tasks is not satisfactory for a number of reasons (cf. Jacoby, 1984; Roediger, 1984; Roediger et al., 1989; Sherry & Schacter, 1987; Squire, 1987; Witherspoon & Moscovitch, 1989).

By our view, the structural description system is dedicated to a particular function: representation of object form and structure. Effective performance of this function would not benefit from, and might even be hindered by, the capacity to represent associative/elaborative information about objects. The function of the structural description system is therefore distinct from and perhaps incompatible with the primary function of the episodic system: representation of various kinds of contextual and elaborative information that render events distinctive, coherent, and meaningful (Tulving, 1983; see Schacter, in press, for more general discussion in relation to perceptual representation systems). Postulation of a specialized structural description system thus not only is in accord with the empirical facts that we have observed but also serves to place the present research in a broader context of functional and ecological concerns.

References

Attneave, F. (1957). Transfer of experience with class schemata. *Journal of Experimental Psychology, 54,* 81–88.

Bahrick, H. P., & Boucher, B. (1968). Retention of visual and verbal codes of the same stimuli. *Journal of Experimental Psychology, 78,* 417–422.

Bahrick, H., & Phelps, E. (1988). The maintenance of marginal knowledge. In U. Neisser & E. Winograd (Eds.), *Remembering reconsidered* (pp. 178–192). Cambridge, England: Cambridge University Press.

Bentin, S., & Moscovitch, M. (1988). The time course of repetition effects for words and unfamiliar faces. *Journal of Experimental Psychology: General, 117,* 148–160.

Biederman, I. (1987). Recognition-by-components: A theory of human image understanding. *Psychological Review, 94,* 115–147.

Bruce, V., & Valentine, T. (1985). Identity priming in the recognition of familiar faces. *British Journal of Psychology, 76,* 373–383.

Cohen, N. J., & Squire, L. R. (1980). Preserved learning and retention of pattern analyzing skill in amnesia: Dissociation of "knowing how" and "knowing that." *Science, 210,* 207–209.

Cooper, L. A. (1988). The role of spatial representations in complex problem solving. In S. Steele & S. Schiffer (Eds.), *Cognition and representation* (pp. 53–86). Boulder, CO: Westview.

Cooper, L. A. (1989a). Mental models of the structure of visual objects. In B. Shepp & S. Ballesteros (Eds.), *Object perception: Structure and process* (pp. 91–119). Hillsdale, NJ: Erlbaum.

Cooper, L. A. (1989b). *Probing the structure of the mental representation of three-dimension objects.* Manuscript submitted for publication.

Cowan, T. M. (1977). Organizing the properties of impossible figures. *Perception, 6,* 41–56.

Craik, F. I. M., & Tulving, E. (1975). Depth of processing and the retention of words in episodic memory. *Journal of Experimental Psychology: General, 104,* 268–294.

Diamond, R., & Rozin, P. (1984). Activation of existing memories in the amnesic syndrome. *Journal of Abnormal Psychology, 93,* 98–105.

Donnelly, R. E. (1988). Priming effects in successive episodic tasks. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 14,* 256–265.

Draper, S. W. (1978). The Penrose triangle and a family of related figures. *Perception, 7,* 283–296.

Durso, F. T., & Johnson, M. K. (1979). Facilitation in naming and categorizing repeated pictures and words. *Journal of Experimental Psychology: Human Learning and Memory, 5,* 449–459.

Eich, E. (1984). Memory for unattended events: Remembering with and without awareness. *Memory & Cognition, 12,* 105–111.

Ellis, A., & Young, A. (1988). *Human cognitive neuropsychology.* London: Erlbaum.

Feustal, T., Shiffrin, R. M., & Salasoo, A. (1983). Episodic and lexical contributions to the word repetition effect. *Journal of Experimental Psychology: General, 112,* 309–346.

Flexser, A., & Tulving, E. (1978). Retrieval independence in recognition and recall. *Psychological Review, 85,* 153–171.

Gabrieli, J. D. E., Milberg, W., Keane, M. M., & Corkin, S. (in press). Intact priming of patterns despite impaired memory. *Neuropsychologia.*

Gardiner, J. M., Dawson, A. J., & Sutton, E. A. (1989). Specificity and generality of enhanced priming effects for self-generated study items. *American Journal of Psychology, 102,* 295–305.

Glisky, E. L., Schacter, D. L., & Tulving, E. (1986). Computer learning by memory-impaired patients: Acquisition and retention of complex knowledge. *Neuropsychologia, 24,* 313–328.

Goodman, L. A., & Kruskal, W. H. (1954). Measures of association for cross classifications. *Journal of the American Statistical Association, 49,* 732–764.

Graf, P., & Mandler, G. (1984). Activation makes words more accessible, but not necessarily more retrievable. *Journal of Verbal Learning and Verbal Behavior, 25,* 553–568.

Graf, P., & Schacter, D. L. (1985). Implicit and explicit memory for new associations in normal and amnesic patients. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 11,* 501–518.

Graf, P., & Schacter, D. L. (1987). Selective effects of interference on implicit and explicit memory for new associations. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 13,* 45–53.

Graf, P., & Schacter, D. L. (1989). Unitization and grouping mediate dissociations in memory for new associations. *Journal of Experi-*

mental Psychology: Learning, Memory, and Cognition, 15, 930–940.

Graf, P., Shimamura, A. P., & Squire, L. R. (1985). Priming across modalities and priming across category levels: Extending the domain of preserved function in amnesia. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 11*, 385–395.

Graf, P., Squire, L. R., & Mandler, G. (1984). The information that amnesic patients do not forget. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 10*, 164–178.

Hayman, C. A. G., & Tulving, E. (1989a). Contingent dissociation between recognition and fragment completion: The method of triangulation. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 15*, 222–240.

Hayman, C. A. G., & Tulving, E. (1989b). Is priming in fragment completion based on a "traceless" memory system? *Journal of Experimental Psychology: Learning, Memory, and Cognition, 15*, 941–956.

Hinton, G. (1979). Some demonstrations of the effects of structural descriptions in mental imagery. *Cognitive Science, 3*, 231–250.

Hintzman, D. L. (1980). Simpson's paradox and the analysis of memory retrieval. *Psychological Review, 87*, 398–410.

Hochberg, J. (1968). In the mind's eye. In R. N. Haber (Ed.), *Contemporary theory and research in visual perception* (pp. 308–331). New York: Holt, Rinehart & Winston.

Humphreys, G. W., & Quinlan, P. T. (1987). Normal and pathological processes in visual object constancy. In G. W. Humphreys & M. J. Riddoch (Eds.), *Visual object processing: A cognitive neuropsychological approach* (pp. 43–106). London: Erlbaum.

Humphreys, G. W., & Quinlan, P. T. (1988). Priming effects between two-dimensional shapes. *Journal of Experimental Psychology: Human Perception and Performance, 14*, 203–220.

Humphreys, G. W., Riddoch, M. J., & Quinlan, P. T. (1988). Cascade processes in picture identification. *Cognitive Neuropsychology, 5*, 67–104.

Jacoby, L. L. (1983). Perceptual enhancement: Persistent effects of an experience. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 9*, 21–38.

Jacoby, L. L. (1984). Incidental versus intentional retrieval: Remembering and awareness as separate issues. In L. R. Squire & N. Butters (Eds.), *Neuropsychology of memory* (pp. 145–156). New York: Guilford.

Jacoby, L. L., & Craik, F. I. M. (1979). Effects of elaboration of processing at encoding and retrieval: Trace distinctiveness and recovery of initial context. In L. S. Cermak & F. I. M. Craik (Eds.), *Levels of processing and human memory* (pp. 1–21). Hillsdale, NJ: Erlbaum.

Jacoby, L. L., & Dallas, M. (1981). On the relationship between autobiographical memory and perceptual learning. *Journal of Experimental Psychology: General, 110*, 306–340.

Jacoby, L. L., & Witherspoon, D. (1982). Remembering without awareness. *Canadian Journal of Psychology, 36*, 300–324.

Johnson, M. K., Kim, J. K., & Risse, G. (1985). Do alcoholic Korsakoff patients acquire affective reactions? *Journal of Experimental Psychology: Learning, Memory, and Cognition, 11*, 27–36.

Kirsner, K., Milech, D., & Standen, P. (1983). Common and modality-specific processes in the mental lexicon. *Memory & Cognition, 11*, 621–630.

Kirsner, K., Milech, D., & Stumpfel, V. (1986). Word and picture identification: Is representational parsimony possible? *Memory & Cognition, 14*, 398–408.

Kroll, J. F., & Potter, M. C. (1984). Recognizing words, pictures, and concepts: A comparison of lexical, object, and reality decisions. *Journal of Verbal Learning and Verbal Behavior, 23*, 39–66.

Kunst-Wilson, W. R., & Zajonc, R. B. (1980). Affective discrimination of stimuli that cannot be recognized. *Science, 120*, 557–558.

Light, L. L., Singh, A., & Capps, J. L. (1986). Dissociation of memory and awareness in older adults. *Journal of Clinical and Experimental Neuropsychology, 8*, 62–74.

Mandler, G. (1980). Recognizing: The judgment of previous occurrence. *Psychological Review, 87*, 252–271.

Mandler, G., Nakamura, Y., & Van Zandt, B. J. S. (1987). Nonspecific effects of exposure on stimuli that cannot be recognized. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 13*, 646–649.

Marr, D. (1982). *Vision*. San Francisco: W. H. Freeman.

Marr, D., & Nishihara, H. K. (1978). Representation and recognition of the spatial organization of three-dimensional shapes. *Proceedings of the Royal Society (London), B200*, 269–294.

Masson, M. E. J. (1984). Memory for the surface structure of sentences: Remembering with and without awareness. *Journal of Verbal Learning and Verbal Behavior, 23*, 579–592.

Masson, M. E. J. (1989). Fluent reprocessing as an implicit expression of memory for experience. In S. Lewandowsky, J. Dunn, & K. Kirsner (Eds.), *Implicit memory: Theoretical issues* (pp. 123–138). Hillsdale, NJ: Erlbaum.

Milner, B., Corkin, S., & Teuber, H. L. (1968). Further analysis of the hippocampal amnesic syndrome: 14 year follow-up study of H.M. *Neuropsychologia, 6*, 215–234.

Mitchell, D. B., & Brown, A. S. (1988). Persistent repetition priming in picture naming and its dissociation from recognition memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 14*, 213–222.

Morris, C. D., Bransford, J. D., & Franks, J. J. (1977). Levels of processing versus transfer appropriate processing. *Journal of Verbal Learning and Verbal Behavior, 16*, 519–533.

Morton, J. (1979). Facilitation in word recognition: Experiments causing change in the logogen model. In P. A. Kolers, M. E. Wrolstad, & H. Bouma (Eds.), *Processing models of visible language* (pp. 259–268). New York: Plenum Press.

Moscovitch, M., Winocur, G., & McLachlan, D. (1986). Memory as assessed by recognition and reading time in normal and memory-impaired people with Alzeheimer's disease and other neurological disorders. *Journal of Experimental Psychology: General, 115*, 331–347.

Musen, G., & Treisman, A. (in press). Implicit and explicit memory for visual patterns. *Journal of Experimental Psychology: Learning, Memory, and Cognition.*

Nelson, D. L., & Friedrich, M. A. (1980). Encoding and cuing sounds and senses. *Journal of Experimental Psychology: Human Learning and Memory, 6*, 717–731.

Nelson, T. O. (1984). A comparison of current measures of the accuracy of feeling-of-knowing predictions. *Psychological Bulletin, 95*, 109–133.

Penrose, L. S., & Penrose, R. (1958). Impossible objects: A special type of visual illusion. *British Journal of Psychology, 49*, 31–33.

Reynolds, H. T. (1977). *The analysis of cross-classification.* New York: Macmillan.

Richardson-Klavehn, A., & Bjork, R. A. (1988). Measures of memory. *Annual Review of Psychology, 36*, 475–543.

Riddoch, M. J., & Humphreys, G. W. (1987a). Picture naming. In G. W. Humphreys & M. J. Riddoch (Eds.), *Visual object processing: A cognitive neuropsychological approach* (pp. 107–143). London: Erlbaum.

Riddoch, M. J., & Humphreys, G. W. (1987b). Visual object processing in optic aphasia: A case of semantic access agnosia. *Cognitive Neuropsychology, 4*, 131–186.

Riddoch, M. J., Humphreys, G. W., Coltheart, M., & Funnell, E. (1988). Semantic systems or system? Neuropsychological evidence re-examined. *Cognitive Neuropsychology, 5*, 3–26.

Rock, I. (1973). *Orientation and form.* New York: Academic Press.

Rock, I., & DiVita, J. (1987). A case of viewer-centered perception. *Cognitive Psychology, 19,* 280–293.

Roediger, H. L. III (1984). Does current evidence from dissociation experiments favor the episodic/semantic distinction? *Behavioral and Brain Sciences, 7,* 252–254.

Roediger, H. L. III, & Blaxton, T. A. (1987a). Effects of varying modality, surface features, and retention interval on priming in word-fragment completion. *Memory & Cognition, 15,* 379–388.

Roediger, H. L. III, & Blaxton, T. A. (1987b). Retrieval modes produce dissociations in memory for surface information. In D. S. Gorfein & R. R. Hoffman (Eds.), *Memory and cognitive processes: The Ebbinghaus centennial conference* (pp. 349–379). Hillsdale, NJ: Erlbaum.

Roediger, H. L. III, Weldon, S., & Challis, B. H. (1989). Explaining dissociations between implicit and explicit measures of retention: A processing account. In H. L. Roediger III & F. I. M. Craik (Eds.), *Varieties of memory and consciousness: Essays in honor of Endel Tulving* (pp. 3–42). Hillsdale, NJ: Erlbaum.

Sartori, G., & Job, R. (1988). The oyster with four legs: A neuropsychological study on the interaction of visual and semantic information. *Cognitive Neuropsychology, 5,* 105–132.

Sartori, G., Masterson, J., & Job, R. (1987). Direct-route reading and the locus of lexical decision. In M. Coltheart, G. Sartori, & R. Job (Eds.), *The cognitive neuropsychology of language* (pp. 59–98). London: Erlbaum.

Schacter, D. L. (1985a). Multiple forms of memory in humans and animals. In N. Weinberger, J. McGaugh, & G. Lynch (Eds.), *Memory systems of the brain* (pp. 351–379). New York: Guilford.

Schacter, D. L. (1985b). Priming of old and new knowledge in amnesic patients and normal subjects. *Annals of the New York Academy of Sciences, 444,* 41–53.

Schacter, D. L. (1987). Implicit memory: History and current status. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 13,* 501–518.

Schacter, D. L. (1989). On the relation between memory and consciousness: Dissociable interactions and conscious experience. In H. L. Roediger III & F. I. M. Craik (Eds.), *Varieties of memory and consciousness: Essays in honor of Endel Tulving* (pp. 355–389). Hillsdale, NJ: Erlbaum.

Schacter, D. L. (in press). Perceptual representation systems and implicit memory: Toward a resolution of the multiple memory systems debate. *Annals of the New York Academy of Sciences.*

Schacter, D. L., Bowers, J., & Booker, J. (1989). Intention, awareness, and implicit memory: The retrieval intentionality criterion. In S. Lewandowsky, J. Dunn, & K. Kirsner (Eds.), *Implicit memory: Theoretical issues* (pp. 47–65). Hillsdale, NJ: Erlbaum.

Schacter, D. L., Delaney, S. M., & Merikle, E. P. (in press). Priming of nonverbal information and the nature of implicit memory. In G. H. Bower (Ed.), *The psychology of learning and motivation.* New York: Academic Press.

Schacter, D. L., & Graf, P. (1986). Effects of elaborative processing on implicit and explicit memory for new associations. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 12,* 432–444.

Schacter, D. L., & Graf, P. (1989). Modality specificity of implicit memory for new associations. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 15,* 3–12.

Schacter, D. L., & McGlynn, S. M. (1989). Implicit memory: Effects of elaboration depend on unitization. *American Journal of Psychology, 102,* 452–481.

Schacter, D. L., McLachlan, D. R., Moscovitch, M., & Tulving, E. (1984, August). *Tracking memory disorders over time.* Paper presented at the annual meeting of the American Psychological Association, Toronto, Ontario, Canada.

Schwartz, M. F., Marin, O. S. M., & Saffran, E. M. (1979). Dissociations of language function in dementia: A case study. *Brain and Language, 7,* 277–306.

Shallice, T. (1988). Specialisation within the semantic system. *Cognitive Neuropsychology, 5,* 133–142.

Shepard, R., & Cooper, L. A. (1982). *Mental images and their transformations.* Cambridge, MA: MIT Press.

Sherry, D. F., & Schacter, D. L. (1987). The evolution of multiple memory systems. *Psychological Review, 94,* 439–454.

Shimamura, A. P. (1985). Problems with the finding of stochastic independence as evidence for the independence of cognitive processes. *Bulletin of the Psychonomic Society, 23,* 506–508.

Shimamura, A. P. (1986). Priming effects in amnesia: Evidence for a dissociable memory function. *Quarterly Journal of Experimental Psychology, 38A,* 619–644.

Squire, L. R. (1987). *Memory and brain.* New York: Oxford University Press.

Sugihara, K. (1982). Classification of impossible objects. *Perception, 11,* 65–74.

Tulving, E. (1972). Episodic and semantic memory. In E. Tulving & W. Donaldson (Eds.), *Organization of memory* (pp. 381–403). New York: Academic Press.

Tulving, E. (1983). *Elements of episodic memory.* Oxford, England: Clarendon.

Tulving, E. (1985). How many memory systems are there? *American Psychologist, 40,* 385–398.

Tulving, E., & Schacter, D. L. (in press). Priming and human memory systems. *Science.*

Tulving, E., Schacter, D. L., & Stark, H. A. (1982). Priming effects in word-fragment completion are independent of recognition memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 8,* 336–342.

Tulving, E., & Thomson, D. M. (1973). Encoding specificity and retrieval processes in episodic memory. *Psychological Review, 73,* 540–549.

Warrington, E. K. (1975). The selective impairment of semantic memory. *Quarterly Journal of Experimental Psychology, 27,* 635–657.

Warrington, E. K. (1982). Neuropsychological studies of object recognition. *Philosophical Transactions of the Royal Society, London, B298,* 15–33.

Warrington, E. K., & Shallice, T. (1980). Word-form dyslexia. *Brain, 103,* 99–112.

Warrington, E. K., & Taylor, A. M. (1978). Two categorical stages of object recognition. *Perception, 7,* 695–705.

Warrington, E. K., & Weiskrantz, L. (1968). New method of testing long-term retention with special reference to amnesic patients. *Nature, 217,* 972–974.

Warrington, E. K., & Weiskrantz, L. (1974). The effect of prior learning on subsequent retention in amnesic patients. *Neuropsychologia, 12,* 419–428.

Weldon, M. S., & Roediger, H. L. III (1987). Altering retrieval demands reverses the picture superiority effect. *Memory & Cognition, 15,* 269–280.

Winnick, W. A., & Daniel, S. A. (1970). Two kinds of response priming in tachistoscopic recognition. *Journal of Experimental Psychology, 84,* 74–81.

Winston, P. H. (1975). Learning structural descriptions from examples. In P. H. Winston (Ed.), *The psychology of computer vision* (pp. 157–209). New York: McGraw-Hill.

Witherspoon, D., & Moscovitch, M. (1989). Stochastic independence between two implicit memory tasks. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 15,* 22–30.

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