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Effects of Imagery on Perceptual Implicit Memory Tests

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Four experiments demonstrate that imagery can promote priming on perceptual implicit memory tests. When Ss were given words during a study phase and asked to form mental images of corresponding pictures, more priming was obtained on a picture fragment identification test than from a study condition in which Ss performed semantic analyses of words. Imaginal priming of picture fragment identification occurred for recoverable fragments, but not for nonrecoverable fragments. The imagery effect was restricted to the imaged type of material: Imagining pictures (when presented with words) enhanced priming on a picture fragment identification test but not on word fragment completion. Similarly, when pictures were presented, imagining the corresponding words increased priming on word fragment completion but not on picture fragment identification. Overall, results support the hypothesis that imagining engages some of the same mechanisms used in perception and thereby produces priming.

Over the past decade, researchers have been intensively studying a class of memory tests that seem to reflect principles of learning and memory different from those reflected by the classic tests of memory; these new memory tests have been referred to as *implicit tests* (Graf & Schacter, 1985, 1987). Implicit tests differ from traditional memory tests (i.e., explicit tests) in the requirement of intentionality: Implicit tests do not require subjects to try to remember previous experiences. Rather, subjects are given the test as if it were just another in a series of unrelated tasks they are performing, and they are told to perform that task as well as possible. Retention is manifested in transfer achieved (relative to a baseline measure) from relevant prior experiences; the speed or accuracy of performance in the test phase is enhanced by the study phase. This facilitation is termed *priming*.

Researchers have identified two classes of implicit memory tests: perceptual and conceptual (Blaxton, 1989; Jacoby, 1983; Roediger & Blaxton, 1987a, 1987b; Tulving & Schacter, 1990). Perceptual implicit tests are those that challenge the perceptual system; for example, subjects might be asked to identify perceptually degraded forms of words or pictures (e.g., briefly presented words or pictures). Perceptual implicit memory tests can be contrasted with conceptual implicit memory tests, in which people are asked to draw on their general knowledge to answer questions of a semantic nature (e.g., "What is the fastest animal on earth?") or to free-associate to semantic cues (e.g., "Say the first 8 types of fruit that come to mind"). The most commonly used implicit memory tests are perceptual in nature, and this type is the focus of the present article.

Perceptual implicit tests can be dissociated from explicit tests as a function of several independent variables. For example, studying either the word *chimney* or a picture of a chimney does not transfer equally well to the implicit word fragment completion task; studying the picture transfers only minimally (or not at all in some experiments), whereas studying the word augments performance substantially (Srinivas & Roediger, 1990; Weldon & Jackson-Barrett, 1993; Weldon & Roediger, 1987). This finding exemplifies the differential sensitivity of implicit and explicit tests to independent variables in that all standard explicit tests show a picture superiority effect: Pictures are better remembered than words (Madigan, 1983; Paivio, 1971; Paivio & Csapo, 1973; Weldon, Roediger, & Challis, 1989).

The effects of independent variables on performance on perceptual implicit memory tests seem to be guided by two general principles: (a) Priming is sensitive to the degree to which the test stimuli match the study stimuli, and (b) priming is little affected by processing strategies used by subjects during the study phase.

The importance of a match between study and test stimuli has been documented in many experiments (see Schacter, 1990). As just noted, words produce more priming than pictures on word fragment completion tests. Similarly, pictures produce more priming than do words on picture fragment identification tests (Weldon & Roediger, 1987, Experiment 4). In addition, words presented in one language produce little priming on their translation equivalents in a different language for bilingual subjects (Durgunoğlu & Roediger, 1987). With regard to the second general principle, a variety of subject strategies that produce large effects on explicit memory tests

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produce little or no effect on implicit memory tests. These include the levels-of-processing manipulation (Graf, Mandler, & Haden, 1982; Jacoby & Dallas, 1981; Roediger, Weldon, Stadler, & Riegler, 1992), intentional and incidental learning (Bowers & Schacter, 1990; Green, 1986; Roediger et al., 1992), and directions to forget or to remember stimuli that have recently been presented (Basden, Basden, & Gargano, 1993; MacLeod, 1989; Paller, 1990). Further evidence for the importance of these two principles is provided by Roediger and McDermott (1993).

Although numerous studies have produced results consistent with this explanation of priming on perceptual implicit tests (e.g., Blaxton, 1989), many experiments have demonstrated that a match between the physical aspects of stimuli (and the accompanying low-level perceptual processes invoked by these stimuli) is not required to produce some priming on perceptual implicit tests. That is, although the tests are sensitive to the form of the stimuli, some cross-form priming often occurs. For example, seeing a picture often produces a small amount of priming to the corresponding word fragment (Weldon & Jackson-Barrett, 1993; Weldon & Roediger, 1987). In addition, auditorily presented words usually prime verbal implicit memory tests when the test stimuli are given visually (e.g., Rajaram & Roediger, 1993). Note that these findings do not undermine the claim that these tests are sensitive to perceptual features, but they do argue against the idea that priming is due solely to a match in physical aspects of the data. Some researchers (e.g., Bowers, 1994; Weldon, 1991, 1993; Weldon & Jackson-Barrett, 1993) have argued that such priming might be based on higher level perceptual processes, such as lexical access. Such reports have led Roediger and his colleagues to deemphasize the importance of lower level, "data-driven" processes in obtaining perceptual priming and to stress the importance of the (more ambiguous) "perceptual" processes that are assumed to arise at later stages in perception (Roediger & Srinivas, 1993).

If higher level processes can influence perceptual priming over and above the effects of the physical stimulus, the following question arises: Can subjects exert control over these processes in a way that might affect perceptual priming? Exceptions to the claim that subject strategies do not affect perceptual priming might be found if experimental situations could be devised in which subjects could intentionally generate their own "data" that would promote perceptual priming. As reviewed below, visual imagery is often assumed to engage the same central neural processes used in actual visual perception. If so, perhaps visual imagery could sufficiently mimic the relevant neural processes required to produce priming on perceptual implicit tests. For example, although words typically produce very little priming on picture fragment identification tests, if subjects imagined a picture when given a word, pictorial priming might be enhanced.

The basis for the hypothesis that imagery might promote priming on perceptual implicit memory tests lies in the notion that imagery and perception engage similar neural processes. Evidence supporting this view exists in several forms. Farah (1988, p. 307) noted that the idea that imagery comprises "the top-down activation of perceptual representations, that is, representations that are also activated automatically by an external stimulus during perception" has existed for many years, dating at least as far back as the early eighteenth century (Hume, 1739/1969). More recent proponents include Farah (1985, 1988), Finke (1980), Shepard (1978, 1984), and Kosslyn (Finke & Kosslyn, 1980; Kosslyn, 1983). Shepard and Cooper's mental rotation studies (e.g., Cooper, 1976; Shepard, 1984; Shepard & Cooper, 1982; Shepard & Metzler, 1971) argue for the functional equivalence of imagery and perception in showing that the time taken to determine whether a target stimulus possesses the same shape as a second stimulus is directly proportional to the magnitude of the difference in rotation (e.g., items differing by a 180° rotation take longer to compare than those differing by 120°). The similarity of times necessary for mental rotation and physical rotation (in conjunction with other evidence) led Shepard and his colleagues to infer that imagery and perception are functionally equivalent (Podgorny & Shepard, 1978). Numerous other studies have shown imagery to display other effects similar to those observed in visual perception. For example, Finke and Kosslyn (1980) showed that images have limited resolution; two imagined points seem to fuse when they are brought close together.

In addition to the studies from cognitive psychology, Farah (1988) noted that two types of evidence for the imagery–perception relation exist in the neuropsychological literature: (a) evidence that imagery and perception share neural mechanisms and (b) evidence from patient populations that imagery and perception are functionally related. Studies that traced regional cerebral blood flow during cognitive tasks have shown that the occipital lobes and posterior superior parietal and posterior inferior temporal areas show increased activation during both imagery and visual perception (e.g., Roland & Friberg, 1985). Event-related potential (ERP) techniques (Farah, Peronnet, Gonon, & Girard, 1988; Farah, Weisberg, Monheit, & Peronnet, 1989) and positron-emission tomography (PET) studies (Kosslyn et al., 1993) have also led to the conclusion that imagery engages processing in the occipital lobes. In addition, patient populations have shown patterns of performance that would be predicted by the view that the same neural mechanisms are involved in imagery and visual perception: Patients with cortical lesions show impairments in imagery as well as in performance on visual tasks (Farah, 1988, 1989; Farah, Soso, Dasheiff, 1992). In fact, Farah (1988) concluded that "for all the types of selective visual deficits due to cortical lesions in which imagery has been examined, parallel imagery deficits have been observed" (p. 312). All of the aforementioned studies converge on the idea that visual imagery and visual perception are at some level invoking some of the same processes.

On the basis of the body of evidence linking imagery and perception, we asked if imagery could be used to enhance cross-form (i.e., word-to-picture) priming. If subjects see words under standard instructions to study them or to rate their semantic properties and are transferred later to picture fragment identification, priming is negligible (Srinivas, 1993; Weldon & Roediger, 1987). But if subjects were instructed to form visual images of the pictures that correspond to the words, would priming be enhanced? The current experiments were designed to address this question.

According to the assumption that perceptual implicit memory tests are sensitive to the match between the physical forms of the study stimuli and test stimuli, a necessary condition for obtaining priming from imagery is that the image be relevant to the type of stimulus presented at test. That is, imaging pictures at study would enhance priming on a pictorial test but not on a verbal test. The imagery effect would be restricted to those conditions in which the processes involved in imaging more closely approximated the processes required by the test stimulus than did the processes involved in visually resolving the study stimulus. This hypothesis is in line with the theory of transfer-appropriate processing, which holds that performance on a test will benefit to the extent that the processes required by the test overlap those performed during encoding (see Morris, Bransford, & Franks, 1977; Roediger, 1990).

There is some evidence in the literature indicating that, at least in the verbal domain, imaging relevant objects can facilitate priming on implicit tests. However, the evidence is mixed. Jacoby and Witherspoon (1982) first reported such evidence; on a test of word identification (identification of words from very brief displays), hearing and then spelling a word produced .21 priming, compared with .30 priming from actually reading the word. It seems plausible that subjects imagined written forms of the words when spelling them; Jacoby and Witherspoon (1982) suggested that this might be the case. However, because they did not report the control condition of having subjects hear the word only (in the absence of instructions to spell the word), the precise effect of spelling cannot be ascertained from this study. In other similar experiments, though, hearing words produced no priming (.01) for high-frequency words and a small effect (.06) for low-frequency words on word identification (Jacoby & Dallas, 1981, Experiment 6). Donnelly (1988) found a similar effect in word fragment completion: Spelling of auditorily presented words at study produced .22 priming on a later word fragment completion test, compared with .27 priming in the visual condition and .16 priming in an auditory condition without spelling instructions (Donnelly, 1988, Experiment 4). However, in a direct test of the hypothesis that visual imagery mediates this effect, Donnelly (1988, Experiment 6) found no evidence for this: Subjects who heard words and formed images of the words as they would appear if they were typed exhibited a level of priming equivalent to those subjects who heard words in the absence of imagery instructions (.13 and .11 priming, respectively); visually presented words produced a higher level of priming (.23).

More promising evidence for the hypothesis that imagery can be sufficiently similar to perception to produce priming on word fragment completion comes from an experiment by Roediger and Blaxton (1987a, Experiment 1; see also Roediger et al., 1992, Experiment 1) in which word fragment completion was found to be primed more by hearing a word and forming an image of the typed word (.21 priming) than by simply hearing the word (.15 priming). In fact, priming in the imagery condition approximated that obtained by actually having seen the word (.24). In addition, Schacter and Graf (1989, Experiment 4) found that imaging the typed versions of auditorily presented word pairs enhanced priming to the level of visually presented words on a test of implicit memory for new associations (e.g., completing *mother–cal*____ with the first word that comes to mind after having studied word pairs such as *mother–calendar* or *officer–calendar*). Thus, from the foregoing studies, it seems as though imagery can facilitate priming in verbal tests, although not all researchers have obtained an effect.

Surprisingly, although imagery is more frequently studied with object and picture processing than with verbal processing, thus far all the implicit tests that have been used to examine priming from imagery have been verbal tests. The present studies were designed to examine whether (and under what conditions) imagery might be used to induce or enhance priming on a nonverbal implicit test (i.e., picture fragment identification).

Experiment 1

In the first experiment we used a picture fragment identification test to examine whether forming an image of a word's referent at study might facilitate priming relative to reading a word in the absence of imagery instructions. A subsidiary question was whether the facilitation would approximate that obtained from seeing the actual intact picture from which the fragment was constructed.

Subjects participated in one of three study conditions: (a) reading words and rating their pleasantness (hereafter called the *word condition*); (b) reading words, forming images of the words' referents, and rating their pleasantness (*word-image picture condition*); or (c) seeing pictures and rating their pleasantness (*picture condition*). After a brief distractor task, all subjects took an implicit test of picture fragment identification. The test phase was modeled after that used by Srinivas (1993); line drawings with some of the contours deleted were flashed briefly on a computer screen; the subjects' task was to identify the fragmented pictures as accurately as possible. If imagery involves processes similar to those used in perception, and if priming is sensitive to these higher order perceptual processes, then the condition in which subjects formed images of pictures should prime the picture fragment identification test. On the basis of past research (e.g., Srinivas, 1993; Srinivas & Roediger, 1990; Weldon & Roediger, 1987) and the theory of transfer-appropriate processing (Roediger, 1990; Roediger, Weldon, & Challis, 1989) we predicted that priming from the word condition would be absent or negligible and that priming from the picture condition would be highly reliable.

Method

Subjects and materials. Forty-eight undergraduates from Rice University participated for course credit or for money. Forty-eight items (concrete nouns and their corresponding line drawings) were taken from Srinivas's (1993, Experiment 1) selection of items; she obtained the items from the Snodgrass and Vanderwart (1980) norms and created picture fragments by deleting sections of contour from the pictures.

Design. The experiment comprised a 3 (study condition: word, word-image picture, or picture) × 2 (test condition: studied or nonstudied) mixed design. Study condition was manipulated between subjects (with 16 subjects in each group); test condition was manipulated within subjects.

Items were divided into four sets of 12 items each. Each subject studied two sets of these items (with sets and items within sets presented in a different random order for each subject) and was tested on the total pool of 48 items (also presented in a different random order for each subject). The two nonstudied sets that were tested served as the baseline measure from which priming was assessed. Item sets were counterbalanced so that each set served in the studied and nonstudied conditions an equal number of times across subjects.

Procedure. Subjects were tested in groups of 1 to 4 on IBM-compatible (386 SX, 20 MHz) computers; as in all experiments reported in this article, display of items was controlled by software from Micro Experimental Laboratory (Schneider, 1988). Sixteen subjects were assigned to each of the three study conditions (word, word-image picture, and picture). In the study phase, all subjects were told that they were participating in a series of short experiments, the first of which addressed the meaning and pleasantness of various items.

Subjects in the word and picture conditions were told that they would see a series of words (or pictures), and that each item would appear for 10 s. At the end of the 10-s period, a tone would sound indicating that it was time for them to rate the immediately preceding item according to how pleasant it seemed to them. They were told that this rating was to be done on a scale of 1 (*extremely unpleasant*) to 7 (*extremely pleasant*) and that they should enter their responses by pressing the appropriate key on the keyboard. Several examples were given, questions were answered, and then the study phase began.

Subjects in the word-image picture condition were told that they would see a series of words, each presented for 10 s, and that their task was to form an image or mental picture of the referent of each word. They were instructed to form an image of the most typical instance of that object that they could construe and to think of what a simple line drawing of that object might look like. They were told that at the end of the 10-s period, a tone would sound that would signal them to rate the pleasantness of the imagined item. Several examples were given and questions were answered before the study phase commenced.

Following the study phase, all subjects were treated identically. They participated in a 10-min distractor task in which they attempted to solve word fragments of the states of the United States. Then instructions for the picture fragment identification task were administered. Subjects were told that they were about to participate in a different experiment—one that involved perception. They were told that they would be presented with very brief presentations of fragmented pictures on the computer screen and that their job was to try to identify each picture; they were encouraged to write an answer on the response sheet for as many items as they could, even if they were only guessing.

Before each fragment was presented, a warning signal appeared for 2 s. Display times for the fragments were chosen so that the overall baselines would be approximately equal; fragments were displayed for either 100 ms or 200 ms followed by a 500-ms mask of concentric circles and then a prompt to write down the response. After the response was recorded on an answer sheet, subjects pressed a key on the keyboard to initiate the next trial. Subjects were not informed that some of the fragments corresponded to items they had previously encountered; no mention was made of any relation to the first phase of the experiment.

Results and Discussion

Priming scores for the three study conditions and their nonstudied base rates are presented in Table 1. Study of pictures transferred best to the picture fragment identification test (.22 priming), whereas the study of words produced negligible priming (.03). This outcome replicates past work (Srinivas, 1993; Weldon & Roediger, 1987). The finding of principal interest occurred in the condition in which subjects saw words and imaged their referents; substantial priming occurred in this condition (.11), although it was only half as much as that obtained from pictures.

Table 1
Overall Identification Rates and Priming Scores for Each Study Condition in Experiment 1

Study condition	Identification rates: Studied	Identification rates: Nonstudied	Priming
Pictures	.54	.32	.22
Words with imagery	.43	.32	.11
Words with pleasantness rating	.32	.29	.03

A 3 (study condition: word, word-image picture, or picture) × 2 (test condition: studied or nonstudied) mixed analysis of variance (ANOVA), with study condition serving as a between-subjects variable and test condition as a within-subjects variable, was performed on the data. The results of this analysis indicated a reliable main effect of study condition, $F(2, 45) = 4.96$, $MS_e = 0.025$, a reliable main effect of test condition, $F(1, 45) = 53.4$, $MS_e = 0.006$, as well as a significant interaction between the two, $F(2, 45) = 12.04$, $MS_e = 0.006$. (All results reported as reliable in this article are reliable at the .05 level of confidence. In addition, because priming effects were assumed to be facilitative, one-tailed t tests were used.)

The reliable effect of the interaction was predicted and indicates that the effect of test condition (i.e., studied–nonstudied, or level of priming) differed across study conditions. We tested simple main effects to determine which study conditions resulted in priming. As expected, reliable priming was found in the picture condition, $t(15) = 7.47$, and the word-image picture condition, $t(15) = 3.34$; however, priming in the word condition fell short of significance, $t(15) = 1.28$, $p = .11$. Planned comparisons showed that the word-image picture condition produced greater priming than the word condition, $t(30) = 2.08$, but less than the picture condition, $t(30) = 2.73$.

The critical result of Experiment 1 was the finding that subjects are able to generate pictorial images that prime picture fragment identification. To assure ourselves of the robustness of the phenomenon, we replicated the word-image picture condition twice, in Experiments 2A and 2B.

Experiments 2A and 2B

Experiment 2A was an exact replication of the word-image picture condition of Experiment 1. Experiment 2B was an exact replication with one exception: Instead of forming images of the words and rating them for pleasantness, subjects were instructed to form images and make ratings on the basis of vividness. We thought that this change in instructions might boost the effect of imagery because subjects would be required to inspect visual qualities of the image in making the judgments.

Method

Subjects and materials. Sixteen Rice University students participated in return for course credit or money in Experiment 2A; a different set of 16 students from the same subject population participated in Experiment 2B. In both experiments, materials were identical to those used in Experiment 1.

Design and procedure. All subjects participated in the word-image picture condition. As in Experiment 1, all materials were counterbalanced so that over subjects each item served as a studied and nonstudied item equally often. The procedure was the same as that for Experiment 1, except for there being only one study condition, not three. We did not include the other two conditions, because Srinivas's (1993) results and the results of Experiment 1 with these materials all consistently showed no priming from words and substantial priming from pictures. The only finding needing replication was priming in the word-image picture condition.

Results and Discussion

Results from the two experiments are summarized in Table 2. Priming occurred in both experiments (M = .06, SD = 0.11, and M = .08, SD = 0.12 for Experiments 2A and 2B, respectively), although it was not as large as that obtained in Experiment 1. Statistical analyses showed that priming was reliable in both experiments: $t(15)$ = 2.20 for Experiment 2A, and $t(15)$ = 2.53 for Experiment 2B.

Results from Experiments 1, 2A, and 2B indicate that imagery can be used to obtain perceptual priming. In Experiment 1, words presented in the absence of imagery instructions failed to produce reliable priming to the picture fragment identification task (replicating the work of Srinivas, 1993, Experiment 1), whereas words whose referents were imaged did produce significant priming. Attempts to boost this priming by changing study instructions from a semantic judgment (i.e., pleasantness rating) to a more perceptual judgment (i.e., vividness rating) were unsuccessful. The magnitude of the imagery effect was somewhat variable across the three experiments—.11, .06, and .08—for reasons we do not understand. However, it is reliably observed. Recall that no control was exerted over how closely subjects' images in the word-image picture condition matched those pictures from which the test fragments were obtained.

In Experiment 3 we changed the strategy by which we attempted to manipulate the amount of priming attained from imagery; instead of manipulating the instructions accompanying the imagery condition (pleasantness or vividness ratings), we focused on the test phase. Specifically, we tried to predict on what types of test stimuli effects of imagery on priming might be observed.

Experiment 3

The task of picture fragment identification originated as a technique for studying object recognition (Gollin, 1960; Leeper, 1935) and is still used for such research (Biederman, 1987; Biederman & Cooper, 1991). A number of researchers have proposed that perceptual priming is useful in object recognition (Roediger & Srinivas, 1993; Tulving & Schacter, 1990). If this is true, then theories of object recognition should be useful in predicting when priming will be observed.

Table 2
Identification Rates and Priming Scores in Experiments 2A and 2B

Experiment	Identification rates		Priming
	Studied	Nonstudied	
2A	.39	.33	.06
2B	.36	.28	.08

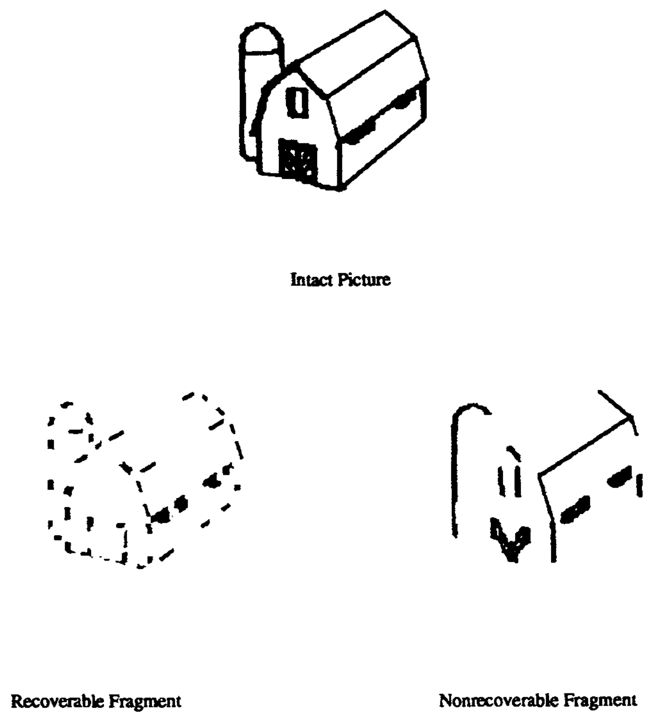

Figure 1. Example of an intact picture with its recoverable and nonrecoverable fragments from Srinivas's (1993) set of materials. From "Perceptual Specificity in Nonverbal Priming" by K. Srinivas, 1993, *Journal of Experimental Psychology: Learning, Memory, and Cognition, 19,* p. 587. Copyright 1993 by the American Psychological Association. Adapted by permission of the author.

One important theory of object recognition is Biederman's (1987) recognition-by-components approach, which holds that objects are recognized by the parsing of whole objects into the component parts, or "geons" (the primitive geometric volumes), inherent in the objects. According to this view, priming in object recognition is the facilitated recovery of the component geons in an object. Therefore, study of a picture will transfer to a later test of picture fragment identification to the extent that the geons present in the former match those present in the latter.

To test this prediction, Srinivas (1993) created two types of fragment for each intact picture. One type of fragment, *recoverable* fragments in Biederman's (1987) terminology, permitted access to the geons comprising the picture because the deleted areas were not critical to recovery of the component parts. The second type, *nonrecoverable* fragments, had contours deleted at critical regions of concavity; the result is access to misleading geons when the contours are extended by principles of collinearity and curvature. Examples of the two types of fragment appear in Figure 1. (Srinivas, 1993, normed

Table 3
Response Rates and Priming as a Function of Type of Test Fragment and Study Condition for Experiment 3

	Recoverable			Nonrecoverable			Overall		
Study condition	Studied	Nonstudied	Priming	Studied	Nonstudied	Priming	Studied	Nonstudied	Priming
Word–image	.47	.34	.13	.30	.28	.02	.39	.31	.08
Word	.40	.36	.04	.26	.29	−.03	.33	.32	.01

these fragments and showed that they met the operational definition specified by Biederman, 1987: Increasing exposure time enhanced the proportion of recoverable fragments correctly identified but did not affect the proportion of nonrecoverable fragments that subjects could correctly name.)

We performed Experiment 3 to test the hypothesis that imagery would allow access to (at least some of) the component geons of the pictures and would therefore prime recoverable fragments but not nonrecoverable fragments. Imagery may involve constructing "percepts" from component parts of objects. Because images were to be prototypical, the subjects may use parts similar to those in recoverable fragments, but not nonrecoverable fragments. Therefore, some match between the geons existing in the imaged picture and the recoverable fragment could be expected, but little or no match between the imaged picture and the nonrecoverable fragment was likely. The mismatch between the geons in the intact pictures and the nonrecoverable fragments would result in little or no priming in this condition.

Method

Subjects. Thirty-two undergraduates and summer students at Rice University served as subjects in return for pay.

Materials. The materials for Experiment 3 were identical to those used in Experiments 1, 2A, and 2B, in which recoverable fragments were displayed for 100 ms and nonrecoverable fragments for 200 ms.[1] In addition, items were counterbalanced at study and test in the same way.

Design. A 2 (study condition: word or word-image picture) × 2 (study status: studied or nonstudied) × 2 (fragment type: recoverable or nonrecoverable) within-subjects design was used. As in the previous experiments, items were divided into four sets of 12 items each. Each subject studied two sets (one set in the word condition, and one in the word-image picture condition) and was tested on all four sets. Two of the sets of items were tested as recoverable fragments (one studied [either in the word or word-image picture condition] and one nonstudied), and two were tested as nonrecoverable fragments (one studied [either in the word or word-image picture condition] and one nonstudied). Thus, for half of the subjects, the word-image picture condition corresponded to items tested as recoverable fragments and the word condition corresponded to items later tested as nonrecoverable fragments, whereas for the other half of the subjects, the items in the word-image picture condition were tested as nonrecoverable fragments and those in the word condition were tested as recoverable fragments. As before, item sets and items within sets occurred in a different random order for each subject at study. In addition, items and fragment types occurred in a different random order for each subject at test. Sets were counterbalanced such that each served in each study and test condition an equal number of times. Items in a study condition occurred in a blocked fashion; order of study condition (word first, or word-image picture first) was counterbalanced across subjects. This factor did not influence the results and is not mentioned further.

Procedure. Subjects were tested in groups of 1 to 4 on IBM-compatible computers. They were first given instructions specific to the first block of the study phase: either word-image picture or word. That is, half of the subjects were told that they should form images of the words' referents (in the form of typical line drawings) and rate each for vividness. The other half were told simply to rate each item according to its pleasantness. Following the first block, the other set of instructions was given for the second block. Study instructions, the distractor phase, and the test phase were the same as those in Experiments 1, 2A, and 2B.

Results and Discussion

Results are summarized in Table 3. As in the previous experiments, forming images of words' referents promoted priming ($M = .08$, $SD = 0.20$) on the combined recoverable and nonrecoverable fragments, whereas rating words' pleasantness produced no priming ($M = .01$, $SD = 0.20$). However, when the results are broken down according to fragment type, it is evident that this overall effect in the imagery condition was due solely to priming of the recoverable fragments ($M = .13$, $SD = 0.15$), because negligible priming occurred to the nonrecoverable fragments ($M = .02$, $SD = 0.23$).

Statistical analyses confirmed the above description. The word-image picture condition produced reliable overall priming, $t(31) = 2.27$, whereas the word condition did not, $t(31) < 1$. However, a test of the difference between priming on the word-image picture and word conditions fell short of significance, $t(30) = 1.60, p = .06$.

When only recoverable fragments were examined, priming in the word-image picture condition was, of course, reliable, $t(15) = 3.50$, whereas no priming was observed in the word condition, $t(15) < 1$. In the nonrecoverable test condition, neither the word-image picture condition nor the word condition led to reliable priming, $ts(15) < 1$.

The results provide support for Biederman's recognition-by-components theory. Components of the images apparently overlapped sufficiently with those extracted from the recoverable fragments to produce priming on picture fragment identification. This overlap presumably did not occur in the nonrecoverable condition. That is, the nonrecoverable fragments gave rise to misleading geons, which did not overlap with the geons composing the images formed at study; therefore, no priming was observed.

[1] Both types of fragments were used in Experiments 1, 2A, and 2B, but we were unable to analyze for this factor in these experiments.

Experiment 4

Throughout this article, we have argued that the reason that imagery instructions enhance priming on the implicit tests is that the processes invoked during imagining overlap sufficientlywith those used during perceiving to produce priming. However, one could argue that the effect of imagining pictures at study on later picture fragment identification is due to a general memory enhancement from imagery and not to a specific perceptual effect. That is, perhaps all memory tests would be enhanced by subjects' forming images of referents (relative to subjects' simply performing a semantic analysis). Experiment 4 was designed to rule out such an explanation.

We designed Experiment 4 to show the perceptual basis of the imagery effect by demonstrating that imagining is effective in perceptual priming only when the image formed more closely matches the test cue than does the form of the study stimulus. Thus, as before, we expected the word-image picture condition to prime picture fragment identification. However, we added a condition in which the picture was presented and subjects were told to image what the corresponding word would look like if it were typed. This condition was not expected to raise priming on the picture fragment identification test above that achieved by a picture condition (i.e., the extra processing engendered by imagining a word should not affect priming on picture fragment identification if it is only imagining relevant scenes that enhances priming and not just any extra cognitive effort; see, too, Watkins, Peynircioglu, & Brems, 1984).

In addition, a verbal perceptual implicit test was added in Experiment 4 as a comparison test. Different predictions were made for this test. Reading the word at study should produce substantial priming on this test, and the priming should be insensitive to conceptual elaboration. Because forming an image of a picture would not increase the perceptual similarity of study and test items (relative to simply reading the word), the word-image picture condition was not expected to aid priming (above that obtained in the word condition). Unlike on the picture fragment identification test, however, imaging the word when seeing the picture (a picture-image word condition) should increase the perceptual similarity of study and test items relative to seeing the picture, so the picture-image word condition was expected to prime word fragment completion.

Method

Subjects. Subjects were 240 U.S. Air Force recruits tested at Lackland Air Force Base. They participated as a requirement of their basic training.

Materials. Twenty critical items and their corresponding recoverable fragments were chosen from the 48 items used in Experiments 1 and 2. The item pool was restricted in this experiment so that all items were words with at least five letters. Items were divided into two sets (10 items per set). For each subject, one of the sets served in the studied condition (along with 15 filler items chosen from the remaining items in Srinivas's, 1993, set); these items were presented in a different random order for each subject. All 20 target items were tested, along with five additional fillers, which differed from the fillers used in the study phase. Items were presented at test in the same random order for each subject. The picture fragment identification test included only recoverable fragments.

Design. The experiment comprised a 2 (item format: picture or word) × 2 (study instruction: pleasantness rating or imagery-plus-vividness rating) × 2 (test type: word fragment completion or picture fragment identification) × 2 (study status: studied or nonstudied) design; study status was manipulated within subjects, whereas all other conditions were realized between subjects. Thus, 30 subjects served in each of the eight conditions.

Procedure. Subjects were tested in groups of about 40 on IBM-compatible (286 SX, 8 MHz) computers at Lackland Air Force Base by a tester who was completely unaware of the nature of the experiment; all instructions were presented via computer. Study instructions for each group were as follows.

Subjects in the word condition were told that they were participating in an experiment designed to assess people's comprehension of words, specifically, that the research dealt with the pleasantness of various words. They were told that they would see a series of words at a rate of 10 s per word. Their task was to think about the meaning of each word for 10 s, after which time a tone would sound that would signal them to make a rating of the pleasantness of the concept (with 1 being *extremely unpleasant* and 7 *extremely pleasant*). Ratings were made by typing in the appropriate number on the keyboard. Subjects were then given four practice trials and a summary of the instructions, and then the study session began. (Items used in the practice trials were items taken from the Snodgrass and Vanderwart, 1980, norms and were not used later in the experiment.)

Subjects in the word-image picture condition were informed that they were participating in an experiment designed to assess people's imagery abilities. They were told that they would see words presented at a rate of 10 s per word; their task was to think of an image of the word's referent. They were told to think of a common black-and-white line drawing, such as might be found in a children's coloring book. They were to do this for the entire 10 s; at the end of this period, a tone would sound that would signal them to determine how vivid the image had been and to rate this vividness on a 7-point scale. Subjects were given two examples to guide what their images might look like and then two practice trials followed by a short summary of instructions. The study phase then began.

Subjects in the picture condition were told that they were participating in an experiment designed to assess people's comprehension of pictures, specifically, that the researchers were interested in comparing different pictures with respect to how pleasant people thought they were. The presentation rate (10 s per picture) and rating scale were explained. Subjects were then given four practice trials.

Subjects in the picture-image word condition were told that they were participating in a study designed to assess people's imagery abilities, specifically, that the researchers were interested in comparing pictures with respect to how well people could form mental images or mental pictures of the words that named them. Subjects were told that they would see a series of pictures, each presented for 10 s. During the 10 s, they were to think of what the word naming the picture would look like if it were typed on a piece of white paper. After the 10 s had elapsed, the computer would beep, which would be a signal to them to determine how vivid that image had been and to assign it a rating on a 7-point scale. They were then given four practice trials and a brief summary of instructions, and then the study phase commenced.

Following the study phase, all subjects received a 10-min distractor task in which they solved word fragments; this task was followed by test instructions. Subjects in the picture fragment identification condition were given instructions comparable to those in the previous experi-

Table 4
Response Rates and Priming as a Function of Study Condition and Test Type for Experiment 4

Study condition	Word fragment completion			Picture fragment identification		
	Studied	Nonstudied	Priming	Studied	Nonstudied	Priming
Word	.65	.39	.26	.31	.32	−.01
Word–image picture	.62	.39	.23	.37	.29	.08
Picture	.32	.31	.01	.50	.29	.21
Picture–image word	.47	.39	.08	.50	.28	.22

ments.[2] Subjects in the word fragment condition were told that they would be given a series of word puzzles to solve. Each would appear on the screen in the same order as on their test sheet. The word fragments would remain on the screen for 20 s each, after which a tone would sound. Subjects were to fill in the letters on the test sheet if they could think of a word that fit the cue. If the tone sounded before they had solved the fragment, they should begin work on the next fragment. They were told not to work ahead or go back to any unsolved fragments but instead to keep pace with the computer.

Results and Discussion

Results are summarized in Table 4. As predicted, items in the word condition primed the word fragment completion test ($M = .26$, $SD = 0.20$) but not the picture fragment identification test ($M = .01$, $SD = 0.14$). Likewise, items in the picture condition primed the picture fragment identification test ($M = .21$, $SD = 0.24$) but not the word fragment completion test ($M = .01$, $SD = 0.18$). This pattern replicates the work of Weldon and Roediger (1987, Experiment 4), except that they obtained slightly greater cross-form priming.

The results of greatest interest occurred in the other two study conditions. As in the previous experiments, the word-image picture condition produced priming on the picture fragment identification test ($M = .08$, $SD = 0.18$). However, in the word fragment completion test, this study condition did not raise priming above that observed in the word condition. This finding is in accordance with the prediction that imagery exerts an effect on priming tests for perceptual reasons (i.e., similarity in perceptual processes between the image formed at study and the test fragment); the facilitation is not due to general elaborative processing.

As predicted, the picture-image word condition produced the opposite pattern of results. Imaging a word was sufficiently similar to reading a word to produce priming ($M = .08$, $SD = 0.20$) on the word fragment completion test. However, in line with the argument that this effect is perceptual in nature, this study condition did not raise priming scores in the picture fragment identification test above those obtained in the picture condition.

Statistical analyses confirmed the foregoing summary. Reliable priming on the word fragment completion test was found in the word condition, $t(29) = 9.49$, and the word-image picture condition, $t(29) = 7.22$, but did not differ between these conditions, $t(58) < 1$. Reliable priming also occurred in the picture-image word condition, $t(29) = 2.04$, but not in the picture condition, $t(29) < 1$. Although the picture-image word condition did produce reliable priming, it was not as great as that in the word condition, $t(58) = 4.19$, and it fell short of being reliably greater than that found in the picture condition, $t(58) = 1.18, p = .12$.

On the picture fragment identification test, reliable priming was identified in the word-image picture condition, $t(29) = 2.31$, the picture condition, $t(29) = 4.74$, and the picture-image word condition, $t(29) = 5.86$. Although the word-image picture condition did produce reliable priming, it was not as great as that obtained in the picture condition, $t(58) = 2.41$, but it was reliably greater than that in the word condition, $t(58) = 2.06$.

Analyses based on item variability demonstrated a pattern of results consistent with the foregoing analyses. To summarize, reliable priming was found on the word fragment completion test in the picture-image word condition, $t(19) = 2.20$, but not the picture condition, $t(19) < 1$. However, as found in the above analyses, priming in the picture-image word condition, although reliable, fell short of being reliably greater than priming in the picture condition, $t(38) = 1.06$. On the picture fragment identification test, priming in the word-image picture condition was significant, $t(19) = 2.3$, and it was significantly greater than that in the word condition, $t(38) = 1.80$, which did not produce reliable priming, $t(19) = 0.28$.

Overall, the results of Experiment 4 support the claim that the effects of imagery on perceptual implicit tests are due to the perceptual nature of imagery and cannot be attributed to a general factor of more elaborate encoding. Imaging words when presented with pictures enhanced priming on a word fragment completion test but not on a picture fragment identification test. Conversely, imagining pictures when presented with words enhanced picture fragment identification priming but not word fragment completion priming.

General Discussion

The experiments reported here produced three primary new findings. First, when subjects were presented with words and instructed to imagine the corresponding pictures, reliable

[2] However, because display times for Micro Experimental Laboratory depend on processor speed and because we used relatively slow machines in this experiment, items were actually presented for a longer duration than in previous experiments. Thus, although the program was written to display picture fragments for 100 ms, the fragments actually appeared on the screen for more than 100 ms. Nevertheless, the base rates in this experiment were comparable to those in the previous experiments; therefore, our data are not compromised by this change.

priming was obtained later on a picture fragment identification test. In addition, this imaginal priming was greater than that obtained from the words when the encoding orientation involved rating their pleasantness. Priming from imagery, however, was found to be less than that obtained from subjects who viewed pictures during the study phase. The second principal result was that imagining pictures facilitated later identification of recoverable picture fragments but not nonrecoverable fragments (Experiment 3). The third main result was that imagining pictures (when presented with words) facilitated priming on picture fragment identification but did not facilitate priming on a word fragment completion test (above that in the condition in which subjects saw the words in the absence of imagery instructions). Similarly, imagining words (when presented with pictures) primed word fragment completion but did not facilitate picture fragment identification (above that in the condition in which subjects saw the pictures in the absence of imagery instructions).

The results summarized above support four points: (a) They back the claim made previously (Roediger & Srinivas, 1993; Roediger et al., 1989; Schacter, 1990; Tulving & Schacter, 1990; Weldon & Roediger, 1987) that priming on perceptual implicit memory tests is specific to conditions in which there is overlap in the perceptual processes performed during the study and test phases. (b) They show that perceptual priming need not be data-driven, or stimulus-driven in a strict sense; rather, higher order processes can invoke perceptual experiences that produce priming. (c) They lend further credence to the claim that the processes engaged in imagery overlap with those engaged in actual visual perception. (d) They suggest that implicit memory tests are not badly contaminated by intentional recollection. These four points are discussed in turn.

In Experiments 1, 3, and 4, no reliable cross-form priming was obtained (in the absence of imagery instructions), which indicates that priming on perceptual implicit memory tests is highly sensitive to the physical forms of the study and test stimuli. Specificity was observed both in manipulation of actual physical stimuli between study and test (pictures primed picture fragment identification, whereas words did not; words primed word fragment completion, whereas pictures did not) and in manipulations via imagery (imagining a picture when given a word enhanced picture fragment identification but not word fragment completion; imagining a word when given a picture enhanced word fragment completion but not picture fragment identification). Additional evidence for specificity of priming was exhibited in Experiment 3, in which it was found that imagining pictures primed later identification of recoverable picture fragments but not of nonrecoverable picture fragments. This finding is consistent with Biederman's (1987) recognition-by-components theory, which posits that recoverable fragments will be primed whenever the component geons of the studied picture match those of the test fragment. If we assume that subjects formed images of canonical pictures and that therefore some of the geons inherent in the images overlapped with those in the recoverable fragments, then priming should have occurred on the recoverable fragments. However, because nonrecoverable fragments give rise to misleading geons, the geons inherent in the images formed during the study phase likely did not match those abstracted in the test phase; therefore, no priming occurred in this condition.

It should be noted that Srinivas (1993) found that pictures primed nonrecoverable fragments. This finding is inconsistent with predictions she made based on the recognition-by-components theory and may, at first glance, seem incompatible with the results reported here. A plausible reason for this difference is that when subjects study the actual picture from which the nonrecoverable fragment is made, enough other features overlap between the picture and the fragment to support priming. Therefore, the specificity of perceptual priming can facilitate recovery of geons even from "nonrecoverable" fragments. Srinivas (1993, Experiment 2) presented evidence consistent with this hypothesis. For example, seeing a nonrecoverable fragment and its name at study produced greater priming on the nonrecoverable fragment at test than did seeing the intact picture (from which the fragment was constructed). The same pattern was found for viewing the recoverable fragment at both study and test. Thus, situations can be devised in which the importance of resolving component geons is overridden by perceptual specificity, or seeing the same stimulus at study and test. This reasoning suggests that if subjects could be induced to form images of the exact pictures from which the fragments were derived, imaginal priming to nonrecoverable fragments might be produced.

The second main conclusion that can be drawn from these results is that perceptual priming is not strictly data-driven, as was suggested by Roediger and Blaxton (1987b). For a picture-based test to be primed, it is not necessary that the picture be presented as a distal stimulus and driven through the perceptual system; instead, imaginal processes can sufficiently mimic those of perceiving for perceptual priming to occur. Although inconsistent with the original terminology (involving data-driven processes), this finding is not inconsistent with the theory of transfer-appropriate processing as put forward by Roediger and his colleagues (see Roediger, 1990). Perceptual priming is sensitive to the form of the study and test stimuli, as predicted, but higher level perceptual processes can also exert an influence over and above the match between physical stimuli at study and test.

The findings reported here have implications for the study of imagery and its relation to perception. They are consistent with theories that postulate an overlap in the mechanisms involved in imagery and perception (e.g., Farah, 1988; Finke, 1980). Overall, imagery appropriate to the later test primed fragment identification, but not to the extent that was observed from perceiving the stimulus. On the basis of Experiment 1, one might attribute the imagery–perception difference to the possible mismatch between the pictures imaged and the pictures from which the fragments were obtained (because the pictures viewed at study were the same pictures from which the fragments were obtained). However, the results of Experiment 4 seem to challenge this claim. We would expect that when subjects are presented with pictures and told to imagine typed words, there would be a high level of match between imagined stimuli and the actual stimuli from which the word fragment test was constructed; furthermore, we would expect the match to be greater in the picture-image word condition than in the study–test condition in which subjects were given words and told to imagine pictures before being tested on picture fragment identification. That is, there would seem to be less room for variability in images in the picture-image word condition than in the word-image picture condition. However, cross-form imaginal priming did not differ for picture fragment identification and word fragment completion. That is, the word-image picture condition produced .08 priming on picture fragment identification; equivalent priming was obtained from the picture-image word condition to word fragment completion. Thus, it seems as though imagery, although perceptual in nature, produces less powerful effects than actual visual presentation. Imagery apparently involves a weak arousal of relevant perceptual processes.

One interesting aspect of the experiments reported here is that they seem less vulnerable to the criticisms often levied against work investigating the imagery–perception relation; this is especially true of Experiments 3 and 4. Farah (1988) posited that most of the imagery–perception findings in cognitive psychology are susceptible to explanations of tacit knowledge of subjects or experimenter bias. It would seem a far stretch to argue that tacit knowledge of subjects could produce results such as those in Experiment 3, in which imagery primed recoverable fragments but not nonrecoverable fragments. Also, in Experiment 4, a between-subjects design was used; therefore, subjects had no knowledge of other study conditions or test conditions in the experiment. In addition, implicit tests were used, so intentional recollection was less likely to have affected the results. Finally, both study and test instructions were presented via computer, thus controlling for experimenter bias.

The final main point made by the data reported here is that implicit tests may not be as susceptible to contamination by intentional recollection as many researchers claim (e.g., Jacoby, Toth, & Yonelinas, 1993; Toth & Hunt, 1990). Seeing a word and rating its pleasantness never produced reliable priming on the picture fragment identification test. Seeing a picture and rating its pleasantness did not produce reliable priming on the word fragment completion test. If intentional recollection had been invoked during these tests, we would have seen cross-form priming on all tests. For example, Weldon et al. (1989) showed that when subjects were given word fragments or word stems as retrieval cues under explicit test conditions, recall of pictures was far above baseline performance. Weldon, Roediger, Beitel, and Johnston (1993) replicated this result in word fragment completion and extended it to picture fragment cued recall: When subjects were given picture fragments with instructions to recall items from the study phase, they were able to recall words at a rate significantly above the base rate. Thus, cross-form recall is possible. Therefore, when cross-form priming does not occur, we can conclude that subjects have not invoked recollective strategies. Additional evidence that intentional recollection was not invoked on the priming tests is that imagery produced selective facilitation: Imagining pictures primed picture fragment identification but not word fragment completion, whereas the converse was true for imagining words (i.e., this process primed word fragment completion but not picture fragment identification). If subjects had invoked intentional recollection, one would expect to see the extra processing accompanying imagery produce general enhancement on all tests.

Our finding of imagining leading to perceptual priming is inconsistent with a hypothesis forwarded by Stadler and McDaniel (1990), who speculated that "when time and other events intervene, imagery does not prime perception" (p. 369). They based this claim on the observation that having subjects view a word presented in uppercase letters and imagine the word in lowercase letters (to count the number of ascenders and descenders) did not prime later perception of the word (counting the number of ascenders and descenders when the word was presented in lowercase letters). It is unclear why Stadler and McDaniel did not obtain priming in this paradigm; perhaps the fact that actual visual perception did not produce large amounts of priming (34 ms) contributed to their failure to find reliable effects of imagery. We did obtain priming from imagery to perception with a time delay and distractor task intervening between prime and target, contrary to Stadler and McDaniel's (1990) hypothesis.

In sum, the experiments reported here demonstrate that perceptual implicit memory tests can be primed through the use of imagery and that this imagery effect is perceptual in nature (i.e., not due to a general enhancement from elaborative processing or from intentional recollection). The importance of the match between the image and the test stimulus remains to be examined. Another question for future research is whether imaginal priming varies as a function of individual differences in imagery ability. These issues will be examined in future research.

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Correction to Logan and Etherton

In the article "What Is Learned During Automatization? The Role of Attention in Constructing an Instance," by Gordon D. Logan and Joseph L. Etherton (*Journal of Experimental Psychology: Learning, Memory, and Cognition,* 1994, Vol. 20, No. 5, pp. 1022–1050), the Appendix on page 1050 was incomplete. The complete Appendix is presented here.

Appendix

Words Used in the Experiments

Metals	Countries	Vegetables	Furniture
Iron	France	Carrot	Chair
Copper	America	Peas	Table
Steel	Russia	Corn	Bed
Gold	England	Bean	Sofa
Aluminum	Germany	Lettuce	Desk
Silver	Canada	Spinach	Lamp
Tin	Italy	Asparagus	Couch
Zinc	Spain	Broccoli	Dresser
Brass	Mexico	Celery	Bureau
Lead	Ireland	Cabbage	Chest
Bronze	Japan	Cauliflower	Bookcase
Platinum	Sweden	Radishes	Cabinet
Nickel	Brazil	Potato	Davenport
Magnesium	Switzerland	Tomato	Footstool
Uranium	Norway	Cucumber	Buffet
Tungsten	Australia	Beets	Bench