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Effects of imagery on perceptual implicit tests of memory

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Rice University, 1994
RICE UNIVERSITY

EFFECTS OF IMAGERY ON PERCEPTUAL IMPLICIT TESTS OF MEMORY

by

KATHLEEN B. MCDERMOTT

A THESIS SUBMITTED
IN PARTIAL FULFILLMENT OF THE
REQUIREMENTS FOR THE DEGREE
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APPROVED, THESIS COMMITTEE

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ABSTRACT

Effects of Imagery on Perceptual Implicit Tests of Memory

by

Kathleen B. McDermott

Experiments reported here demonstrate that imagery can promote priming on perceptual implicit memory tests. In Experiment 1, when subjects 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 condition in which subjects performed a semantic analysis of words. Experiments 2a and 2b replicated the finding of imaginal priming. In Experiment 3, imaginal priming of picture fragment identification occurred for recoverable fragments, but not nonrecoverable fragments. Experiment 4 showed that the imagery effect was restricted to the imaged type of material: imagining pictures (when presented with words) primed picture fragment identification but not word fragment completion. Similarly, when pictures were presented, imagining the corresponding words primed word fragment completion but not picture fragment identification. Overall, results support the hypothesis that imagining engages the same mechanisms used in perception, thereby producing priming.
Acknowledgments

I am extremely grateful to Roddy Roediger for his advice and encouragement throughout all phases of this project. I would like to thank the other members of my committee, Randi Martin and Mike Watkins, for providing helpful comments on the thesis; additionally, I thank Jim Pomerantz for reading and commenting on an earlier version of the thesis. Finally, my friends (both at Rice and beyond) contributed in various ways, directly and indirectly, to the culmination of this project.
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Introduction

Over the past decade, researchers have been intensively studying a class of memory tests that seem to reflect different principles of learning and memory from the classic tests of memory; these new memory tests have been referred to as implicit tests (Graf & Schacter, 1985; 1987). In traditional paradigms of studying memory, subjects are given a set of materials (e.g. a list of words) to remember and later are asked to think back to that set and try to recall (or recognize) as many of the items as possible. That is, subjects are asked to intentionally retrieve the information encountered earlier. Such tests are termed explicit tests. Implicit tests differ from 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. That is, although the implicit test is ostensibly unrelated to other parts of the experiment, performance in the test phase (e.g. completing fragmented words: _ h _ m _ _ y) is facilitated by experiences in the study phase (e.g. rating the pleasantness of various words, one of which was chimney); the speed or accuracy of performance in the test phase is enhanced by the study phase, and this facilitation is termed priming. Because it is possible to perform the task without having encountered the study phase, intentional retrieval of recent events is not required to perform the implicit test. Of course, instructions given for implicit tests do not guarantee that subjects will not try to recollect items from the list when given test cues; further evidence is necessary. Roediger and McDermott (1993) list six types that may be used.

The first evidence leading to the distinction between explicit and implicit tests came from amnesic patients, who are largely unable to engage in intentional recollection yet show intact performance on implicit tests (Warrington & Weiskrantz, 1968, 1970; Graf,
Squire, & Mandler, 1984). Indeed, it has now been shown that implicit tests are impervious to a plethora of subject variables that do affect performance on explicit tests (see Tulving & Schacter, 1990); priming on implicit memory tests has been shown to be intact in the aged (Light & Singh, 1987; Howard, 1991), in children (Carrol, Byrne, & Kirsner, 1985; Naito, 1990; Greenbaum & Graf, 1989), in depressed subjects (Roediger & McDermott, 1992), in subjects under the influence of alcohol (Hashtroudi, Parker, DeLisi, Wyatt, & Mutter, 1984), and in patients under the influence of general anesthetics (Jelicic, Bonke, Wolters, & Phaf, 1992).

Researchers have identified two classes of implicit memory tests: perceptual and conceptual (Blaxton, 1985; 1989; Roediger & Blaxton, 1987; Tulving & Schacter, 1990). Perceptual implicit tests are those which 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 world 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). Roediger, Weldon, & Challis (1989) specified a set of converging operations for defining the two types of test. The primary one employed a Read/Generate manipulation; they classified as conceptual those implicit tests that reflect greater priming from generating a word from a conceptual clue than from reading a word in isolation. Conversely, they proposed that tests could be classified as data-driven (or perceptual) if reading a word in isolation produced more priming than did generating a word from a conceptual clue. Most commonly used implicit memory tests are perceptual in nature, and this type will be the focus of the present paper.
Characteristics of Perceptual Implicit Tests

Perceptual implicit tests differ from explicit tests not only as a function of subject variables, but also as a function of 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 (Paivio, 1971; Paivio & Csapo, 1973; Madigan, 1983).

The effects of independent variables on performance on perceptual implicit memory tests seem to be guided by two general principles: (1) Priming occurs to the extent that the physical features of the study stimulus and test stimulus match and (2) priming is little affected by processing strategies employed by subjects during the study phase. These two characteristics will be discussed in turn.

Specificity of priming

Findings such as the reversal of the picture superiority effect described above led some researchers to propose that most perceptual implicit tests are sensitive to the match of physical features between the study and test phases (Jacoby, 1983; Roediger & Blaxton 1987a, 1987b). Following Jacoby (1983), Roediger and Blaxton (1987a, 1987b) labeled these tests data-driven; they predicted that priming would occur when the data displays were similar between study and test because similar displays invoke similar cognitive processes. According to this hypothesis, in the example presented above, greater priming occurs from words to word fragment completion than from pictures to word fragment completion because in the former, the physical displays (and hence the
cognitive processes used in recognizing them) are similar; likewise, minimal priming occurs from pictures to word fragment completion due to the mismatch in the physical features of the study and test stimuli. The reverse effect would be predicted on an implicit test of picture fragment identification, in which subjects are required to identify pictures from which contours have been deleted. (The pictures from which the fragments are constructed are the same pictures as those appearing in the study phase.) This prediction was borne out in another condition of Weldon and Roediger's (1987) Experiment 4: on a picture fragment identification test, pictures produced reliable priming (.17), whereas words did not (.03). Srinivas (1993) replicated this result.

Further evidence that a critical determinant of the level of priming achieved on perceptual implicit memory tests is the match of perceptual features between the study and test phases occurs in experiments employing a generate/read study manipulation. Using the implicit test of perceptual identification (i.e. identifying words from very brief displays), Jacoby (1983) found that generating words at study from antonyms (hot-XXX for COLD) produced no reliable priming (.04 averaged across Experiments 1-3), whereas reading words at study (COLD) produced substantial priming (.19 average). This basic finding of reading producing greater priming than generating has been replicated numerous times on tests of word fragment completion (Blaxton, 1989; Smith & Branscombe, 1988; Srinivas & Roediger, 1990), word stem completion (Bassili, Smith, & MacLeod, 1989; Tajika & Neuman, 1992), and perceptual identification (Schwartz, 1989; Weldon, 1991). The finding of reading words producing performance superior to generating words, like the reversal of the picture superiority effect discussed previously, is remarkable in that generation produces much better performance than reading on explicit tests such as free recall (Slamecka & Graf, 1978; Blaxton, 1989), cued recall (Blaxton, 1989) and recognition (Jacoby, 1983). According to the claim that a defining feature of perceptual implicit tests is their sensitivity "to the
match in surface characteristics of presentation format between study and test,"
(Roediger & Blaxton, 1987a, p.386), the finding that reading an item produces greater
priming than generating an item from a conceptual clue occurs because reading a word in
isolation, like the visual implicit memory tests, requires bottom-up analysis of the visual
features of a word, whereas generating lacks this perceptual component.

A third study manipulation that has been used to investigate the importance of
physical displays in perceptual priming is the language of presentation for bilingual
subjects. This manipulation can be used to present the same concept in one of two verbal
ways, depending on language of study presentation. Durgunoglu and Roediger (1987;
see also Watkins & Peynircioglu, 1983) obtained no reliable cross-language priming on a
word fragment completion test; when bilingual subjects studied words in either English
or Spanish and then were tested on English word fragments, no reliable cross-language
priming (.05) was obtained, whereas same language priming was reliable (.25). In free
recall, there was a tendency for the reverse pattern: words presented in Spanish were
slightly better recalled than those presented in English (.23 and .16, respectively).
Additionally, although within-language priming is observed on a lexical decision test, no
cross-language priming is commonly found (Kirsner, Brown, Abrol, Chadha, & Sharma,
1980; Scarborough, Gerard, & Cortese, 1984). Most of the literature on cross-language
priming supports the claim that sharp specificity is found in these situations (although see
Smith, 1991, for an exception).

In summary, results obtained from studies employing the three study manipulations
reviewed above (picture/word, generate/read, first/second language for bilingual
subjects) are generally consistent with the claim that perceptual implicit memory tests are
sensitive to the match in physical features of study and test displays: substantial priming
is obtained when the displays match, whereas little priming is obtained across different
forms of display.
**Subject strategies and priming**

A second general characteristic of perceptual implicit memory tests is their insensitivity to subject strategies during encoding. One of the best-established findings in the explicit memory literature is the effect of level of processing at study; attention to the semantic aspects of items generally produces better retention than attention to surface characteristics (Craik & Lockhart, 1972). Level of priming on perceptual implicit memory tests, however, has often been found to be invariant (or nearly so) across level of processing; this has been found on tests of perceptual identification (Jacoby & Dallas, 1981), word stem completion (Graf, Mandler, & Haden, 1982; Graf & Mandler, 1984; Roediger, Weldon, Stadler, & Riegler, 1992), and word fragment completion (Roediger et al., 1992; but see Srinivas & Roediger, 1990 for an exception).

A second example of invariance of priming across subject strategies exists in experiments comparing intentional and incidental learning: whether subjects intend to learn a set of items or are exposed to them under the guise of performing some other task has no effect on level of priming on word stem completion (Greene, 1986; Roediger et al., 1992; Bowers & Schacter, 1992) and word fragment completion (Roediger et al., 1992; Neill, Beck, Bottalico, & Molloy, 1990), whereas intention to learn does affect performance on most explicit tests, including those with the same kinds of test cues (word stems or word fragments [see Roediger & McDermott, 1993, for a review]).

Rehearsal strategies performed during the study phase do not affect the level of priming obtained on perceptual implicit memory tests. Greene (1986) found that having subjects repeat words aloud for a rehearsal interval of 2 s and 10 s produced equivalent priming on a word stem completion test (.18 and .14, respectively); the same study manipulation exerted a reliable effect on word stem cued recall: the longer rehearsal interval produced a higher level of recall (.22 and .32, respectively).² (This is not surprising because overt repetition does not enhance priming; Challis and Sidhu [1993]
found that 16 massed presentations of a word produced a level of priming equivalent to that obtained by one presentation.) Therefore, study rehearsal is a third example of a subject strategy that does not affect level of performance on perceptual implicit memory tests.

A fourth example of the insensitivity of priming to processing strategies exists in the directed forgetting literature. No effect of directed forgetting has been obtained on word stem completion (Paller, 1990) and word fragment completion (Basden, Basden, & Gargano, 1993). MacLeod (1989) did find a small yet significant effect (5%) of directed forgetting on primed word fragment completion; the reason for this discrepant finding is unclear, but the effect was much greater on the explicit test of recognition (19%). Nevertheless, instructions to forget items after they have been encoded generally has been found to exert little influence on perceptual priming. Since subjects likely rehearse to-be-remembered words but not to-be-forgotten words, this finding supports the third conclusion, too. These four observations -- absence of effects of level of processing, intention to learn, rehearsal, and directed forgetting -- are consistent with the claim that priming on perceptual implicit tests is insensitive to subject strategies during encoding.

Thus, a variety of study/test manipulations have provided evidence for the claim that two principal characteristics of perceptual implicit memory tests are their sensitivity to the match in physical form of the study and test stimuli and their insensitivity to subject strategies during the study episode. In brief, if one sees a word or picture, then there is generally a fixed amount of priming on the relevant test (verbal or pictorial). Who the subjects are and how they process the material does not much matter.

Rationale for the Present Research

Although numerous studies have produced results consistent with this explanation of priming on perceptual implicit tests (e.g. Blaxton, 1989), other studies have demonstrated that a match between the physical aspects of stimuli (and the accompanying low-level
perceptual processes invoked by these stimuli) is not the only way in which perceptual implicit tests can be primed. That is, although the tests are sensitive to the form of the stimuli, some cross-form priming often occurs. Why is a small (albeit usually nonsignificant) amount of priming often obtained following manipulations in which the surface features of the study and test stimuli do not match? For example, seeing a picture often produces some small amount of priming to the corresponding word fragment (Weldon & Roediger, 1987; Weldon & Jackson-Barrett, 1993). Additionally, auditorily-presented words usually prime verbal implicit memory tests when the test stimuli are given visually (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. Weldon, 1991; 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 de-emphasize the importance of "data-driven" processes in obtaining perceptual priming, stressing the importance of the (more ambiguous) "perceptual" processes (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, maybe subjects could imagine a picture when given a word and thereby enhance this pictorial priming.

The basis for the hypothesis that imagery might promote priming on perceptual implicit memory tests lies in the hypothesis that imagery and perception engage similar neural processes. Evidence supporting this view exists in several forms. Farah (1988, p. 307) notes 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 been around for many years, dating as 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's mental rotation studies (e.g. 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 degree rotation take longer to compare than those differing by 120 degrees). 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) has noted that two types of evidence for the imagery/perception relation exist in the neuropsychological literature: (1) evidence that imagery and perception share neural mechanisms and (2) evidence from patient populations that imagery and perception are functionally related.
Studies in which regional cerebral blood flow was traced have shown that the occipital lobes and posterior superior parietal and posterior inferior temporal areas show increased activation during both imagery and visual perception (Roland & Friberg, 1985; Goldenberg et al., 1992). Event-related potential (ERP) techniques have also led to the conclusion that imagery engages processing in the occipital lobes (Farah, Weisberg, Monheit, & Peronnet, 1989; Farah, Peronnet, Gonon, & Girard, 1988). Additionally, 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; Farah, Soso, Dasheiff, 1992; Farah, 1989). 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 the same processes.

Based on the body of evidence linking imagery and perception, we hypothesized that it might be possible to use imagery to mimic the perceptual processes required to obtain perceptual priming. Specifically, we hypothesized that 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). If subjects were instructed to form visual images of the pictures that corresponded 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 in physical form of the study 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 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 (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, as seen in Table 1. The table shows priming (i.e., facilitation over the nonstudied base rate) on verbal implicit memory tests in which study instructions accompanying auditorily-presented words have either asked subjects to spell the words or to imagine the words as they would appear typed. Jacoby and Witherspoon (1982) first reported such evidence; as seen in Table 1, on a test of perceptual identification (identification of words from very brief displays), hearing and then spelling a word produced .21 priming compared to .30 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 the words produced no priming (.01) for high frequency words and a small effect (.06) for low frequency words on perceptual identification (Jacoby & Dallas, 1981, Experiment 6). In other experiments, Donnelly (1988) found a similar effect in word fragment completion with the control condition included: as shown in Table 1, spelling of auditorily-presented
Table 1.

Priming on verbal perceptual implicit memory tests as a function of study condition.

<table>
<thead>
<tr>
<th>Reference</th>
<th>Auditory</th>
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<th>Visual</th>
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<tr>
<td></td>
<td>No Instruction</td>
<td>Image Typed</td>
<td>Spell</td>
<td>Typed</td>
<td>Nonstudied</td>
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<tr>
<td>Jacoby &amp; Witherspoon (1982)</td>
<td>----</td>
<td>----</td>
<td>.21</td>
<td>.30</td>
<td>.42</td>
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<tr>
<td>Donnelly (1988)</td>
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<tr>
<td>Exp't 4</td>
<td>.16</td>
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<td>.22</td>
<td>.27</td>
<td>.23</td>
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<tr>
<td>Exp't 6</td>
<td>.11</td>
<td>.13</td>
<td>----</td>
<td>.23</td>
<td>.20</td>
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<tr>
<td>Roediger &amp; Blaxton (1987)</td>
<td>.15</td>
<td>.21</td>
<td>----</td>
<td>.24</td>
<td>.27</td>
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<tr>
<td>Schacter &amp; Graf (1989)</td>
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<td></td>
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<tr>
<td>same context</td>
<td>----</td>
<td>.22</td>
<td>----</td>
<td>.17</td>
<td>.14</td>
</tr>
<tr>
<td>different context</td>
<td>----</td>
<td>.09</td>
<td>----</td>
<td>.11</td>
<td>.11</td>
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</table>
words at study produced .22 priming on a later word fragment completion test, compared to .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), 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 simply hearing the word (.15 priming). In fact, priming in the imagery condition approximated that obtained by actually having seen the word (.24). Roediger et al. (1992, Experiment 1) provided a conceptual replication and extension of this effect. They presented subjects with pictures, asking them to imagine the words corresponding to the pictures' referents and to count the number of ascenders (letters that rise above the midline of text [such as b,d,f]) and descenders (letters that fall below the line [such as g,j,p]) in each word. This condition produced reliably greater priming on both word fragment completion and word stem completion than a condition in which subjects performed a semantic analysis (i.e., rating pleasantness) on the pictures. Imagery in their experiments produced approximately half as much priming as did actually viewing the word from which the fragment was obtained. Additionally, 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 beginning with the letters cal 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 (Donnelly, 1988, Experiment 6).

Surprisingly, although imagery is generally more studied in the domain of objects and pictures than in a verbal domain, thus far all the implicit tests that have been employed 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 showed that when presented with words and instructed to image the corresponding pictures, subjects performed reliably better on the picture fragment identification test than when they saw words and were asked to rate them according to their pleasantness. Experiments 2a and 2b replicated the finding of reliable priming from imagining pictures to a picture fragment identification test. In Experiment 3, different types of test fragments were examined with respect to imaginal priming; one type of test fragment benefited from imaginal priming, whereas the other did not. Finally, in Experiment 4, it was shown that the effect of imagery is restricted to cases in which the match of physical features of the study and test stimuli are enhanced due to imagery. It should be noted at the outset that these studies were exploratory in nature; there was no attempt to control or determine how closely the pictorial images the subjects formed matched the actual pictures from which the picture fragments were constructed. Variables such as size, orientation, level of detail, viewing angle, and others were not specified. Thus, the domain (i.e., picture or word) in which the images should be formed was specified; details within domain (i.e. orientation), however, were left unspecified.
Experiment 1

The first experiment 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 if imagery did benefit priming, would the facilitation approximate that obtained from seeing the actual intact picture from which the fragment was constructed?

Subjects participated in one of three study conditions: (1) reading words and rating their pleasantness (hereafter called the Word condition); (2) reading words, forming images of the words' referents, and rating their pleasantness (Word-Image Picture condition); or (3) 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. Based on past research (e.g., Srinivas, 1993; Weldon & Roediger, 1987; Srinivas & Roediger, 1990), and the theory of transfer appropriate processing (Roediger, 1990; Roediger et al., 1989), it was hypothesized 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 & 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; and Picture) x 2 (test condition: studied; 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 4 sets of 12 items each. Each subject studied 2 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 2 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 computers. Sixteen subjects were assigned to each of the three study conditions (Word, Word-Image Picture, 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-second period, a tone would sound, signaling 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-minute distractor task in which they attempted to solve word fragments of the states of the U.S. Then instructions for the picture fragment identification task were administered. Subjects were told that they were about to participate in a different experiment--one which 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 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 baserates are presented in Table 2. 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 themselves.

A 3 (study condition: Word; Word-Image Picture; Picture) x 2 (study status: studied; nonstudied) mixed analysis of variance (ANOVA), with study condition serving as a between-subjects variable and study status a within-subjects variable, was performed on the data. The results of this analysis indicated a reliable main effect of study condition, $F(2, 45) = 4.96, MSe = .025$, a reliable main effect of study status, $F(1, 45) = 53.4, MSe = .006$, as well as a significant interaction between the two, $F(2,45) = 12.04, MSe = .006$. (All results reported as reliable in this paper are reliable at the .05 level of confidence. Additionally, 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 study status (i.e. studied-nonstudied, or level of priming) differed across study conditions. Simple main effects were tested 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, $t(30) = 2.73$. 
Table 2.

Overall identification rates and priming scores for each study condition in Experiment 1.

<table>
<thead>
<tr>
<th></th>
<th>Studied</th>
<th>Nonstudied</th>
<th>Priming</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pictures</td>
<td>.54</td>
<td>.32</td>
<td>.22</td>
</tr>
<tr>
<td>Words w/ Imagery</td>
<td>.43</td>
<td>.32</td>
<td>.11</td>
</tr>
<tr>
<td>Words w/ Pleasantness</td>
<td>.32</td>
<td>.29</td>
<td>.03</td>
</tr>
</tbody>
</table>
The critical result of Experiment 1 was the finding that subjects are able to generate pictorial images that prime picture fragment identification. In order 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 instead to form images and make ratings on the basis of vividness. It was 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 exactly 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 show no priming from words and substantial priming from pictures. The only finding needing replication is the finding of reliable priming in the Word-Image Picture condition.
Results and Discussion

Results from the two experiments are summarized in Table 3. Priming occurred in both experiments (.06 and .08 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 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 -- .11, .08, and .06-- 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 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 (Leeper, 1935; Gollin, 1960) and is still employed for such research (Biederman, 1987; Biederman & Cooper, 1991). A number of researchers have proposed
Table 3.

**Completion rates and priming scores in Experiments 2a and 2b.**

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Studied</th>
<th>Nonstudied</th>
<th>Priming</th>
</tr>
</thead>
<tbody>
<tr>
<td>Experiment 2a</td>
<td>.39</td>
<td>.33</td>
<td>.06</td>
</tr>
<tr>
<td>Experiment 2b</td>
<td>.36</td>
<td>.28</td>
<td>.08</td>
</tr>
</tbody>
</table>
that perceptual priming is useful in object recognition in the real world (Tulving & Schacter, 1990; Roediger & Srinivas, 1993). If this is true, then theories of object recognition should be useful in predicting when priming will be observed.

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, "geons" -- the primitive geometric volumes -- inherent in the object. 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 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.)

Experiment 3 was performed 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, there would be some match between the geons existing in the imaged picture and the recoverable fragment but little or no match between the imaged picture and the nonrecoverable fragment; the lack of match 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. Additionally, items were counterbalanced at study and test in the same way.

Design. A 2 (study condition: Word; Word-Image Picture) x 2 (study status: Studied; Nonstudied) x 2 (fragment type: Recoverable, Nonrecoverable) within-subjects design was used. As in the previous experiments, items were divided into 4 sets of 12 items each. Each subject studied 2 sets (1 set in the Word condition, and 1 in the Word-Image Picture condition) and was tested on all 4 sets. Two of the sets of items were tested as recoverable fragments (1 studied [either in the Word or Word-Image Picture condition] and 1 nonstudied) and two were tested as nonrecoverable fragments (1 studied [either in Word or Word-Image Picture], 1 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. Additionally, 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 will not be 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 was 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 4. As seen in the previous experiments, forming images of words' referents promoted priming (.08) on the combined recoverable and nonrecoverable fragments, whereas rating words' pleasantness produced no priming (.01). However, when the results are broken down according to fragment type, it is evident that this overall effect in the imagery condition is due solely to priming of the recoverable fragments (.13), because negligible priming occurred to the nonrecoverable fragments (.02).

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 just short of significance, $t(30) = 1.6$, $p = .059$. 
Table 4.

Response rates and priming as a function of type of test fragment and study condition for Experiment 3.

<table>
<thead>
<tr>
<th>Study</th>
<th>Recoverable</th>
<th>Nonrecoverable</th>
<th>Overall</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Studied</td>
<td>Nonstudied</td>
<td>Priming</td>
</tr>
<tr>
<td>Word-Image</td>
<td>.47</td>
<td>.34</td>
<td>.13</td>
</tr>
<tr>
<td>Word</td>
<td>.40</td>
<td>.36</td>
<td>.04</td>
</tr>
</tbody>
</table>
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 nor Word conditions led to reliable priming, $t(15)<1$.

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 comprising the images formed at study; therefore, no priming was observed.

Experiment 4

Throughout this paper, it has been argued that the reason that imagery instructions enhance priming on the implicit tests is that the processes invoked during imagining overlap sufficiently with those employed 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 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.

Experiment 4 was designed 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).

Additionally, 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 identification.

Method

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

Materials. Twenty-two critical items and their corresponding recoverable and nonrecoverable 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 5 letters. Items were divided into 2 sets (10 items/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 5 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) x 2 (study instruction: pleasantness or imagery-plus-vividness rating) x 2 (test type: word fragment completion or picture fragment identification) x 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 8 conditions.

**Procedure.** Subjects were tested in groups of about 40 on IBM-compatible computers at Lackland Air Force Base. The experimenter was completely blind to 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, 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, signaling 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. They were then given four practice trials, 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 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 what 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, signaling 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 peoples' comprehension of pictures; specifically, the researchers were interested in comparing different pictures with respect to how pleasant people think they are. The presentation rate (10 s/ picture) and rating scale were explained. They 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 peoples' imagery abilities. Specifically, 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, signaling them to determine how vivid that image had been and to assign it a rating on a 7-point scale. They were then given 4 practice trials, a brief summary of instructions, and then the study phase commenced.

Following the study phase, all subjects received a 10-minute distractor test in which they solved word fragments, followed by test instructions. Subjects in the picture fragment identification condition were given instructions comparable to those in the previous experiments. 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. They 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 5. As predicted, items in the Word condition
primed the word fragment completion test (.26) but not the picture fragment
identification test (-.01). Likewise, items in the Picture condition primed the picture
fragment identification test (.21) but not the word fragment completion test (.01). This
pattern replicates Weldon & Roediger (1987, Experiment 4), except they obtained
slightly greater cross-form priming.

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 (.08). 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
(.08) 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 on 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
Table 5.

Response rates and priming as a function of study condition and test type for Experiment 4.

<table>
<thead>
<tr>
<th>Study Condition</th>
<th>Word Fragment Completion</th>
<th>Picture Fragment Identification</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Studied</td>
<td>Nonstudied</td>
</tr>
<tr>
<td>Word</td>
<td>.65</td>
<td>.39</td>
</tr>
<tr>
<td>Word-Image Picture</td>
<td>.62</td>
<td>.39</td>
</tr>
<tr>
<td>Picture</td>
<td>.32</td>
<td>.31</td>
</tr>
<tr>
<td>Picture-Image Word</td>
<td>.47</td>
<td>.39</td>
</tr>
</tbody>
</table>
$t(58) < 1$. Reliable priming also occurred on the Picture-Image Word condition, $t(29) = 2.04$, but not from 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 on 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, $t(58) = 2.06$.

Overall, 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. Imagining words when presented with pictures enhanced priming on a word fragment completion test but not 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 priming was obtained later on a picture fragment identification test. Additionally, 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 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 the condition in which subjects saw the pictures in the absence of imagery instructions). These three results will be discussed in relation to contemporary issues in priming and imagery research.

The results summarized above support four points: (1) they back the claim made previously (Roediger & Srinivas, 1993; Roediger et al., 1989; 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; (2) 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; (3) they lend further credence to the claim that the processes engaged in imagery overlap with those engaged in actual visual perception; and (4) they suggest that implicit memory tests are not badly contaminated by intentional recollection. These four points will be discussed in turn.

In Experiments 1, 3, and 4, no reliable cross-form priming was obtained, indicating that priming on perceptual implicit memory tests is highly sensitive to the physical forms of the study and test stimuli. This 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 picture fragment identification of recoverable fragments but not of nonrecoverable fragments. This finding is consistent with Biederman’s (1987) theory of recognition-by-components, 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 therefore some of the geons inherent in the image overlapped with those in the recoverable fragment, then priming should have occurred on the recoverable fragments. However, because nonrecoverable fragments give rise to misleading geons, the geons inherent in the image 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 theory of recognition-by-components and may, at first glance, seem incompatible with the results reported here. A plausible explanation for this difference is that specificity of perceptual processes can override the influence of the match in recovered geons between study and test phases. That is, when the perceptual features of study and test stimuli match very closely, priming will occur, regardless of the recoverable/nonrecoverable status of the 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." 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 the processes of actual 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 forwarded by Roediger and his colleagues (see Roediger, 1990). It does not argue against the basic notion that perceptual priming is sensitive to the form of the study and test stimuli; instead, it points out that higher level perceptual processes can exert an influence over and above these factors.

The findings in the experiments reported here have implications for the study of the nature of the relation between imagery and perception. They are consistent with theories that postulate an overlap in the neural 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 in visual perception. On the basis of Experiment 1, one might attribute the imagery/perception difference to the possible mismatch in pictures imaged and the pictures from which the fragments were obtained (whereas, of course, in the Picture condition, the pictures viewed at study were the same pictures from which the fragments were obtained). However, the results of Experiment 4 seem to refute this claim: when presented with pictures and told to image typed words, subjects did not obtain any greater priming to word fragment completion than the Word-Image Picture condition primed picture fragment identification.
Presumably, there would be less variability between the perceptual features of imaged words and the actual typed words than between imaged pictures and the actual pictures employed in this study. Thus, if a mismatch in imaged pictures and the actual pictures used was the basis for the difference in picture fragment identification priming between the Picture and Word-Image Picture conditions, we would expect that the Picture-Image Word condition would produce greater priming to word fragment completion than did the Word-Image Picture condition to picture fragment identification; this did not occur. Thus, it seems as though imagery, while perceptual in nature, produces less powerful effects on picture priming at a later time 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) posits 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. Additionally, the tests were implicit in nature, so intentional recollection was less likely to have affected the results. Finally, the experimenter was blind to the nature of the experiment, and both study and test instructions were presented via computer.

The final main point made by the data reported here is that implicit tests may not be nearly as susceptible to contamination by intentional recollection as many researchers claim (e.g. Toth & Hunt, 1990; Jacoby et al., 1993). Seeing a word and rating its
pleasantness never produced reliable priming to 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 expect to have seen enhanced cross-form priming from this manipulation 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, and Beitel (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 significantly above the baserate. 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 producing general enhancement on all tests.

An additional interesting aspect of the results reported here is that our finding of imagining leading to perceptual priming is inconsistent with a hypothesis forwarded by Stadler & 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 upper case letters and imagine the word in lower case 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 lower case letters). It is unclear why they 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 the failure to find reliable imagery effects. We did obtain priming from imagery to perception with a time delay and distractor task intervening between prime and target, contrary to Stadler & McDaniel's (1990) hypothesis.

Brown, Neblett, Jones, & Mitchell (1990) questioned the validity of the entire literature that shows perceptual specificity effects on implicit tests of memory. They claimed that the experiments showing these results were flawed in that they consistently employed within-subjects designs; when Brown et al. (1990) used a between-subjects design, perceptual specificity effects disappeared. Specifically, they found that latency to name pictures was primed equivalently by prior naming of pictures and words in a between-subjects design. They then generalized to hypothesize that this problem would exist on all implicit tests. Experiment 4 provides clear evidence against this claim: in a between-subjects design, pictures primed picture fragment identification but not word fragment completion. Likewise, words primed word fragment completion but not picture fragment identification, also in a completely between-subjects design. Srinivas (1993) reported similar evidence.

Overall, 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 closeness with which imagined material resembles the priming test stimulus remains to be examined and will be addressed in future research. Additional research possibilities suggested by these results include the role of individual differences in imagery ability in predicting imaginal priming.
Footnotes

1. Recently, Masson and MacLeod (1992) have failed to find a difference between Read and Generate in perceptual identification, but the reason for their failure to replicate the effect is unclear (see Roediger & McDermott, 1993, for discussion).

2. An apparent exception to the generalization that rehearsal does not affect perceptual priming was reported by Watkins, Peynircioglu, and Brems (1984). They presented subjects with a picture and a word (the name of the picture) at study and then instructed subjects to rehearse one or the other (the picture or the word) for 15 s before the next pair of items was presented. Subjects were given a short practice sequence in which just four items were studied (one in the verbal rehearsal condition, one in the pictorial rehearsal condition and two with no rehearsal interval) and then a test was given. In this practice test, two rehearsed items were tested, both in the same form in which rehearsal had occurred (i.e. an item rehearsed verbally was tested verbally--with a word fragment-- and an item rehearsed pictorially was tested pictorially-- with a degraded picture); additionally, two nonstudied items were tested. One assumes that the relation of the test phase to the study phase would have been transparent to the subjects, and they were "led to expect that the practice study-test procedure would be a precise miniature version of that for the experiment proper" (p.555). During the experiment proper, subjects were instructed at the time of test that " in all cases, there task was the same: to try to identify the items of which the cues were fragments." (p.555)

Although this instruction is the same as that used in implicit memory tests, the overall instructional set probably induced subjects to use the test cues to recall items from the study list that were rehearsed in the same mode as the test cue (i.e. to use degraded pictures to try to recall items rehearsed pictorially and to use word fragments to try to recall items rehearsed verbally), and, failing that, to respond with the first item that came to mind. To put it in modern terms, subjects were likely adopting the strategy that
Jacoby, Toth, & Yonelinas (1993) call Inclusion: subjects should try to include studied items on the test, but failing that to respond with any item that occurs to them.

Although the Watkins et al. (1984) data are provocative, in order to draw firm conclusions for the implicit memory literature, it would be necessary to conduct the experiment under conditions such as Greene's (1986), in which the relation between the study and test was made less transparent. Although the Watkins et al. (1984) results show specificity of rehearsal under their test conditions, the question of interest in the present experiments is whether subjects can, when given just one form of an item at study (picture or word) imagine the other form (without its overt presentation) and whether this imagined form will enhance priming.

3. I would like to thank Kavitha Srinivas for making available to me the recoverable and nonrecoverable picture fragments that she created.

4. Both types of fragments were employed in Experiments 1, 2a, and 2b, but I was unable to analyze for this factor in these experiments.
References


