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Direct Comparison of Four Implicit Memory Tests

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Four verbal implicit memory tests, word identification, word stem completion, word fragment completion, and anagram solution, were directly compared in one experiment and were contrasted with free recall. On all implicit tests, priming was greatest from prior visual presentation of words, less (but significant) from auditory presentation, and least from pictorial presentations. Typefont did not affect priming. In free recall, pictures were recalled better than words. The four implicit tests all largely index perceptual (lexical) operations in recognizing words, or visual word form representations.

Implicit memory tests are those in which retention is measured indirectly by having subjects perform some task ostensibly unrelated to a prior study phase in the experiment (Graf & Schacter, 1985). Retention is indicated when performance on studied items exceeds that on similar items not presented in a prior study phase, a phenomenon commonly referred to as priming. For example, subjects might be exposed to a word such as *polliwog* during the study phase and then later be asked to identify the word from a brief display (a word identification test), to respond with the first word they can think of when provided with the first three letters (a word stem completion test), to complete a word puzzle such as p__l__iwo__ (a word fragment completion test), or to rearrange presented letters such as *olpliwgo* to form a word (an anagram solution test). Priming refers to better performance on studied than on nonstudied words in these tasks. These four implicit memory tests will be examined in the present research.

When subjects are given these sorts of tests, the instructions given to disguise the implicit nature of the tests do not guarantee that subjects will eschew the conscious use of memory in performing the task. However, one reason for suspecting that implicit tests measure something different from standard explicit memory tests such as recall or recognition is that often the two types can be dissociated. Independent variables may have a large effect on explicit tests and little or no effect on implicit tests (e.g., Jacoby & Dallas, 1981) or vice versa (Roediger & Blaxton, 1987a, 1987b). Similarly, subject variables (such as brain damage) may greatly affect performance on explicit tests but leave priming on implicit tests unaffected. (Reviews of this literature may be found in Richardson-Klavehn & Bjork, 1988; Roediger & McDermott, in press; Schacter, 1987; and Schacter, Chiu, & Ochsner, in press).

The typical experiment conducted in this area of inquiry uses the strategy of comparing one measure of explicit memory (usually recall or recognition) with one measure of implicit memory (priming on one of the four tasks described above is most common). This research strategy has produced many important findings but also has left the field with numerous puzzles. Researchers often seem to assume that if a dissociation can be produced between an explicit and an implicit measure, this result will generalize readily to other similar measures. However, it is well known that explicit memory measures can be dissociated (e.g., Blaxton, 1989; Morris, Bransford, & Franks, 1977; see Tulving, 1983, chap. 14, for a review), and the same seems to be true for implicit measures (Blaxton, 1989; Srinivas & Roediger, 1990; see Roediger, Srinivas, & Weldon, 1989, for a review). If this is so, one can have little confidence about generalizing from findings on one implicit test to another. Indeed, some researchers have concluded that there are important differences between implicit memory tests. For example, most researchers who have studied the effects of delay on primed word fragment completion have concluded that it lasts at least a week (e.g., Roediger & Blaxton, 1987a; Tulving, Schacter, & Stark, 1982) and perhaps much longer than that (Sloman, Hayman, Ohta, Law, & Tulving, 1988). On the other hand, priming effects in word stem completion usually disappear within two hours (Graf & Mandler, 1984; Squire, Shimamura, & Graf, 1987).

Noting such differences in duration of priming, Graf and Mandler (1984) suggested (a) that word stem completion may represent a purer measure of implicit memory, and (b) that word fragment completion may be compromised by subjects' use of explicit retrieval strategies. One difficulty in this conclusion, however, is that the experiments reviewed all involved between-experiments (and usually between-laboratories) comparisons, and so the experiments differed

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on many dimensions besides the type of implicit test used. When Roediger, Weldon, Stadler, & Riegler (1992) performed experiments directly comparing word fragment and word stem completion under implicit test conditions, no differences were found as a function of delay, level of processing, or type of materials (pictures or words). This direct comparison strategy to examine performance on implicit tests is the one used in the present research, because (in our opinion) it represents the best approach for determining similarities and differences between tasks.

Others have reached this same conclusion. In his 1987 review, Schacter stated that

> One of the most striking features of the historical survey and review of current research is the sheer diversity of implicit memory phenomena that have been observed. The fact that implicit memory has been observed across a wide variety of tasks and subject populations has both empirical and theoretical implications. On the empirical side, it seems clear that a critical task for future research is to delineate systematically the similarities and differences among the various implicit memory tests that have been used. Within the domain of repetition priming, for example, it would be desirable to further explore the relations among word stem and fragment completion, word identification, lexical decision, free association, and other implicit memory tasks; each of these tasks may be tapping different aspects of implicit memory (p. 512)

Thus, it seems fundamentally important for us to understand the nature of implicit memory tasks and to obtain more empirical information, collected under conditions in which tasks are directly compared, so that we can construct theoretical explanations for various dissociations observed in memory tasks.

Many different measures of implicit memory have been devised: Roediger and McDermott (in press) covered about a dozen in their review and omitted several in doing so. We can be certain that many more will be devised. Despite the abundant use of implicit memory tasks, only a few studies have attempted to compare these tasks within one experiment with extraneous factors controlled. These studies are reviewed briefly before the motivation for the current research is presented.

Weldon and Roediger (1987, Experiment 4) directly compared two implicit tests, word fragment completion and picture fragment naming. Subjects saw a list of words and pictures in the study phase, and either participated in the word fragment completion or picture fragment naming tasks. Prior study of words produced much greater priming on word fragment completion than did prior study of pictures; the opposite result was obtained in picture fragment naming. Weldon and Roediger interpreted these results within a transfer appropriate processing framework; prior study of pictures rather than words aided naming of fragmented pictures because processing operations engaged at the study and test phases were more similar when pictures and their fragmented forms were the study and test stimuli. A similar case can be made for the verbal stimuli. Impressive support for this transfer appropriate view came from later experiments that showed that when the actual word or picture fragment had to be decoded in the study phase, greater priming occurred on word fragment completion or picture fragment naming, respectively, than when the intact word or picture itself constituted the study material (see Gardiner, Dawson, & Sutton, 1989, for the case of verbal materials and Srinivas, 1993, for a corresponding example with pictorial materials). The results of Weldon and Roediger show how two implicit memory tests, both measuring a form of perceptual memory, can be dissociated. Nelson, Canas, Bajo, and Keelean (1987) have also shown that two implicit tests, fragment completion and stem completion (using end cues), dissociate as a function of meaning set size (determined by the number of words that subjects thought were related to the target words), although the two tasks behave similarly as a function of lexical set size (determined by the number of words that subjects thought sounded like the target words).

In a different type of study, Perruchet and Baveaux (1989) compared four implicit memory tasks. Subjects first studied a list of 120 words (e.g., *basket*) and later participated in two explicit- and four implicit memory tasks[1] (using 20 different studied items in each task) in the following order: recall, perceptual clarification (subjects attempted to identify words that were covered with a mask, which was gradually removed), word fragment completion, word identification, anagram solution, and recognition. Positive correlations were obtained among recall, recognition, perceptual clarification, and fragment completion measures. On the other hand, priming on word identification and anagram solution measures were positively correlated to each other but were unrelated to the other tasks. Although a comparison of several implicit memory tests yielded useful data, this study did not examine the effect of any independent variable on these tasks, nor were the test–retest reliabilities reported. Witherspoon and Moscovitch (1989) also found stochastic independence between priming in word fragment completion and priming in word identification. However, low correlations between tests might arise from unreliability of the test or from low variance in some of the measures (Ostergaard, 1992).

Blaxton (1989) examined the effect of modality of presentation (visual and auditory) on two implicit tasks—word fragment completion and answering general knowledge questions (subjects answered general knowledge questions to queries, the answers to some of which were presented in the study phase; for example, "What did Socrates drink at his execution?" Answer: Hemlock). Blaxton's results showed that modality of presentation influenced performance on word fragment completion (presumed to draw on perceptual processing) such that the greatest priming was obtained for visually studied items, and smaller (but significant) priming was obtained for auditorily studied items. However, this variable had no effect on priming on the general knowledge test, which requires conceptual processing. Thus, the modality variable produced a dissociation between two implicit memory tasks. These two tasks also dissociated as a function of

[1] For the implicit memory tasks, subjects were told that some of the items they would be presented with are studied words, but their task was to simply use the first word that came to mind to perform the respective tasks.

studying words by generating them (betrayal of one's country—t__________) or by reading them with no context (XXX-treason). The generation effect (better memory for generated than for read words) was obtained in the general knowledge test and was reversed for the word fragment completion test, where read items produced more priming than did generated items.

Srinivas and Roediger (1990) reported comparisons among three implicit memory tests—word fragment completion, anagram solution, and category association (in this task, subjects produce exemplars to given category names, and no reference is made to the study list that contained some of the exemplar names)—across different study conditions. Their results showed that anagram solution and word fragment completion are generally similar in nature. Both tasks showed the largest priming from visually studied words, smaller priming from auditorily studied words, and little or no priming from studied pictures. Also, both tasks showed a small levels-of-processing effect (i.e., better performance on items that were semantically rather than phonetically processed at study). On the other hand, the category association task behaved more like free recall, showing no effect of modality and a significant levels-of-processing effect. Again, these results indicate that dissociations can be obtained between implicit memory tests.

Weldon (1991, Experiment 1) compared two implicit tasks, word fragment completion and word identification, as a function of four study conditions. Subjects were presented with words visually, auditorily, or pictorially, or they generated the study words from semantic cues. Weldon reported maximal priming on both tasks for visually studied words. Although significant priming was obtained for auditorily studied and generated words, it was significantly less than the priming obtained for visually studied words. Pictures did not produce any priming in either of the implicit tasks. Note that Weldon's conclusions differ from the one Perruchet and Baveaux (1989) and Witherspoon and Moscovitch (1989) drew from their correlational analyses, that performance on word identification and word fragment completion were uncorrelated. Weldon, Roediger, and Challis (1989) also compared performance on two implicit tasks, word fragment and word stem completion, and found greater priming from studied words than from studied pictures on both tasks with both implicit and explicit instructions.

In the present experiment we were interested in examining performance on four commonly used verbal implicit memory tests (all believed to be largely perceptual in nature) as a function of three variables: symbolic form (word or picture), modality of presentation for words (visual or auditory), and typeface for visually presented words (same or different between study and test). The aim was to see if all four tests would be similarly affected by the variables. The rationale for the inclusion of each variable is provided next.

The symbolic form—study of words or pictures—has large effects on perceptual implicit tests. Very little priming occurs from pictures on verbal tests (Weldon, 1991; Winnick & Daniel, 1970) and from words on pictorial tests (Weldon & Roediger, 1987), though occasionally, priming from pictures on word fragment completion has been reliable (e.g., Weldon & Roediger, 1987). If these inconsistencies arise from cross-experimental comparisons and if these implicit tests are perceptual in nature, then the study of pictures should produce little priming on the four verbal tests that we examined.

Modality of presentation of words also has a sizable effect on most verbal implicit memory tests. In their reviews of the literature, Donnelly (1988) and Kirsner, Dunn, and Standen (1989) concluded that priming from auditory presentations averages about half that of visual presentations. However, the range of variation is often great: Jacoby and Dallas (1981) reported virtually no priming from auditorily presented words on a word identification test, and McAndrews and Moscovitch (1990) obtained the same outcome with an anagram-solution test. However, in studies of word fragment completion (e.g., Blaxton, 1989; Donnelly, 1988; Roediger & Blaxton, 1987a) and word stem completion (e.g., Graf & Mandler, 1984; Graf, Shimamura, & Squire, 1985) considerable cross-modal priming has been reported. In fact, auditory priming has been reported for the word identification task (Kirsner, Milech, & Standen, 1983; Kirsner, Milech, & Stumpfel, 1986; Postman & Rosenzweig, 1956) and for the anagram-solution task (Srinivas & Roediger, 1990) too. An experiment in which cross-modal priming is directly compared across four tasks should prove to be informative as to whether prior differences are to be attributed to the tests per se or to differences in materials and other extraneous factors. For instance, Weldon (1991) found little difference in the magnitude of cross modal priming when she directly compared word identification and word fragment completion.

The final variable to be considered is typeface of visually presented words. The prior literature here is even messier than in the case of modality variations. The expectation is that providing the perceptual cue at test in the same typeface as the word at study will increase priming relative to the case when typeface changes. For example, Jacoby and Hayman (1987) found small but significant effects of rather large variations in typeface between study and test. Roediger and Blaxton (1987a) found similar effects in two experiments, and larger effects when they presented words either blurred or clearly (Experiment 3). However, in other experiments effects of typography have not appeared under similar conditions (Feustel, Shiffrin, & Salasoo, 1983; Graf & Ryan, 1990; Morton, 1979; Scarborough, Cortese, & Scarborough, 1977). In the present research we used a rather simple manipulation by having subjects study and be tested on words in either the same or different typefaces. The manipulation was rather small, but we thought that perhaps priming would vary on some tests (but not others) from this typeface manipulation.

In summary, four modes of presentation at study—visual-same type font (as test), visual-different type font (from test), auditory, and pictures—and four implicit memory measures at test—word fragment completion, word stem completion, word identification, and anagram solution—were included. One set of tested items was not included at study to measure performance on a nonstudied baseline. At test, all items were presented on the computer screen visually in a verbal form in all the implicit tests. Finally, we also included an explicit memory task, free recall, to replicate the well-established dissociation reported in the literature between free recall and the perceptual implicit memory tasks with our materials, procedure, and subject population. Ours is the first experiment to provide a direct comparison of four implicit memory tests under the same conditions.

Method

Subjects

One hundred ten Rice University and University of Houston undergraduates participated in this experiment in partial fulfillment of a course requirement. Subjects from both universities were randomly distributed across all five tasks.

Design

A 5 (study conditions: visual-same typeface, visual-different typeface, auditory, picture, and nonstudied) × 5 (test conditions: word fragment completion, word stem completion, word identification, anagram solution, and free recall[2]) mixed-factorial design was used in the experiment. Study conditions were manipulated within subjects, whereas test conditions were manipulated between subjects. Twenty subjects participated in each task except in the anagram solution task where 30 subjects were tested. One hundred critical items were selected, from which 20 items were randomly assigned to each study condition, and were rotated through the study conditions using a Latin square design, resulting in 10 study lists for complete counterbalancing. This design was used in all the tasks. At test, cues representing studied, nonstudied, and filler items were randomly presented, and the same random order was followed for all the implicit memory test lists.

Materials

One hundred 5–9-letter concrete words were selected from the Snodgrass and Vanderwart (1980) norms such that the pictorial representations provided for these words carried about 90% or higher name agreement according to the norms. The average frequency of these words was 29.7 per million (Kucera & Francis, 1967). All words were selected such that there was no overlap between the first three letters of any 2 words. This was necessary to ensure that in the stem completion task, each stem would complete only 1 of the target words in the pool of the 100 critical words used in this experiment (e.g., bas______). However, it should be noted that each stem offered multiple solutions outside the pool of the critical words. Word fragments were constructed by randomly deleting 40%–50% of the letters in the words (e.g., b__ __ke__). Anagrams were constructed by randomly scrambling the letters in a word (e.g., *asbekt*). Both the fragments and anagrams usually had only one solution, although some had more than one. All the words at study and at test were presented in lowercase letters. The set of 100 critical items used and their respective stems, fragments, and anagrams are presented in the Appendix.

A set of 20 practice items and 30 filler words were also selected and transformed appropriately for each test. In word identification, the intact filler words were interspersed throughout the list exactly as in the other three implicit memory tests. In addition, another set of 120 words, conforming to the same specifications of word length and frequency as the critical words, was selected to determine the exposure duration for threshold identification in the word identification test.

For the study phase, picture and word slides were used. For pictures, Snodgrass and Vanderwart's (1980) slides were used. For words, slides were prepared using 12-point Courier type for the visual-same typeface condition, and by handwriting in script style in approximately the same size for the visual-different typeface condition. For auditory presentation, the words were presented on a tape recorder in a female voice. For the test phase, in all implicit memory tasks, items were presented on the computer screen in 12-point Courier.

Procedure

Subjects were tested individually or in groups of 2 to 3. They were assigned randomly to each task as they reported for the experiment. For all the tasks the items were presented in the following manner in the study phase. Subjects received 20 items blocked together in each study condition, and the order of conditions at study was balanced across subjects. Items were presented at the rate of 6 s per item, both in the auditory presentation and in the visual presentation conditions. Slides were advanced manually with timing by a stopwatch, with a 0.75-s interslide interval. Subjects were required to judge the pleasantness of the meaning of each item presented on a scale ranging from *the least pleasant* (1) to *the most pleasant* (5). No mention was made of the test phase. After the study phase, a 5-min distractor task followed in which subjects wrote as many names of U.S. Presidents as possible.

The procedure in the test phase varied for subjects depending on the particular task in which they participated. The presentation of test items and the collection of responses in all four implicit tests were controlled by a program written in the Turbo Pascal programming language and run on IBM (AT)-compatible computers. In all cases, subjects responded to studied (20 items from each study condition) and nonstudied items (i.e., 20 target items for the nonstudied baseline, 30 filler items, and 20 practice items). In the word fragment completion, word stem completion, and anagram solution tasks, subjects were asked to complete the fragments or stems, or to solve the anagrams presented, one at a time, with the first word that came to mind. No mention was made of a relation between test items and the prior study phase. On each trial, a warning signal ("--- ---") was first presented for 2 s. This was followed by a fragment presented for 15 s. Subjects were required to press a key labeled "Y" as soon as they had a solution for the word, and they were then prompted to type their solution. If subjects failed to respond to the test item in 15 s, the computer timed out that trial, and subjects pressed a key to initiate the next trial.

In the word identification task, subjects first participated in the threshold-setting phase before the study phase was administered. The threshold-setting phase was conducted before the study phase instead of the test phase to ensure that the duration of the distractor phase was held constant for all the tasks. At test, subjects were told that the effect of practice on threshold identification was being recorded. In the threshold-setting phase, subjects were presented with several lists of 20 words each. These words did not overlap with the critical set of 100 words, nor did they overlap with the practice and filler words used in the experiment. In addition, all

[2] We also included the lexical decision task as an implicit memory test in this experiment. However, we have not reported the results for this task because we failed to obtain priming in any of the study conditions either for the RT data or for the accuracy data. This was true in both the variations of the lexical decision task conducted—one using pronounceable nonwords and the other using unpronounceable nonwords. We have no ready explanation for this failure to obtain priming on the lexical decision task under our conditions.

these words conformed to the same range of length and frequency as the critical set of words. Each trial consisted of four stages—a warning signal ("--- ---") for 2 s, a forward mask ('XXXXXXXXX'), the to-be-identified word, and a backward mask ('XXXXXXXXX'). The use of a forward mask was necessary because in the pretesting sessions conducted with a different set of 15 subjects, the backward mask alone was not sufficient to reduce the baseline performance to approximately 50%. (High baseline performance may have been due to the high-resolution monitors used in the experiment.) We began with 500-ms exposure rate for the masks and a 50-ms exposure rate for the to-be-identified word. The same exposure duration was used for both the forward and the backward masks. Depending on the subject's performance with these parameters, we increased or decreased the mask exposure duration, the word exposure duration, or both until the subject identified between 20% and 70% of the words in a list of 20. After this threshold phase came the study phase and then the distractor phase.

In the test phase of the word identification test, subjects were asked to identify the items presented to them, and they were encouraged to guess if they were unsure. The time parameters for the forward and backward masks and the to-be-identified words were set for each subject on the basis of the threshold phase performance. On average, the forward and backward masks lasted 721 ms each and the target item was presented for 26 ms. Subjects were asked to type in their responses after the item disappeared from the screen. If the subjects had no response, they were asked to press the "Enter" key to get to the next item.

In free recall, subjects were simply asked to write down all the studied items (pictures and words) that they could remember. They were given 7 min to perform this task. At the end of their respective test phases, subjects were debriefed and thanked. The entire session took approximately 1 hr each for the four implicit memory tasks and 30 min for free recall.

Results

The mean proportion correct in each study condition for all five tests is provided in Table 1. Separate analyses were conducted for the five memory tests because different baselines that are typically obtained in these tests make interpretation of cross-test analyses difficult. These analyses are reported in separate sections before a final section directly comparing performance on the tests. Although reaction time (RT) data were collected for word fragment completion, word stem completion, and anagram solution tests, we have not reported them because of their great variability. In general, the RT data, although not always significant, paralleled the pattern of results obtained with accuracy data. The significance level was set at $p < .05$.

Free Recall

Recall performance was the highest for studied pictures (.39) and was roughly equivalent in the visual-same typeface, visual-different typeface, and auditory conditions (.30, .29, and .27, respectively). A repeated measures analysis of variance (ANOVA) including the four study conditions confirmed these observations, $F(3, 57) = 4.31$, $MS_e = .014$. The least significant difference (LSD) computed was .08. Thus, the performance in the picture study condition was significantly better than the performance on the other three study conditions, which did not significantly differ from one another. These free recall results confirm those of many others (e.g., Paivio, Rogers, & Smythe, 1968; Weldon & Roediger, 1987) and indicate that our set of materials is normal in this respect.

Word Fragment Completion

In this task, subjects completed .30 of the nonstudied items. Relative to this baseline performance, the greatest amount of priming was obtained in the visual-same typeface (.14) and visual-different typeface (.15) conditions. Priming in the cross-modality conditions was relatively lower, with .06 priming in the auditory condition and .04 priming in the picture condition. A repeated measures ANOVA including all five study conditions (i.e., including the baseline nonstudied condition) yielded significant results, $F(4, 76) = 9.68$, $MS_e = .009$, and the LSD computed for this analysis was .06. Thus, the priming was significant for both visual conditions and for the auditory condition, but not for the picture condition. It should be noted that the priming obtained in the visual-same typeface and visual-different typeface conditions did not differ and that priming in both these conditions was significantly greater than that obtained in the auditory and picture conditions, which did not differ.

Word Stem Completion

The nonstudied stem completion rate was .31. Relative to this baseline, a greater proportion of stems was completed for

Table 1
Proportion Correct Data for Tasks as a Function of Study Conditions

	Type of task				
Study condition	Free recall	Fragment completion	Stem completion	Anagram solution	Word identification
Visual-same typeface	.30	.44	.49	.63	.50
Visual-different typeface	.29	.45	.45	.62	.55
Auditory	.27	.36	.36	.59	.47
Picture	.39	.34	.32	.54	.46
Nonstudied	0	.30	.31	.52	.43
Least significant difference	.08	.06	.05	.07	.06

items studied in the visual-same typeface condition and visual-different typeface condition, which gave rise to .18 and .14 priming scores, respectively. The priming score obtained in the auditory condition (.05) was lower than the two visual conditions, and no priming was observed in the picture condition (.01). A repeated measures ANOVA including all five study conditions yielded significant results, $F(4, 76) = 17.68$, $MS_e = .007$, and an LSD score of .05. This value indicates that the priming obtained in the visual-same and visual-different typeface conditions was significant and roughly equal. The priming score obtained in the auditory condition just reached the level needed for statistical significance, whereas picture priming was not significant. The priming scores obtained in both the visual conditions were reliably higher than the priming scores obtained in the auditory and the picture conditions.

Anagram Solution

As noted in the Method section, we tested 30 subjects in this task as opposed to 20 subjects as in all the other tasks. This was because there was greater variability in performance on this task relative to the other implicit memory tasks used in this experiment. Srinivas and Roediger (1990) reported a similar result.

The anagram solution score in the nonstudied condition was .52. Relative to this condition, priming was observed in the visual-same typeface (.11) and the visual-different typeface (.10) conditions. A smaller amount of priming was obtained in the auditory condition (.07), and little or no priming occurred in the picture condition (.02). A repeated measures ANOVA conducted with all five study conditions was significant, $F(4, 116) = 4.16$, $MS_e = .016$, and an LSD score of .07 was obtained. Thus, the priming scores obtained in the visual-same typeface, visual-different typeface, and the auditory conditions were significant, whereas the priming in the picture condition was not. The performance in the visual-same typeface and the visual-different typeface conditions was once again equivalent. Although the priming scores in the visual-same typeface and the visual-different typeface conditions were numerically higher than the priming score in the auditory condition, this difference was not statistically significant.

Word Identification

As described in the Method section, the exposure durations of the masks and the target words were systematically varied in the threshold-setting condition to obtain reasonably low baseline identification performance. Because individuals differ in their threshold for identification, the baseline performance varied within a range of .21 and .45 across subjects, with a mean identification rate of .33 in the pretest. However, in the test phase, the identification performance for the nonstudied condition was .43. This higher rate may have been due to practice, but nonetheless the baseline completion rate was in the range of baseline rates for the other tasks.

The identification rates in the visual-same typeface condition and the visual-different typeface condition were higher than the baseline, yielding priming scores of .07 and .12, respectively. The auditory and picture conditions produced priming scores of .04 and .03, respectively. A repeated measures ANOVA including all study conditions yielded significant results, $F(4, 76) = 3.79$, $MS_e = .011$, with an LSD score of .06. This LSD score indicates that the priming scores obtained in both the visual-same typeface and the visual-different typeface conditions were significant, whereas those in the auditory and picture conditions were not. Priming in the visual-different typeface condition differed significantly from that in the auditory and picture conditions, but priming in the visual-same typeface condition did not differ from the priming in any of the other study conditions.

The surprising outcome here is that visual word priming was numerically greater in the visual-different typeface than in the visual-same typeface condition. To check this anomaly, we tested 16 additional subjects in the word identification task. However, instead of using the same study conditions as in the main experiment, we introduced a minor variation in the study conditions used in this task. For these additional subjects, we presented the items in three study conditions—visual-same typeface on the computer, visual-same typeface on slides, and visual-different typeface on slides. At test, all the words were presented on the computer monitor. The rationale for using these study conditions was twofold: first, to see if we could replicate the curious finding of numerically larger priming in the visual-different typeface condition compared with the visual-same typeface condition and second, to see if identification performance would be affected by switching from a slide projector to a computer presentation, as has been informally reported (Jacoby & Witherspoon, 1982). Although this manipulation does not address the issue of higher priming in the visual-different typeface condition, it provided us with an opportunity to examine a potentially relevant variable to the issue of specificity of priming.

Subjects' identification performance in the threshold phase varied between .18 and .52, with a mean score of .35. (Average duration of the forward and backward masks was 624 ms each, with the target presented for 31 ms). This average identification performance is comparable with the score observed in the threshold phase of the previous administration of the task (.33). In the test phase, subjects' identification score in the nonstudied condition was .46, again comparable with the baseline performance (.43) in the main experiment. Priming occurred in all three study conditions: .12 for the visual-same typeface on the computer condition, .09 for the visual-same typeface on the slides condition, and .09 for visual-different typeface on the slides condition. A repeated measures ANOVA with the four conditions yielded significant results, $F(3, 45) = 3.26$, $MS_e = .014$, LSD = .08. This indicates that significant priming was obtained in all three study conditions, which did not differ among themselves.

The results of the second administration of the word identification task did not replicate the numerically larger priming obtained in the visual-different typeface condition relative to the visual-same typeface condition in the first administration of this task. We conclude that the anomalous result of the visual-different typeface condition producing numerically greater priming than the visual-same typeface condition in the main experiment was a fluke. In addition, priming obtained in the visual-same typeface on the computer condition was not significantly larger than the priming in the other two visual conditions in the second administration of the word identification task. These results indicate that the manipulation of typography did not influence priming in word identification.

Discussion

The aim of this article was to compare priming on four commonly used perceptual implicit memory tests as a function of variations in mode of presentation. The results obtained may be summarized as follows: (a) In all four tasks, the biggest priming effect was obtained in the within-modality conditions (i.e., visual-study and visual-test conditions); (b) cross-modal priming (auditory to visual) was reliably obtained for all tests, except for word identification, but its magnitude was reliably smaller than same-mode priming in all tasks except anagram solution; (c) no significant cross-form priming (pictures at study, words at test) occurred in any of the implicit memory tasks; (d) the manipulation of typography did not have an effect on any of the implicit memory tasks; and finally, (e) in free recall, the standard picture superiority effect was obtained, and performance did not differ among the other study conditions. Although pictures produced little or no priming on implicit tests, they led to the best free recall as compared with any of the other conditions.

The baseline performance of the four implicit memory tests differed over the range of .30 to .52. Snodgrass and Feenan (1990) have suggested a correction for such differences to permit cleaner comparisons across tasks. Their "relative priming" correction is to divide the priming score (proportion of studied items completed minus proportion of nonstudied items completed) by 1.00 minus the proportion of nonstudied items completed. In effect, this measure provides an estimate of the amount of priming relative to that possible given the baseline level of performance. The results of the four implicit memory tests expressed in this measure are shown in Figure 1. Although we did not statistically analyze these data, they are clearly telling the same story as the data in Table 1. In each task, greatest priming occurred for the visual conditions (combined across same and different typefaces), less priming for auditory conditions, and very little priming from the picture condition. Overall levels of priming were smaller on word identification than for the other measures. Another apparent anomaly is the relatively great priming from auditory presentations on the anagram solution task, a test that has produced puzzling results in other experiments as well (Srinivas & Roediger, 1990). Nonetheless, the results are in general accord with the idea that these four implicit memory tests are measuring a form of data-driven processing (Roediger, 1990), tapping the perceptual record of experience (Kirsner & Dunn, 1985), or drawing on the visual word form memory system (Tulving & Schacter, 1990).

One variation in surface form that had no effect on any task in our experiment was the manipulation of typography. Some researchers have reported effects of typographic manipulations on perceptual priming (e.g., Jacoby & Hayman, 1987; Roediger & Blaxton, 1987a), but these effects were often small and resulted from more powerful manipulations than we used here. For example, Roediger and Blaxton (1987a)

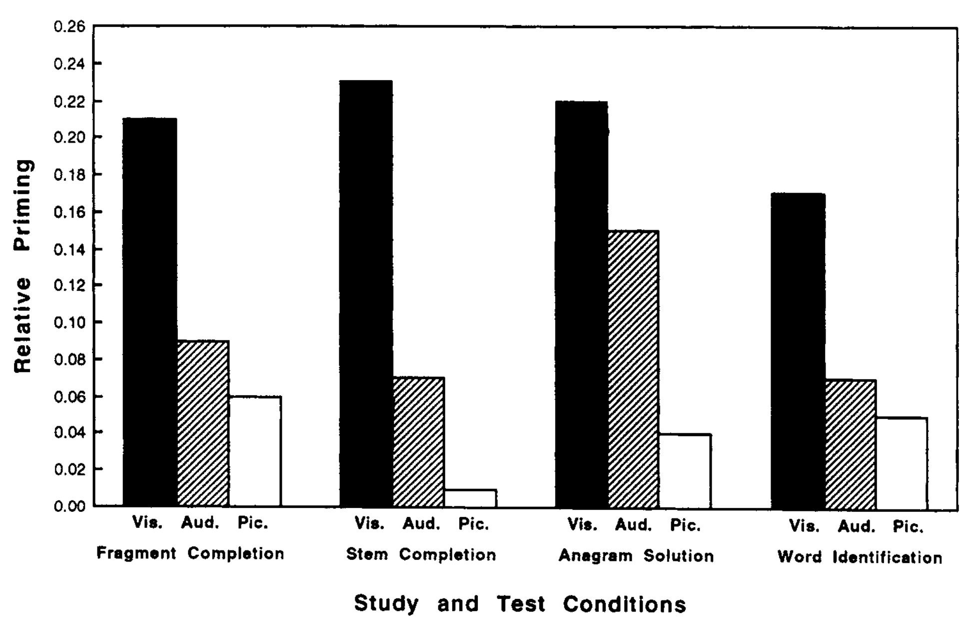

Figure 1. Relative priming for the four implicit memory tasks. (Priming for the visual condition is combined across same and different typefaces. Vis. = visual. Aud. = auditory. Pic. = pictorial.)

had subjects study words in lowercase elite type or in uppercase handprinted letters. At test the typeface of the fragments matched or mismatched that of the studied items. Priming was greater when the two matched, but the effect was of modest size and was asymmetric (it occurred more strongly when subjects studied and were tested in the more unfamiliar handprinted format). The typeface variations used in our experiment were more modest, by design. So, lack of effect is (in retrospect) not too surprising. We had, however, thought that at least word identification would be sensitive to this variable. In addition, our use of a semantic orienting task (pleasantness ratings of words) during the study phase may have lessened our chances of finding an effect. Graf and Ryan (1990) reported that strong changes in typeface produced differences in priming only when the orienting task during study called attention to the visual features of the words. Apparently, the perceptual operations responsible for priming in these tasks seem to be more central than sensory processes that might be highly sensitive to subtle changes in typeface, but not so abstract that modality does not matter (although see Marsolek, Kosslyn, & Squire, 1992, for a further complication in predicting when surface features will affect priming). The relevant procedures responsible for this form of priming would seem to be in lexical processes used in comprehending words from print (Tulving & Schacter, 1990; Weldon, 1991). We return to this point later.

In our comparison, all four implicit memory tasks exhibited similar patterns of priming with two exceptions. First, in word identification, significant priming was obtained only in the visual conditions, and the numerical priming obtained in the auditory condition was not significant. Jacoby and Dallas (1981) similarly reported no priming from auditory presentations in a word identification test, although other experiments have reported slight effects (see Kirsner, Dunn, & Standen, 1989). This pattern may suggest that priming in word identification involves lower level perceptual processes to a greater extent than do the other perceptual implicit memory tasks. However, in our experiments priming in word identification may simply have been less sensitive, because overall priming rates were smaller than on the other tests (see Figure 1).

The second finding to be noted here is that auditory priming in anagram solution was not reliably different from visual priming. Srinivas and Roediger (1990) have suggested that anagram solution may involve a greater degree of conceptual processing relative to the other perceptual tasks on the basis of a slight levels-of-processing effect that they obtained. It may be that the greater use of conceptual processes in anagram solution diminished the modality effect in our experiment, although Srinivas and Roediger did report a modality effect in anagram solution, as have Jacoby and Dallas (1981) and McAndrews and Moscovitch (1990). Our anagrams, like Srinivas and Roediger's, were random rearrangements of letters in the word, whereas Jacoby and Dallas (1981) used anagrams that preserved the first and last letters in the words. Anagram solution may appear to be more perceptual (i.e., to be more affected by manipulations of modality and the like) when some letters from the initial appearance of the word are preserved in their correct positions in the anagrams. However, McAndrews and Moscovitch (1990) used eight different rules to create their anagrams that did not seem to preserve letter order, and yet they obtained results similar to those of Jacoby and Dallas: No reliable priming on the test from auditorily presented words and a reliable modality effect. These matters await further research for a resolution.

Many researchers have worried that supposedly perceptual implicit memory tasks are actually greatly affected by conceptual processes, either such as those used in explicit retrieval or otherwise (e.g., Bassili, Smith, & MacLeod, 1989; Hirshman, Snodgrass, Mindes, & Feenan, 1990; Masson & MacLeod, 1992; Toth & Hunt, 1990). The strong cross-modal priming effect obtained in our experiment, coupled with the weak levels-of-processing effect obtained by Srinivas and Roediger (1990), argues that this fear may be somewhat justified with regard to anagram solution as an implicit memory measure. However, we think the primary implications of our results in conjunction with the recent results of Roediger et al. (1992) are that these four implicit tests are remarkably free of contamination from explicit retrieval processes or other sorts of conceptual processes. The reason is that in all four tests we find little or no priming from pictures. On explicit tests, pictures are normally better remembered than words. This occurs in free recall (our results, among many others) and in recognition (Madigan, 1983; Rajaram, 1993). Similarly, when subjects are given word fragments or word stems as explicit retrieval cues, prior study of words leads to only slightly better performance than prior study of pictures rather than the large differences seen here (Roediger et al., 1992; Weldon et al., 1989; also see Roediger & Weldon, 1987, who found equivalent recall in one experiment). Furthermore, recall of pictures from these cues is far above baseline. If subjects were engaged in explicit retrieval during our four allegedly implicit tests, then we should have seen much better performance from prior study of pictures than the negligible levels observed.

One difficulty with our conclusion is that the explicit test condition (free recall) differed in many ways from the implicit tests. Schacter, Bowers, and Booker (1989) have argued that cuing conditions must be held constant when comparing explicit and implicit tests. Roediger et al. (1992) showed that word fragment completion and word stem completion met Schacter et al.'s (1989) retrieval intentionality criterion as implicit tests; for example, manipulation of levels of processing of words greatly affected performance on explicit and recall tests with word stems or word fragments as cues, but this variable did not affect implicit forms of the tests. If the implicit tests were afflicted by explicit retrieval processes, then of course one would expect to see an effect of levels of processing, just as occurs when subjects receive explicit instructions. Our experiments were conducted under the same general conditions as Roediger et al.'s (1992) experiments with word stems and word fragments. Because results from all four tasks are so similar, we believe that contamination from explicit retrieval is likely slight or nonexistent. Jacoby's (1991) new process dissociation procedure should prove useful for further examination of this issue.

Our results provide more evidence for the general conclusion of Kirsner et al. (1989), that priming on these verbal perceptual tests has both a modality-dependent and modality-independent aspect. Furthermore, our results suggest that for priming to occur the components must be integrated at a lexical level (Monsell, 1985). Weldon (1991) made a similar suggestion, and this idea is consistent with the notion that a perceptual representation system for word forms mediates priming. Kirsner et al. (1989) argue that the modality-independent aspect of priming is based on "pre-production records" that are presumably the same for both visual and auditory presentations. Their proposal could account for the lack of priming for pictures in our experiments and others by assuming that pictures are not covertly labeled at study. If pictures were covertly labeled, then presumably the same pre-production records would be formed to support the modality-independent form of priming. One problem for this approach is that Weldon and Roediger (1987) reported experiments in which they varied labeling of pictures by having subjects examine the picture silently, covertly label it, mouth the name of the picture silently, or name it aloud. The small amount of pictorial priming found in word fragment completion (5–8%) did not vary as a function of any of these manipulations (also see Babbit, 1982, for similar results). Priming from reading the names of these pictures averaged from 16% to 20%. The general conclusion to emerge from Weldon and Roediger's experiments was that the amount of priming from pictures was unrelated to labeling. Weldon and Jackson (in press) also examined this issue and were able to eliminate priming from pictures on the word fragment completion test only when subjects studied pictures at fast rates (250 ms/picture) while simultaneously shadowing a passage given auditorily. It may be that only in these extreme conditions labeling of pictures, and therefore priming, are eliminated. However, future research with additional implicit memory tests would be useful to examine Kirsner et al.'s (1989) theory of the source of "amodal" priming.

We now return to the theme announced in the introduction, the research strategy used here—directly comparing several implicit memory tests rather than comparing one implicit and one explicit test as in virtually all of the relevant literature—strikes us as a useful strategy for advancing our knowledge about implicit memory. By comparing across tests believed to be measuring the same kind of implicit memory, as in the present case, we can see if effects do indeed generalize. Results from such direct comparison experiments are highly encouraging thus far in that word fragment completion, word stem completion, and word identification are quite similar measures. Anagram solution is also likely largely perceptual in the same sense, but further work (by constructing anagrams in different ways) is needed to document the case more convincingly. The small levels of priming from pictures, in conjunction with other evidence, also suggests that these four measures are not badly afflicted by explicit retrieval strategies.

The fact that all four implicit tests used here showed roughly parallel effects should not lead to the conclusion that all implicit memory tests are measuring the same kind of memory. They are not. Conceptual implicit memory tests (Blaxton, 1989; Roediger, 1990; Srinivas & Roediger, 1990) show different properties, such as no modality effect at all. Thus, conceptual implicit tests can be readily dissociated from perceptual implicit tests (Blaxton, 1989; Hamann, 1990; Rappold & Hashtroudi, 1991; Smith & Branscombe, 1988; and see Roediger et al., 1989, for a review). The four implicit tests examined here are similar but (had we included them) could be dissociated from conceptual implicit tests as well as from other explicit tests. Indeed, it is probably possible to find dissociations among these tests, too, from other variables that would capitalize on their differences in perceptual processing.

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Appendix

Words, Fragments, Stems, and Anagrams Used in Experiment 1

Target Word	Fragment	Stem	Anagram
scissors	__ __i__ss__s	sci______	srscosis
lemon	__e__on	lem______	noeml
snake	__n__k__	sna______	kanes
doorknob	d__o__ __no__	doo______	knodroob
dress	__res__	dre______	sreds
spoon	__p__o__	spo______	ponos
pineapple	__i__ea__ __l__	pin______	napielppe
basket	b__s__e__	bas______	betkas
flower	__l__ __er	flo______	lewfor
accordion	__cc__r__ __ __n	acc______	cordionac
mushroom	__us__ro__ __	mus______	shoromum
potato	__ot__t__	pot______	tootap
glass	__l__ __s	gla______	slags
carrot	__ar__o__	car______	racrto
glove	__lo__e	glo______	evogl
skunk	__k__nk	sku______	knusk
clock	__loc__	clo______	kolcc
grapes	__r__p__s	gra______	ragesp
guitar	__u__ta__	gui______	tuirag
hammer	__am__ __r	ham______	ramhem
wheel	__h__el	whe______	hewle
heart	__ea__t	hea______	reath
bicycle	__c__c__e	bic______	libcyec
horse	__or__e	hor______	roseh
kangaroo	__ __ng__ro__	kan______	orangoka
barrel	__ar__el	bar______	rabler
ashtray	__s__t__ay	ash______	trashay
knife	__ni__e	kni______	fenik
chair	__ha__r	cha______	rihca
ladder	__ad__ __r	lad______	dalred
lobster	__ob__t__r	lob______	soblert
turtle	__ur__l__	tur______	rutlet
monkey	__on__ __y	mon______	konyem
candle	c__nd__ __	can______	landec
mountain	__o__n__a__n	mou______	tounnaim
balloon	__ __llo__n	bal______	nooblal
onion	__n__on	oni______	nooni
peanut	p__ __nu__	pea______	tunape
envelope	__nv__ __op__	env______	lopeveen
football	f__ __t__a__l	foo______	tooblalf
truck	__ __u__k	tru______	crtku

(Appendix continues on next page)

Appendix *(continued)*

Target Word	Fragment	Stem	Anagram
snowman	__no__ __an	sno______	namowsn
pitcher	__it__h__r	pit______	tipchre
train	t__a__ __	tra______	rtani
escalator	__sc__l__to__	esc______	caselarto
pliers	__li__r__	pli______	spleri
crown	cr__w__	cro______	worcn
button	__u__to__	but______	tubnot
intestine	__nt__s__i__e	int______	sintteine
house	__o__s__	hou______	sohue
rabbit	__ab__ __t	rab______	bartib
pencil	__ __nc__l	pen______	lincep
ruler	__ul__ __	rul______	relru
sailboat	s__i__b__a__	sai______	toalbais
camel	__am__l	cam______	melac
tomato	t__m__ __o	tom______	matoot
bottle	__ot__l__	bot______	tolebt
screw	__cr__w	scr______	wercs
banana	__an__n__	ban______	nabaan
pretzel	p__et__e__	pre______	terpzle
xylophone	__y__ __p__o__e	xyl______	lopehonyx
shirt	s__i__t	shi______	thris
arrow	__rr__w	arr______	worar
spider	s__i__ __r	spi______	dipser
violin	__io__ __n	vio______	nilivo
squirrel	s__ui__r__ __	squ______	quirlers
anchor	__nc__r	anc______	ranoch
stool	__too__	sto______	lotos
swing	__w__ __g	swi______	winsg
folder	__ol__ __r	fol______	dolref
table	__a__le	tab______	leabt
cigar	c__ __ar	cig______	girca
thumb	t__um__	thu______	tmuhb
tiger	__ige__	tig______	geitr
sandwich	__an__w__c__	san______	danswchi
umbrella	__m__re__l__	umb______	bumralle
broom	__ro__m	bro______	mobor
tornado	__or__ad__	tor______	ronatdo
whistle	__h__s__le	whi______	isthlew
pumpkin	pu__ __k__n	pum______	kinmupp
window	__i__d__ __	win______	donwiw
zebra	__e__ra	zeb______	beraz
church	ch__r__ __	chu______	hruhcc
ambulance	__mb__ __an__e	amb______	bulamance
cactus	__a__ __us	cac______	sutacc
diamond	__i__m__nd	dia______	mianod
elevator	__ __ev__ __or	ele______	vaeletor
fireplace	__i__ __p__ac__	fir______	pirelafec
igloo	i__l__o	igl______	lioog
newspaper	n__ __s__ap__er	new______	papreswen
apple	__p__l__	app______	lepap
octopus	__ct__p__s	oct______	tocopsu
parachute	__a__ac__ut__	par______	dhurapate
toaster	__oa__t__r	toa______	oastter
pyramid	p__ __a__id	pyr______	ramydip
submarine	__ub__ __ri__e	sub______	marsubnei
telescope	__el__ __co__e	tel______	scopteele
giraffe	__ir__ __f__	gir______	rafefig
unicorn	__ni__or__	uni______	corunni
waterfall	__at__r__al__	wat______	rfalwatel

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