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# Repetition Priming in Speeded Word Reading: Contributions of Perceptual and Conceptual Processing Episodes

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Five experiments investigated repetition priming on an indirect speeded word reading (naming) test, a task intended to circumvent conscious recollection. Reading a word or generating it from a semantic cue (either a phrase or an antonym) produced reliable priming of similar magnitude on this indirect test of memory. Efforts to encourage conscious recollection elevated response latencies in speeded reading and improved performance on a direct test of recognition memory, without creating a difference in the amount of priming observed in the Read and Generate conditions. We also found more priming for visually than for auditorily studied words, consistent with the standard pattern for indirect tests assumed to be data-driven. Speeded word reading provides a good measure of repetition priming because the fully exposed target word recruits both perceptual and conceptual aspects of the initial interpretive encoding episode. 

*Key Words:* conceptual encoding; conscious recollection; indirect test of memory; repetition priming; transfer appropriate processing; word reading.

All memory tests are not created equal. As one striking illustration of this principle, Jacoby (1983) reported a contrast between two tests of memory. Consistent with the levels of processing framework (Craik & Lockhart, 1972), words generated from antonyms during study were subsequently more easily recognized than were words that had simply been read during study. This is well known as "the generation effect" (Slamecka & Graf, 1978). Yet on a masked word identification test (which he referred to as a "perceptual identification test"), where subjects were to identify words appearing briefly on the screen prior to a mask, the opposite pattern appeared: Performance benefited more for words that were read than for words that were generated.

Results such as these, constituting a dissociation between the two tests, have become the foundation for a categorization of memory tests as either *direct*—involving conscious recollection, as in the case of recognition—or *indirect*—not requiring conscious recollection, as in the case of masked word identification, a test that can be performed even without a prior study episode. This distinction between categories of tests is now firmly entrenched in the memory literature and indeed has dominated research over the past decade. Much of the attention has been devoted to the newer class of indirect tests, which emphasize the relative improvement in performance for a previously studied item over an item not previously studied, an increment referred to as *priming.*

At a more theoretical level, the Jacoby (1983) pattern of results has also been used to argue for

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a transfer appropriate processing approach to memory (Morris, Bransford, & Franks, 1977; Roediger, 1990). Under such a view, it is the relation between initial processing (at study) and later processing (at test) that determines remembering. The greater the overlap in processing on the two occasions, the more successful remembering is likely to be. The Jacoby pattern in particular has been taken as evidence that reading leads to a data-level analysis of the stimulus as actually perceived, an analysis well matched to a subsequent test assumed to be perceptual in nature, such as masked word identification. Generation, on the other hand, emphasizes conceptual encoding, a process much more akin to that required for successful recollection on a conceptual direct test such as recognition, or priming on a conceptually driven indirect test such as general knowledge question answering (Blaxton, 1989). This is the kind of interpretation that Roediger and his colleagues (Roediger, 1990; Roediger & McDermott, 1993) have championed.

Despite its replicability (e.g., Masson & MacLeod, 1992, Experiment 2; Schwartz, 1989; Weldon, 1991), however, the Jacoby (1983) data pattern is far from ubiquitous. Masson and MacLeod (1992) and MacLeod and Masson (1997) have argued that the advantage of reading over generation from a semantic cue seems to hold only when encoding tasks are presented in blocked format or when generation cues promote strong integration with generated targets (e.g., antonym pairs). Under other conditions, the common pattern for the masked word identification test is priming of similar magnitude for words that were read versus generated, despite a considerable advantage for generated words on a recognition test. We hasten to point out that from our perspective, the important fact is that there is reliable priming for generated items, whether that priming is less than or equal to the priming observed for read items. On this basis, we claim that both conceptual processing and perceptual processing during a first encounter (study) are relevant to performance on a second encounter (test), even on an indirect test.

One of the criticisms that can be leveled at masked word identification is that it may not always be treated as a truly indirect test by subjects. Identifying the test words is a difficult, demanding task, given their exceedingly brief exposure duration. Perhaps, then, subjects occasionally resort to a strategy of conscious recollection of studied words in an attempt to find one that "fits." If so, the nominally indirect test becomes functionally direct. According to this line of reasoning, once conscious recollection intrudes, the retrieval advantage for generated words necessarily also intrudes. On this account, the priming for generated words in studies that have used masked word identification (MacLeod & Masson, 1997; Masson & MacLeod, 1992; Schwartz, 1989; Weldon, 1991) could have occurred because subjects used conscious recollection, which favors generated words and may even offset the advantage of read words found when the task is performed truly indirectly.

Toth, Reingold, and Jacoby (1994) used the process dissociation procedure to show that generating targets from a semantic cue failed to produce an unconscious influence of memory on a word stem completion task. Their analysis indicated that the generation task produced only a conscious influence of memory on that task. Toth et al. further suggested that their findings could be generalized to other indirect tests of memory such as masked word identification that are assumed to be data-driven. By this account, any priming on such tests that is produced by generation during encoding is probably due to contamination by conscious recollection. Contrary to this view, and also using the word stem completion task, Bodner, Masson, and Caldwell (1999) have shown that the process dissociation procedure can underestimate unconscious influences of memory produced by conceptual encoding tasks such as generation.

In our past work, we have argued against this contamination claim. In particular, we demonstrated that in the very same masked word identification paradigm we could produce the advantage for read words over generated words, with no priming in the latter case, when the materials were antonyms—thereby replicating the Jacoby (1983) pattern with his materials—but not for a variety of other materials, including synonyms, phrases, and famous names, among others (see Masson & MacLeod, 1992). It is not clear why conscious recollection would affect only some of our experiments or be induced by only some of our materials. Furthermore, in another indirect test of memory that is assumed to be data-driven—the widely used word fragment completion test—we (MacLeod & Masson, 1997) have produced a consistent priming advantage for read items over generated items like that reported by others (see Roediger & McDermott, 1993, for a review of prior studies). There is no basis for assuming that word fragment completion is any less vulnerable to conscious recollection than is masked word identification. Indeed, we argue the opposite in MacLeod and Masson (1997).

Our explanation for all of these results, like Roediger's (1990), rests on the idea of transfer appropriate processing. However, Roediger argued that indirect tests such as word fragment completion are largely data-driven, or perceptual, and that direct tests such as recall or recognition are largely conceptually driven. Note that this position does allow for conceptually driven indirect tests or data-driven direct tests, and some ingenious experiments have been reported demonstrating such situations (see, e.g., Roediger & McDermott, 1993, for a review). In contrast to this approach to classifying tasks, we have proposed (MacLeod & Masson, 1997; Masson & MacLeod, 1992, 1996) that stimulus identification, whether nominally at encoding or at retrieval, involves both perceptual and conceptual processing. At the time of study, there is a mandatory initial interpretive encoding; this first encoded rendition of the stimulus takes into account multiple dimensions of the stimulus in context and leads to identification of that stimulus. This encoding can be likened to the process of integration described by Graf and Mandler (1984). There may also be a further elaborative encoding, given the appropriate instructions, motivations, opportunities, or the like, that emphasize some aspect of the identified stimulus.

We have proposed that indirect measures ordinarily make contact with the initial interpretive encoding, whereas direct measures normally tap the further elaborative encoding (MacLeod & Masson, 1997; Masson & MacLeod, 1992). Indirect tests are assumed to emphasize the initial interpretive encoding if they measure a subject's ability to identify a specific target stimulus, particularly under data-limited or speeded conditions. A previous interpretive encoding episode is therefore more relevant than previous elaborative encoding. Because interpretive encoding involves both perceptual and conceptual processing, we would expect stimuli encoded by either reading or generating to show priming, which fits with the data that we and others have consistently observed for the masked word identification task. That we have generally obtained similar amounts of priming on masked word identification for read and generate conditions suggests that, for this task, the contribution of conceptual encoding is actually quite substantial, a conclusion at odds with the Roediger (1990) and Toth et al. (1994) proposals.

## THE PRESENT STUDY

Our goal in the series of experiments reported here was to explore the read vs generate manipulation using another indirect measure: speeded word reading. Here, a subject simply reads aloud a fully exposed test word as quickly as possible into a microphone; the dependent measure is response latency. Sometimes called "naming" (e.g., Balota & Chumbley, 1984), speeded word reading appears to be a particularly good candidate as an indirect measure because performance of the task is very rapid and virtually automatic. The claim of automaticity is supported by the well-known Stroop (1935) effect in which color words cannot be disregarded when the task is to name the ink colors in which those words are printed (e.g., say "red" to the word GREEN written in red ink). Because of its automaticity—defined by its ease and speed, as well as by the absence of any need for problem solving, given exposure of the entire word without time restriction—word reading should be relatively uncontaminated by conscious recollection.

This claim receives empirical support from studies by MacLeod (1996) and by Wilson and

Horton (1999). MacLeod contrasted speeded word reading and speeded color naming as indirect measures in a standard study-test framework. In three experiments, speeded color naming of words consistently failed to demonstrate any influence of prior study of some of those words. Yet speeded word reading consistently showed reliable facilitation of the same studied words. In fact, although numerically small (on the order of 20 ms), the priming effects in speeded word reading were impressively consistent over subjects. The task appears very suitable as an indirect measure of memory. Further evidence that using a speeded task prevents conscious recollection has been provided by Wilson and Horton (1999). Contrasting a speeded version of the word stem completion task with a version requiring conscious recollection, they concluded that responding on the speeded version was not contaminated by intentional retrieval processes.

If it is the case that speeded word reading is not affected by conscious recollection, will it behave like masked word identification, showing similar priming for words that have been generated and for those that have been read? Or will it behave like word fragment completion, showing greater priming for words that have been read than for those that have been generated? In the case of reading aloud a target word, the mapping is between an orthographic representation of the word and core aspects of knowledge about that word, including elements of its meaning. Consistent with this idea, Strain, Patterson, and Seidenberg (1995) have shown that reading aloud an isolated word—where conceptual elements of the word might seem to be irrelevant—is nevertheless influenced by conceptual aspects of the word. Specifically, they showed that a word's rated imageability affected time to read it aloud.

Evidently, conceptual aspects of words are recruited quite routinely and unconsciously. Therefore, we would expect the speeded word reading test to respond like the masked word identification test because, unlike word fragment completion, both involve exposure of the entire target stimulus at test. We have previously argued that presentation of a complete stimulus is more likely to recruit conceptual processing episodes than is presentation of a word fragment or stem (MacLeod & Masson, 1997). A complete word, even briefly presented and masked, can make contact with relevant conceptual knowledge (e.g., de Groot, 1983; Sereno, 1991). In contrast, an incomplete stimulus such as a word fragment may not provide sufficient orthographic constraints to specify reliably a particular concept. Incomplete stimuli may more effectively recruit perceptual rather than conceptual aspects of encoding episodes because little contact with conceptual knowledge is possible when the cue consists of only a partial orthographic pattern. Regardless of whether speeded word reading produces a pattern of priming like that found with masked word identification or with word fragment completion, investigating that task will provide generalization. Because of the automatic nature of word reading, that task stands to be a particularly worthwhile addition to the arsenal of indirect measures that have been developed in recent years.

There have, in fact, been several previous studies using speeded word reading as an indirect measure of memory. We have already discussed the MacLeod (1996) study. Earlier studies include the oft-cited Scarborough, Cortese, and Scarborough (1977) work, one of the first uses of the task as an alternative to the lexical decision task in studying priming. A pair of studies by Durso and his colleagues (Durso & Johnson, 1979; Durso & O'Sullivan, 1983) demonstrated that prior study of pictures of objects produced numerically less priming on the speeded reading of words than did prior study of words. Also, Masson and Freedman (1990, Experiments 4, 5, and 6) made use of this type of test to examine repetition priming for context-specific interpretations of words. In every case, priming of previously studied words was observed on the speeded word reading test.

The small amount of priming following study of pictures reported by Durso and his colleagues (Durso & Johnson, 1979; Durso & O'Sullivan, 1983) suggests that speeded word reading might not be very sensitive to prior conceptual processing. We contend, however, that identifying or naming pictures, like auditory presentation of words, involves identification processes that are different from those used to identify a visually presented word. Identification is assumed to require selection of a specific candidate word from among a number of alternatives that are initially recruited by the target stimulus (Masson & MacLeod, 1992, p. 163). Depending on the modality of the stimulus, a different set of candidates will be recruited for the same item (i.e., orthographically similar words, auditorily similar words, objects with similar physical features). Changes in modality between study and test alter the set of candidates among which the subject must discriminate the target. This discriminative process is claimed to be a substantial part of interpretive encoding, and recapitulation of that process following a similar encoding episode is the basis of repetition priming. To the extent that the discriminative process is similar at study and test, more priming will be found, thereby producing modality effects. In comparison to encoding tasks that involve a change in modality, a more robust priming effect should result from an encoding task that requires subjects to generate a target from a semantic cue because we assume that this task emphasizes discrimination of the target's meaning from other similar meanings invoked by the cue. This conceptual processing can effectively support the conceptual processing that we claim is involved when identifying a complete target stimulus on tasks such as masked word identification or speeded word reading.

In this article, we report five experiments. Experiments 1 and 3 used definitions and antonyms as generation cues, materials similar to those used for generation in prior experiments (e.g., Jacoby, 1983; MacLeod & Masson, 1997; Masson & MacLeod, 1992; Schwartz, 1989; Weldon, 1991), to allow straightforward comparison of the speeded word reading test to prior indirect tests such as masked word identification and word fragment completion. In Experiment 2, we attempted to determine whether conscious recollection plays any role in the performance of speeded word reading by forcing conscious recollection to occur on the heels of the indirect testing of each item. Experiment 4 further examined the possible contribution of conscious recollection to priming by substituting a read-and-associate task for the generate task, resulting in an encoding task that included conceptual elaboration that should support conscious recollection. Finally, Experiment 5 used a modality of encoding manipulation to determine whether speeded word reading is sensitive to modality changes between encoding and test, a hallmark characteristic of other indirect tests that are assumed to be data-driven (see Roediger & McDermott, 1993, for a review of modality effects on indirect tests).

## EXPERIMENT 1

In Experiment 1, we attempted to replicate with speeded word reading a result that we have obtained multiple times using the masked word identification test, namely repetition priming for generated as well as for read words. We have typically seen equal priming following read and generate encoding tasks when the latter task involves generating targets from brief definitional phrases (MacLeod & Masson, 1997; Masson & MacLeod, 1992). In the study phase, subjects read some targets aloud and generated others from phrases. In the test phase, each target was presented in clear view for as long as the subject needed to read it aloud. Target words from the study phase were tested along with a set of new, nonstudied target words. If speeded word reading leads subjects to recruit memory from their earlier processing of target words in a way that facilitates word reading performance, then studied targets should be associated with shorter reading latencies than nonstudied targets. Moreover, if that recruitment of prior study episodes operates in a manner similar to what we have observed with the masked word identification test, then generated targets should also produce priming, and that priming should be similar in magnitude to that observed for read targets.

Following the speeded word reading test, targets were again presented on a recognition test in which subjects decided whether those targets had appeared during the study phase. On that test, we expected subjects to classify more generate than read items as having occurred in the study phase, in keeping with the frequently demonstrated observation that generation leads to better performance on direct tests of memory than does reading (e.g., Begg & Snider, 1987; Begg, Snider, Foley, & Goddard, 1989; Masson & MacLeod, 1992; Slamecka & Graf, 1978).

### Method

*Participants.* Twenty-one undergraduate students from the University of Toronto at Scarborough were tested individually. For their participation, all received either $5.00 or one bonus point toward their final grade in Introductory Psychology.

*Materials.* The stimuli were 60 of the definition-word items used by Weldon (1991) and provided in the Appendix of MacLeod and Masson (1997).

*Apparatus.* The experiment was controlled by an IBM-AT compatible microcomputer with a 14-in. color VGA monitor. The controlling program was written in QuickBasic 4.5 and used the routines given by Graves and Bradley (1987, 1988) to achieve millisecond timing accuracy. Items were printed in black on a white background and were presented centered on the middle horizontal line of the monitor. Oral responses during the speeded word reading test phase were collected using a microphone positioned directly below the screen in front of the subject. Response latencies were recorded as the time between stimulus onset on the screen and the subject's oral response into the microphone, which triggered a voice key that sent a signal to the computer.

*Procedure.* For each subject, all 60 items were read into the program and randomized. The first 40 were selected as study items; the remaining 20 served as unstudied items. Thus, each subject received a different set of 40 studied items and 20 unstudied items. For the study phase, the set of 40 items was randomly divided into two sets of 20. In one condition, the subject was required to read the word aloud (e.g., umbrella; say "umbrella"); in the other condition, the subject was required to generate aloud a word that fit a short descriptive phrase (e.g., main course on Thanksgiving - t?; say "turkey"). The two types of items were randomly intermingled in the study sequence.

In the instructions just before the study phase began, subjects were informed that this was a memory experiment. They were told that they would be studying 40 words, 20 of which they were to read aloud and 20 of which they were to generate aloud. Subjects were informed that they should learn all 40 words for a later memory test. When they indicated that they had understood the instructions, the experimenter pressed a key to begin the study trials. On each study trial, the item remained on the screen until the subject made a response, at which point the experimenter pressed a key to input the accuracy of that trial. A 500-ms blank interval separated successive study trials.

The speeded word reading test phase began immediately following the study phase. The subject was told that this was a filler task designed to make the upcoming memory test more demanding. There were 60 word reading trials: the 40 studied items plus the 20 unstudied items. The order of the test trials was randomly determined for each subject. Subjects were told that their task was to "name the word out loud into the microphone as quickly as possible without making mistakes." They were also instructed on how to respond into the microphone. Once the subject indicated having understood the instructions, the experimenter pressed a key and the word reading test trials began.

A 250-ms blank screen preceded the presentation of each test word. Then the word was presented until the subject read it aloud, after which there was a 250-ms blank interval. Then the word "READY?" appeared as a cue both for the subject to prepare for the next trial and for the experimenter to input a key press indicating the response accuracy of the just-completed trial. The "/" key was pressed for correct trials and the "z" key for incorrect trials. The experimenter also wrote down all error responses. The computer then proceeded to the next trial.

Immediately following the word reading trials, the subjects received instructions informing them that the next phase was a memory test for the 40 words they had studied at the beginning of the experiment. They were told that they would see all 40 study items plus 20 new items (that had also appeared on the word reading test as new words) and that their task was to say "yes" if the word was one they had studied and "no" if it was one they had not studied, trying not to let their experience on the speeded word reading test confuse them. Again, once subjects indicated that they understood the task, the experimenter pressed a key to start the recognition test trials. A trial began with a 250-ms blank screen followed by a word presented at the left center of the screen. Once the subject responded, the experimenter input the accuracy of the trial by consulting a protocol sheet indicating the correct response for each trial. Following another 250-ms blank interval, the next trial began.

TABLE 1

Experiment 1, Definitions: Mean Response Latencies in Milliseconds and Proportions of Errors for the Generate, Read, and New Conditions on the Speeded Word Reading Test, and Mean Proportions of "Yes" Responses on the Recognition Test

| | Study/test condition | | |
|---|---|---|---|
| | Generate | Read | New |
| Speeded word reading test | | | |
| Reading latency | 504 | 497 | 520 |
| | (20.6) | (13.5) | (21.8) |
| Proportion error | .007 | .014 | .014 |
| | (.004) | (.005) | (.008) |
| Recognition test | | | |
| Proportion "Yes" | .921 | .560 | .250 |
| | (.016) | (.047) | (.034) |

*Note.* Standard errors are shown in parentheses.

### *Results and Discussion*

In the study phase, subjects failed to generate the correct target on an average of .10 of the generation trials. Because the experimenter provided the subject with the correct answer on such trials, these items were included in the analysis of data from the test phase. Therefore, the results we report are not compromised by concerns about item selection effects. This procedure was followed for all of the experiments reported here. In any case, analyses of data conditionalized on correct responding in the study phase produced the same pattern of results as did the unconditionalized analyses.

For the test phase, word reading latencies that were longer than 300 ms or shorter than 2000 ms were included in the computation of means for each subject. Latencies outside that range were considered errors. Response latency outliers were handled in this way for all of the experiments reported in this article. The Type I error rate for all analyses reported in this article was set at .05.

*Speeded word reading.* Table 1 presents the mean reading latency and mean proportion of errors as a function of encoding task. Three specific issues were of interest in analyzing the word reading data: (1) whether a prior reading episode would lead to significantly shorter word reading latencies, (2) whether the generate encoding task would produce priming, and (3) if so, whether that priming would be similar to that observed for the read encoding task. These issues were addressed by computing a set of three pairwise comparisons using $t$ tests. In the first comparison, the mean latency in the read condition was found to be reliably shorter than in the new condition, $t(20) = 2.19$, $SEdm = 10.321$. There was also a reliable priming effect for generate items, $t(20) = 3.54$, $SEdm = 4.413$, but the difference between the read and the generate conditions was not reliable, $t < 1$. To estimate the upper bound of the power of the comparison between the read and the generate conditions, we used an effect size equal to the observed difference between the read and the new conditions; that effect size was the maximum difference that would be expected between the read and the generate conditions. The resulting estimate of the power of this experiment to detect a difference between the read and generate conditions was .93.

Word reading errors were also analyzed using the same set of comparisons as were applied to the latency data. None of these tests approached significance, $t$s $< 1.40$.

The speeded word reading test provided a clear replication of the pattern of repetition priming we have seen in a number of earlier experiments involving the masked word identification test (MacLeod & Masson, 1997; Masson & MacLeod, 1992). That is, when targets are generated from semantic cues consisting of phrases, they are later identified just as readily as targets that are initially encoded by reading a clearly presented display. The speeded word reading test and the masked word identification test seem, then, to yield very similar outcomes as a result of prior encoding experiences. In both cases, target words are in full view, albeit only briefly in the case of masked word identification. Our claim is that exposure of the entire word, even if only for approximately 30 ms, is adequate to set the stage for recruitment of memory for prior processing episodes that involved either perceptual (visual) or conceptual processing of the target or both.

The use of the speeded word reading test was intended to make it unlikely that subjects would engage conscious recollection strategies to assist their performance on the test. The mean latencies we observed suggest that such strategies were not operating, inasmuch as latencies were very similar to those found in typical word reading studies that do not involve prior exposure to target words (e.g., Andrews, 1992; Forster & Chambers, 1973; Seidenberg, Waters, Barnes, & Tannenhaus, 1984). This issue is examined more closely in Experiment 2.

*Recognition.* The mean probabilities of classifying targets as having occurred during the study phase are shown in Table 1. The probability of classifying generate items as old was substantially higher than the probability of classifying read items as old, $t(20) = 8.43$, $SEdm = 0.043$. This finding is consistent with earlier studies showing a recognition advantage for generate items over read items (e.g., Begg & Snider, 1987; Begg et al., 1989; Masson & MacLeod, 1992; Slamecka & Graf, 1978) and indicates that subjects are more likely to be aware of the past occurrence of generate items. Moreover, by using as foils items belonging to the new condition in the speeded word reading test, performance on the recognition memory test could not be based on a sense of familiarity with an item; rather, conscious recollection of an item's occurrence during the study phase was required to make a positive recognition decision (e.g., Jacoby, 1991). Given the greater probability of recollection among generate items, one might have expected to observe more priming for those items if conscious recollection were operating on the speeded word reading test. Yet repetition priming for generate items was not greater than for read items, thereby failing to support the suggestion of possible contamination by recollection.

## EXPERIMENT 2

Despite the apparent encumbrances associated with attempting to use conscious recollection while performing a word reading test, one might argue that the repetition priming effect we observed for generate targets in Experiment 1 was nevertheless due to such recollection. Toth et al. (1994) made such an argument with respect to the repetition priming effects that we observed in the masked word identification test (Masson & MacLeod, 1992), based on their coupling of the process dissociation procedure with the word stem completion test. Although we agree that a test such as word stem completion, which does not present a complete stimulus to the subject, might not be conducive to automatic or unconscious recruitment of prior conceptual processing episodes, we contend that the masked word identification and speeded word reading tests belong to a different class of indirect tests of memory by virtue of presenting a complete stimulus. Therefore, we argue that our finding of similar repetition priming effects for generate and read encoding tasks is not anomalous and need not result from conscious recollection strategies that favor generate targets.

As a test of this claim, we conducted a replication of Experiment 1 under two different conditions. One condition was a straightforward replication of the procedure used in Experiment 1, including a recognition test given after the speeded word reading test was completed. In the other condition, rather than having subjects read all test targets prior to making recognition decisions about all of them, we instructed subjects to read each target as quickly as possible and then to make an immediate recognition decision about that target. We reasoned that if subjects already were engaged in conscious recollection when responding in the word reading test of Experiment 1, the additional requirement of making a recognition decision after reading a target word should have little or no impact on their reading latency. By adding the recognition decision, we would simply be sanctioning an operation that subjects had already engaged of their own volition.

On the other hand, if subjects do not engage in conscious recollection while constructing responses on the speeded word reading test, adding the requirement to make a recognition decision might have a significant influence on their reading latency. In particular, we expected that requiring a recognition decision after reading each target in the test phase would have a general slowing effect on speeded word reading responses because subjects might be evaluating evidence for an item's prior occurrence even while preparing their reading response. Thus, subjects in this condition should take longer to read targets than subjects who are not required to follow a reading response with a recognition decision.

One other prediction regarding the effects of conscious recollection on speeded word reading was important. If recollection of prior occurrence reduces word reading latency, then by enforcing attempts at recollection, we should observe a reading latency advantage for generate over read targets because the latter are more likely to be recognized. Engaging in conscious recollection should push the pattern on the speeded word reading test in the same direction as that on the recognition test.

### Method

*Participants.* Forty-eight students from the same source as in Experiment 1 received either $5.00 or one bonus point toward their final grade in Introductory Psychology for taking part. Half of the subjects were assigned to the interleaved condition, where a recognition decision was made for each word immediately following the speeded reading of that word; half were assigned to the blocked condition, where the speeded reading and recognition tests were blocked, with all of the speeded reading test trials completed before the recognition test trials began. A further three subjects who began testing did not complete the experiment due to equipment failure, illness, or unwillingness to speak sufficiently loudly for the voice key to detect the response.

*Materials.* The stimuli were the same as those used in Experiment 1.

*Apparatus.* The apparatus and programming were exactly as described in Experiment 1.

*Procedure.* All procedures were carried out as in Experiment 1 except for changes involving the recognition test. In the blocked condition, everything proceeded just as in Experiment 1 until the subject completed the speeded reading task. Then, there was a YES/NO recognition test for the studied words. This consisted of the same 60 words as had just been read aloud, but presented one at a time in a new random order with instructions to say "yes" aloud into the microphone if the word had been studied (either read or generated) and "no" if the word had not been studied. Subjects were cautioned that some of the unstudied words might have appeared during the reading task (in fact, all of them had), but their job was to judge only whether each word had appeared during the study phase. The format of the recognition test followed that of the reading task except that all of the oral responses were either "yes" or "no."

For the interleaved condition, recognition of each word was evaluated immediately after that word had been read aloud. There was a 250-ms blank screen after the subject spoke the word aloud, and then the prompt "Did you say this word in the first phase? YES or NO" was presented, remaining on the screen until the subject responded. The experimenter again pressed a key to indicate the accuracy of the trial, using a preprinted protocol sheet to evaluate the accuracy of the subject's response for both speeded reading and recognition.

### Results and Discussion

The proportion of items that were not correctly generated by subjects in the study phase, averaged over the two groups of subjects, was .06.

*Speeded word reading.* Mean word reading latencies were computed for each subject as in

TABLE 2

Experiment 2: Mean Response Latencies in Milliseconds and Proportions of Errors for the Generate, Read, and New Conditions on the Speeded Word Reading Test, and Mean Proportions of "Yes" Responses on the Recognition Test, Both Shown Separately for the Interleaved and the Blocked Testing Procedure

| | Interleaved test | | | Blocked test | | |
|---|---|---|---|---|---|---|
| | Generate | Read | New | Generate | Read | New |
| Speeded word reading test | | | | | | |
| Reading latency | 578 | 577 | 618 | 498 | 492 | 506 |
| | (16.9) | (17.7) | (21.8) | (11.3) | (9.6) | (10.9) |
| Proportion error | .004 | .002 | .013 | .013 | .013 | .013 |
| | (.003) | (.002) | (.006) | (.005) | (.006) | (.005) |
| Recognition test | | | | | | |
| Proportion "Yes" | .904 | .546 | .052 | .948 | .523 | .227 |
| | (.020) | (.049) | (.013) | (.010) | (.029) | (.027) |

*Note.* Standard errors are shown in parentheses.

Experiment 1, and the means across subjects are shown in Table 2. These means indicate that the requirement to make a recognition decision about a target right after reading it in the test phase generally increased reading latencies, but the pattern of repetition priming effects for the generate and read conditions remained very similar to what we observed in Experiment 1. An ANOVA with group (interleaved recognition test and blocked recognition test) and encoding task (generate, read, and new) as factors confirmed these observations. Subjects in the interleaved group had reliably longer reading latencies than did subjects in the blocked group, $F(1,46) = 19.63$, $MSe = 15{,}727$. There was also a reliable difference among the three encoding conditions, $F(2,92) = 17.56$, $MSe = 609$, as well as a reliable interaction between group and encoding task, $F(2,92) = 5.75$, $MSe = 606$. The interaction indicates that the effect of prior exposure was greater in the interleaved group than in the blocked group. One possibility is that conscious recollection provided assistance to speeded reading responses in the interleaved group. Were that the case, however, there should have been a greater increase in priming in the generate condition relative to the read condition. This did not happen, indicating that attempts at conscious recollection did not penetrate the speeded word reading task. We suspect, instead, that this interaction was due to generally longer reading latencies for the interleaved group brought about by the demand for an immediate recognition decision (see General Discussion).

Because of the reliable interaction, separate sets of comparisons (identical to those computed in Experiment 1) were computed for the two groups of subjects. The pattern of results was similar for the two groups. First, there was a reliable priming effect for read items, $t(23) = 4.02$, $SEdm = 10.128$, and $t(23) = 3.28$, $SEdm = 4.404$, for the interleaved and blocked groups, respectively. Second, the priming effect for generate items was significant in the interleaved group, $t(23) = 4.53$, $SEdm = 8.764$, and approached significance in the blocked group, $t(23) = 2.04$, $SEdm = 3.743$, $p = .053$. Finally, mean latencies for generate and read items did not differ reliably, $t$s $< 1.20$. The estimated upper bound on power to detect a generate–read difference in these two groups, using the observed difference between read and new conditions as the effect size, was .99 for the interleaved group and .70 for the blocked group.

The mean proportions of word reading errors are also shown in Table 2. The error rates were very low, and an ANOVA with group and encoding task as factors yielded no significant effects, $F$s $< 1.70$.

The speeded word reading results of Experiment 2 replicated the pattern of repetition priming found in Experiment 1. In addition, these results showed that requiring subjects to make a recognition decision after reading a word generally slowed the production of reading responses. We take this finding to mean that subjects normally were not engaging in recollective attempts while reading words on the speeded word reading test. Although subjects may notice or perhaps reflect on prior occurrence after reading a target word aloud, it seems unlikely that they actively engage in recollective processes while constructing a word reading response unless task demands lead them to do so. Moreover, despite the interleaved group being affected by recollective processes while forming the word reading responses, there was no hint of a greater benefit for the easily remembered generate targets relative to the read targets. Thus, the success or failure of recollection seems to have had no detectable influence on reading latencies.

*Recognition.* The mean proportions of positive recognition responses are shown in Table 2. Subjects in both test groups discriminated well between studied and new items. False alarms were particularly low in the interleaved group because new items had not previously been presented in the experiment, whereas in the blocked group all items on the recognition test had previously appeared in the speeded word reading test. Hit rates for generate and read items were analyzed in an ANOVA that also included group as a factor. This ANOVA revealed a main effect of encoding task, with a significantly higher hit rate for generate than for read items, $F(1,46) = 217.36$, $MSe = 0.017$. No other effects were significant in this analysis, $Fs < 1.60$.

Although both groups of subjects were more likely by far to recognize generate items than read items, these two sets of items produced very similar amounts of repetition priming on the word reading test. The slowing of word reading responses produced by the interleaved recognition task illustrates why it is not feasible to apply the retrieval intentionality criterion in the standard way (Schacter, Bowers, & Booker, 1989) to examine the potential use of conscious recollection in the speeded word reading task. Implementing that criterion requires that one group of subjects perform the task under instructions to use conscious recollection. The present results show that when a more subtle inducement to use conscious recollection is invoked (i.e., the interleaved recognition test), response latencies are dramatically lengthened. Even then, the generate–read manipulation did not produce a difference in latencies, although it had a large effect on recognition responses. This pattern of results, taken together with the finding that word reading latencies increased substantially when subjects were required to make a recognition decision immediately after reading a word, indicates that conscious recollection of prior occurrence did not play a causal role in repetition priming on the speeded word reading test.

## EXPERIMENT 3

Although we have observed in a number of different experiments that generating or reading words can yield similar repetition priming effects on subsequent masked word identification (MacLeod & Masson, 1997; Masson & MacLeod, 1992), we have found that one particular class of generation cues does not fit this pattern. Generation cues that appear to prompt strong integration of the generated target and its cue tend to produce less repetition priming than the read encoding task (Masson & MacLeod, 1992, Experiments 2 and 6). One type of generation cue in particular, generation from an antonym, has been shown to produce little or no repetition priming on the masked word identification test (Jacoby, 1983; Masson & MacLeod, 1992, Experiment 2).

Masson and MacLeod (1992) suggested that an antonym generation cue might become strongly integrated with its generated target in the memory representation of that encoding event. When later tested with a brief, masked presentation of the target word, the integrated episode would come to mind, but there might be confusion regarding which of the two words in the recruited episode corresponded to the current target. Under conditions of masked target presentation, very little perceptual evidence would be available to resolve this confusion, thereby permitting errors in which the cue member of the pair would be erroneously produced in lieu of the target member, constituting an incorrect response. The speeded word reading test, however, presents a quite different situation. Now, the entire target word remains in view until a response is made. Therefore, substantial perceptual information should be available to help resolve which element in a recruited generation episode is pertinent to the task at hand, and the speeded word reading test might produce a repetition priming effect under conditions that did not yield such an effect in the masked word identification test.

We tested these ideas in Experiment 3 by using antonym–target pairs rather than definition–target pairs as in Experiments 1 and 2. If a clear view of the test word is sufficient to selectively recruit prior experience with that word from a previous encoding episode that involved integration with an antonym generation cue, then even for antonyms we should find similar repetition priming effects for generate and read targets. In contrast, if the integration of antonym cues and generated targets prevents selective application of prior experience regardless of the nature of the target item at test, then little or no repetition priming should be found for generated targets.

### Method

*Participants.* Nineteen new subjects from the same pool as Experiment 1 took part, with the data of one subject discarded due to an exceptionally high generation error rate during study (50%) and extremely long latencies on the speeded word reading test (most longer than 800 ms). All subjects received one bonus point toward their final grade in Introductory Psychology for taking part.

*Materials.* The stimuli were the 60 antonym pair items used by Masson and MacLeod (1992, Experiments 2, 10, and 11; see their Appendix B).

*Apparatus.* The apparatus and programming were exactly as described in Experiment 1.

*Procedure.* The procedure was the same as in Experiment 1 with three exceptions. First, the materials were changed such that the generation rule now required the subject to say the opposite of the cue word beginning with the specified letter (e.g., question - a?; respond “answer”). Second, the speeded word reading test words were presented in one of four colors—red, blue, green, or yellow—randomly and equally often in each condition. The subjects were instructed to ignore the color of print and simply read the word aloud as quickly as possible. Third, there was no recognition test; only the speeded word reading test was conducted.[1]

TABLE 3

Experiment 3, Antonyms: Mean Response Latencies in Milliseconds and Proportions of Errors for the Generate, Read, and New Conditions on the Speeded Word Reading Test

| | Study/test condition | | |
|---|---|---|---|
| | Generate | Read | New |
| Reading latency | 524 | 515 | 537 |
| | (16.1) | (16.1) | (16.0) |
| Proportion error | .022 | .031 | .050 |
| | (.009) | (.011) | (.017) |

*Note.* Standard errors are shown in parentheses.

### Results and Discussion

In the study phase, on average .16 of the items in the generate condition were not correctly reported by subjects. As in the earlier experiments, subjects were told the correct target word whenever they failed to generate it themselves.

The mean word reading latencies as a function of encoding task are shown in Table 3. The pattern of means was very similar to that found in Experiments 1 and 2, with shorter latencies for both generate and read items than for new items, $t(17) = 2.48$, $SEdm = 5.433$, and $t(17) = 3.82$, $SEdm = 5.665$, respectively. There was no reliable difference between generate and read

[1] In fact, there was another indirect test administered after the speeded word reading test. This was a test of color naming analogous to the familiar Stroop (1935) task. Originally, Experiment 3 was to form part of another series comparing speeded word reading and color naming (MacLeod, 1996), but ultimately the present experiment was not included in that series. For this reason, only the speeded word reading data are reported here. Color naming showed no effect of prior study.

items, $t(17) = 1.74$, $SEdm = 4.717$, $p = .10$. The estimated upper bound on the power of this contrast to detect a difference between generate and read items, based on an effect size equal to that observed between read and new items, was .98.

The mean proportions of errors on the word reading test are also shown in Table 3. Pairwise comparisons did not find any significant differences, all *t*s $< 1.83$.

The results of the speeded word reading test clearly show that targets generated from antonym cues produced about as much repetition priming as did targets that were read. This outcome contrasts with results obtained using the masked word identification test (Jacoby, 1983; Masson & MacLeod, 1992, Experiment 2), in which little or no repetition priming was found among targets generated in that way during the study phase. Although it might be suggested that the different results found with masked word identification and speeded word reading could be due to conscious recollection strategies operating during the speeded word reading test, the results of Experiment 2 argue against that possibility.

The finding of similar repetition priming for targets generated from antonyms and for targets that were read during study is not entirely new. Masson and MacLeod (1992, Experiment 11) reported such a result with the masked word identification test. In that experiment, however, the encoding phase involved a mixture of three types of encoding tasks: generate from an antonym cue, generate from a synonym or associate cue, and read in isolation. The rationale for that mixture was that the use of two different generation cues would reduce the likelihood of strong integration of cues and targets because of the requirement to deliberately select the correct generation rule. No such requirement was in place for Experiment 3, yet generation of the targets from antonym cues produced as much repetition priming as did reading the targets. This result is consistent with the proposal that a clear view of the target at the time of test is an adequate basis for selectively recruiting prior experience with the target word from memory. Selective recruitment apparently is less likely to occur when the target is available only briefly so that there is little basis for determining which element of an integrated episode is the current target.

With the results of Experiment 3 in hand, we have three independent demonstrations of similar repetition priming for generate and read items. Because this similarity constitutes a null effect, we have been particularly concerned about power to detect a difference between the generate and the read conditions. Although three of our four tests for this effect had high upper bounds on power, we note that in all four tests there was a small advantage for the read over the generate condition (between 1 and 7 ms).

To conduct a more powerful test for a difference between the generate and the read conditions, we combined the data from Experiments 1–3. The mean latencies for the generate and read conditions, based on data from 87 subjects, were 527 and 522 ms, respectively. These two means were not reliably different, $t(86) = 1.56$, $SEdm = 3.570$. The power of this test to detect an effect of 12.5 ms, which is half the size of the advantage of the read condition over the new condition averaged across all 87 subjects, was .94. Therefore, if there is a very small systematic difference between the generate and the read conditions, it most likely is less than half the size of the repetition priming effect found in the read condition and quite possibly close to the 5-ms average difference observed across the three experiments reported here.[2] That small difference does not threaten the proposition that a conceptually based encoding episode can subsequently enhance word reading speed as well

[2] One might question the inclusion of the results from the interleaved group in Experiment 2 in this combined analysis over experiments on the ground that subjects in that group were treating the speeded word reading task somewhat differently from other subjects in these experiments due to the requirement to make a recognition decision on each trial. In view of this concern, we recomputed these analyses omitting the interleaved group from Experiment 2. Based on 63 subjects, the resulting 6.5-ms generate–read difference was not reliable, $t(62) = 1.64$, $SEdm = 3.972$, and the estimated power to detect a difference equal to half the priming effect found in the read condition was .78.

as, or nearly as well as, a perceptually based encoding episode.

## EXPERIMENT 4

In Experiment 4, we sought further evidence regarding the possibility that repetition priming in the speeded word reading test could be affected by conscious recollection or by elaborative encoding. We followed a strategy similar to that used by MacLeod and Masson (1997) in the context of the masked word identification test. Namely, we introduced an encoding task that involved both interpretive and elaborative conceptual processing components: Subjects were required to read aloud a target word, which we expected would involve perceptual and conceptual components of interpretive encoding, and then to produce an associate to that word, thereby invoking elaborative conceptual encoding. The added conceptual processing that is part of this read–associate task was intended to provide substantial opportunity for conscious recollection and elaborative encoding processes to influence performance on the masked word identification test. If such influences were to operate, the read–associate condition would gain additional sources of benefit relative to the read condition and would be expected to yield greater repetition priming than the read condition. If those influences do not operate on the speeded word reading task, however, the read and read–associate encoding tasks should lead to similar amounts of repetition priming because of their common interpretive encoding component. In our view, generation of an associate is primarily an elaborative operation and therefore should contribute little to repetition priming in the speeded word reading task. For this reason, a recognition test was given after the speeded word reading test as a manipulation check to verify that subjects had substantially better conscious recollection for read–associate items than for read items.

### Method

*Participants.* Twenty-four subjects from the same pool as Experiment 1 participated in this experiment. The data of four subjects were discarded due to language difficulties. All subjects received one bonus point toward their final grade in Introductory Psychology for their participation.

*Materials.* The stimuli were the same words as used in Experiment 1.

*Apparatus.* The apparatus and programming were exactly as described in Experiment 1, except that stimulus presentation was now left-justified on the middle horizontal line.

*Procedure.* There were two changes with respect to Experiment 1; otherwise, everything was identical to that experiment. First, this time, the two encoding conditions were blocked; MacLeod and Masson (1997, Experiment 4) have shown that this change does not seem to alter the outcome of such experiments when only two encoding tasks are used. Second, one of the encoding tasks was changed: In one condition, the subject was required to read the word aloud; in the other, the subject was required to read the word aloud and then to produce an associate aloud (e.g., sandwich; respond “sandwich. . . bread”). The order of study blocks was counterbalanced across subjects, with a reminder of the task change preceding the second block. The order of study trials within the two study blocks was randomly determined for each subject. As in Experiment 1, a recognition test followed the speeded word reading test.

### Results and Discussion

*Speeded word reading.* The mean word reading latencies shown in Table 4 indicate that the read and read–associate conditions both produced reliable repetition priming relative to the new condition, $t(19) = 2.77$, $SEdm = 7.500$, and $t(19) = 2.81$, $SEdm = 10.268$, respectively. Mean response latency in the read and read–associate conditions did not reliably differ, $t < 1.10$. The upper bound on the power of the latter comparison to detect a difference between the read and the read–associate conditions, assuming an effect size equal to that observed between the read and the new items, was estimated to be .87.

The mean proportions of errors in each of the encoding conditions are also shown in Table 4. Comparisons involving each pair of conditions yielded no significant effects, $t$s $< 1.40$.

TABLE 4

Experiment 4: Mean Response Latencies in Milliseconds and Proportions of Errors for the Read-Associate, Read, and New Conditions on the Speeded Word Reading Test, and Mean Proportions of "Yes" Responses on the Recognition Test

| | Study/test condition | | |
|---|---|---|---|
| | Read–Associate | Read | New |
| Speeded word reading test | | | |
| Reading latency | 492 | 500 | 521 |
| | (8.2) | (12.2) | (15.4) |
| Proportion error | .025 | .033 | .043 |
| | (.011) | (.009) | (.012) |
| Recognition test | | | |
| Proportion "Yes" | .938 | .508 | .225 |
| | (.017) | (.062) | (.040) |

*Note.* Standard errors are shown in parentheses.

*Recognition.* The mean proportions of positive recognition decisions in each encoding condition are shown in Table 4. The proportion of hits in the read–associate condition was substantially higher than that in the read condition, and this difference was statistically significant, $t(19) = 5.95$, $SEdm = 0.072$.

The results of Experiment 4 indicate that the added benefit of elaborative conceptual processing in the read–associate condition, as evidenced by improved recognition performance relative to the read condition, had no detectable effect on word reading latencies. This outcome is consistent with the view that conscious recollection of prior occurrence, or elaborative conceptual encoding, makes no substantial contribution to the repetition priming found in the speeded word reading test. Consistent with our earlier proposal (Masson & MacLeod, 1992), indirect tests of memory that involve the identification of target words appear to be affected by the initial interpretive encoding but not by the subsequent elaborative encoding of words during study episodes.

When generating a word from a semantic cue, the mapping is between conceptual knowledge recruited by the cue and conceptual knowledge about the cued word. Elaborative encoding operations of the sort required by the associate generation part of the read–associate task are engaged after the target word has been identified through interpretive encoding and involve moving outward or diverging from the target. In contrast, interpretive encoding serves to converge on a particular interpretation of the target. It is the reenactment of this convergence that is assumed to support repetition priming on identification tests.

## EXPERIMENT 5

In Experiments 1–4, we consistently showed that prior encoding led to repetition priming in speeded word reading. None of our encoding tasks, however, brought about reliably different amounts of repetition priming. One might be concerned, therefore, that any prior experience with target words would reduce word reading latencies by about the same amount on a subsequent speeded word reading test. That is, the test may just be a blunt instrument, not sensitive enough to detect different amounts of repetition priming among different encoding tasks. We addressed this question to some extent by providing power estimates but the disadvantage of that approach is that power estimates depend on the effect size one assumes.

In Experiment 5, we took a different approach in testing the possibility that the word reading test was not adequately sensitive to be able to detect differences between encoding tasks. To do this, we manipulated the nature of the perceptual experience with target words during the encoding phase. Following earlier work that has shown modality-specific effects in tests such as word fragment and word stem completion and masked word identification (e.g., Graf, Shimamura, & Squire, 1985; Jacoby & Dallas, 1981; Kirsner, Dunn, & Standen, 1989; Rajaram & Roediger, 1993; Roediger & Blaxton, 1987; see Roediger & McDermott, 1993, for a review), we varied the modality of presentation of words during the encoding phase. Half of the studied items were presented visually to be read silently, unlike in the usual read encoding task where they were read aloud. The other half of the studied items were presented auditorily to be heard. In this way, no overt response was required for either condition. The speeded word reading test, like other indirect tests of memory for words, has a strong perceptual component inasmuch as the target word is presented visually for identification. We expected that this test would therefore be sensitive to differences in the modality of the encoding task. More specifically, the read encoding task should produce more repetition priming than the auditory encoding task.

## Method

*Participants.* Twenty-one subjects participated in this experiment. The data from one subject were discarded due to language difficulties. All subjects received one bonus point toward their final grade in Introductory Psychology for their participation.[3]

*Materials.* The stimuli were the same words as used in Experiment 1.

*Apparatus.* The apparatus and programming were exactly as described in Experiment 4, with one addition. For auditory items, an Eiki Model 3192 tape player was used to record and present the stimuli to the subject in a male voice.

*Procedure.* As in Experiment 4, the two encoding conditions were presented in blocked format. One set of 20 words was presented visually; the other set was presented auditorily. Order of study block presentation was counterbalanced across subjects. The order of study trials and the assignment of individual words to the visual and auditory study conditions were randomly determined for each subject.

In the visual presentation encoding block, each word appeared at the center of the left side of the screen for 750 ms, followed by a blank screen for 750 ms. Subjects were instructed to read the words silently as they appeared. In the auditory presentation, the stimuli were prerecorded on tape for each subject and the screen was blank. The audio tape was constructed so as to mimic the visual study presentation. Specifically, a word was read aloud into the tape recorder every 750 ms. The audible word was then followed by a 750-ms blank interval. Subjects were instructed to listen carefully to the words as they were presented and no response was required. Thus, the pacing of the auditory and visual trials was as similar as possible, the only difference being that the visually presented words were on continuously for the entire 750 ms whereas the auditory words were not. Between study blocks, subjects were reminded of the switch from auditory to visual presentation (or vice versa). The recognition test followed the speeded word reading test as in Experiment 1.

TABLE 5

Experiment 5: Mean Response Latencies in Milliseconds and Proportions of Errors for the Auditory (Hear), Visual (Read), and New Conditions on the Speeded Word Reading Test, and Mean Proportions of "Yes" Responses on the Recognition Test

| | Study/test condition | | |
|---|---|---|---|
| | Auditory | Visual | New |
| Speeded word reading test | | | |
| Reading latency | 572 | 558 | 588 |
| | (17.4) | (16.8) | (18.8) |
| Proportion error | .025 | .025 | .038 |
| | (.007) | (.008) | (.011) |
| Recognition test | | | |
| Proportion "Yes" | .755 | .718 | .548 |
| | (.021) | (.029) | (.035) |

*Note.* Standard errors are shown in parentheses.

## Results and Discussion

*Speeded word reading.* The mean word reading latency and mean proportion of errors for each encoding condition are shown in Table 5. It is worth keeping in mind that the visual condition is identical to our usual read condition, except that subjects did not read aloud. Pairwise comparisons indicated that words in the visual and auditory study conditions were both read in less time than new words, $t(19) = 4.16$, $SEdm = 7.278$, and $t(19) = 2.52$, $SEdm = 6.282$, respectively. Also, response latencies in the visual condition were reliably shorter than those in the auditory condition, $t(19) = 2.20$, $SEdm = 6.562$. The same comparisons applied to the error rates in Table 5 failed to detect any

[3] All of the subjects in this experiment participated in another experiment as well. Ten subjects did this experiment first and then a Stroop-type experiment; the other 10 did the reverse. Order of experiment participation had no impact on the speeded word reading data.

significant effects, *t*s < 1.30. The speeded word reading test, then, was sufficiently sensitive to detect different amounts of repetition priming in visual and auditory study conditions. Thus, this test shares with other widely used indirect tests of memory (i.e., word fragment and word stem completion and masked word identification) the characteristic of being sensitive to changes in modality.

*Recognition.* The mean proportion of positive recognition decisions in each condition is shown in Table 5. Although the mean hit rate was slightly less in the visual condition than in the auditory condition, the two means did not significantly differ, $t < 1.30$. Therefore, despite similar performance on the recognition test, the visual and auditory conditions led to different amounts of repetition priming on the speeded word reading test.

Experiment 5 clearly demonstrates that speeded word reading is sensitive as an indirect measure of memory. One of the most well-established findings in the literature—the reliable modality effect (see Roediger & McDermott, 1993, for a review)—emerged here. More specifically, the speeded word reading measure was affected by modality, whereas the recognition measure was not—the typical dissociation. Thus Experiment 5 assures us that speeded word reading is not simply a general "prior occurrence" detector, immune to the nature of that prior occurrence. Rather, this indirect measure shares the most prominent characteristic of other indirect measures that are assumed to be data-driven, in addition to offering the virtues of full exposure of the test stimuli and reduced opportunity for conscious recollection to intrude.

## GENERAL DISCUSSION

This series of five experiments has provided at least four noteworthy results. First, speeded word reading is a reasonable indirect measure of memory: Prior processing of a word, whether through reading it or generating it, results in reliable priming on this test, apparent in all five experiments. Second, with the notable exception of antonym generation (the present Experiment 3 versus Experiment 2 of Masson & MacLeod, 1992), the pattern of priming in speeded word reading coincides with that previously reported for masked word identification (MacLeod & Masson, 1997; Masson & MacLeod, 1992, 1996), establishing the generalizability of that pattern. Third, as a sort of litmus test for its indirect status, the familiar modality effect seen on other indirect tests that are assumed to be data-driven (for a review, see Roediger & McDermott, 1993) is also apparent for speeded word reading. Finally, precautions to evaluate whether conscious recollection might be contaminating the speeded word reading measure, and thereby undermining its indirect test status, were also reassuring.

### *Speeded Word Reading as an Index of Memory*

We maintain that speeded word reading is a very good indirect index of memory and should see more use as such. The measure involves full exposure of the test item, obviating the need for any sort of problem solving such as that which might be required in the word fragment completion task. Because of this full exposure, the task is also easy for the subject and does not lead to any item selection difficulties. Also, the measure is speeded, with subjects urged to perform as quickly as possible. Together, these three features work against any tendency on the part of subjects to try using conscious recollection to assist their performance. The task is readily performed without such recollection; indeed, performance would in all likelihood be harmed by attempts to recollect (e.g., the slowing in Experiment 2). Moreover, the task shows the most prevalent signature of purportedly data-driven indirect tests in the occurrence of the modality effect (Experiment 5).

Although we observed in Experiment 5 that the priming effect in the auditory condition was less than that in the read condition, it was nonetheless, in absolute terms, as large as the priming effects observed in Experiments 1–3 for the generate encoding task. This observation might be seen as suggesting that the priming effects in the auditory and generate conditions stem from a common source, namely auditory perception of the word—in the act of generating the items, the subjects pronounced them and hence also heard them. There are two arguments against this notion. First, in Experiment 5, subjects did not hear words in the read condition (they read silently), yet the priming effect in this condition was larger than that in any of the read conditions where the subjects read aloud (with the exception of the interleaved condition of Experiment 2). This comparison indicates that hearing the targets in the study phase does not make a substantial contribution to priming.

Second, we suggest that the relatively large priming effects seen in Experiment 5 were exaggerated because of the generally long response times in that experiment. Although it is not clear why response times were so long in Experiment 5, there is evidence across our experiments for a strong relation between the size of priming effects and the absolute magnitude of response latency: Across the 127 subjects in our five experiments, the correlation between size of the priming effect in the read condition and response latency in the new condition was $r(125) = .64$, $p < .001$. The priming effects in the interleaved condition of Experiment 2, like those of Experiment 5, appear to have been exaggerated because of their generally long latencies. Note that the generate priming effect in the interleaved condition of Experiment 2 (40 ms) was significantly larger than the auditory priming effect in Experiment 5 (16 ms), $t(42) = 2.13$, $SEdm = 11.189$.

We are particularly encouraged to see the close parallels between the speeded word reading data pattern in the present article and the masked word identification data pattern in our previous work (MacLeod & Masson, 1997; Masson & MacLeod, 1992, 1996). Both tasks fully expose the test word, albeit only very briefly in the masked word identification task. Our argument is that this complete exposure recruits the record of prior processing of the item, in particular accessing the initial interpretive encoding of the item. This encoding, which we have argued contains both perceptual and conceptual aspects (see Masson & MacLeod, 1992), supports priming of words that have been read or generated, or indeed read and associated.

The only discrepancy between the data patterns on the two tasks is in the case of antonym generation. In masked word identification, there appears to be little or no priming for words generated from antonyms (Jacoby, 1983; Masson & MacLeod, 1992, Experiment 2), whereas in speeded word reading, generated antonyms produce priming similar to that for read words (the present Experiment 3). Of course, any account we offer for this discrepancy is necessarily post hoc. However, we suggested (Masson & MacLeod, 1992) that the cue in antonym generation might become integrated with the target during encoding. At the time of test, there might therefore be confusion about which of the two words in the recruited episode is in fact the target. A brief, masked presentation of the target would provide little perceptual evidence to resolve this confusion. In contrast, full exposure on the speeded word reading test would provide the necessary perceptual information. This appears to be a plausible explanation for the fact that antonyms behave differently on the two types of indirect test.

### *The Influence of Prior Conceptual Processing*

Our key point is not that the priming is equivalent for the generate and read conditions but rather that even conceptually processed words do show substantial priming on indirect tests of this sort. There is, therefore, evidence of prior conceptual processing affecting subsequent processing on indirect tests. Obtaining this result with an indirect test—one that appears very unlikely to be affected by attempts at conscious recollection—runs counter to the proposal made by Toth et al. (1994) to the effect that conceptual encoding operations do not have an automatic influence on memory when data-driven indirect tests of memory are used. We assume that the speeded word reading test would be considered a data-driven test by Roediger's (1990) classification, given the task requirement of identifying an isolated stimulus and the modality-specific nature of priming on this task (Experiment 5).

Some indirect tests that are assumed to be data-driven, such as speeded word reading and masked word identification, nevertheless show nearly equivalent priming for perceptually and for conceptually encoded items. Others, such as word fragment completion (MacLeod & Masson, 1997; Weldon, 1991), show considerably more priming for perceptually encoded items, but still show priming for conceptually encoded items as well. We are quite certain that this difference is real given the numerous experiments we and others have done using these measures. Our view is that the availability of a fully specified orthographic pattern, as in the masked word identification and the speeded word reading tasks, recruits both perceptual and conceptual processing episodes. A test involving partially specified orthographic patterns, such as word fragment completion, must rely more heavily on recruitment of perceptual processing episodes because the impoverished test stimulus is often insufficient to specify a particular conceptual meaning and therefore is less likely to recruit conceptual processing episodes.

There exists a possible alternative account for why the generation encoding task produces priming in speeded word reading. The occurrence of errors during generation might indicate that subjects resort to spelling the targets to themselves because of uncertainty regarding their responses. Such spelling would constitute a kind of covert perceptual processing of the targets, which could then underlie the observed priming. Although not decisive, there is some evidence that is inconsistent with this possibility: When we used the antonym generation task previously (Masson & MacLeod, 1992, Experiment 2), we obtained no evidence of priming in the masked word identification task, which suggests that at least this encoding task does not necessarily induce covert perceptual processing. Nevertheless, this is a plausible account and we are currently conducting experiments to test its viability.

### *Direct and Indirect Tests of Memory*

Gradually, we are learning more about the differences in how people use their memories on direct and indirect tests. Like Roediger's (1990) account, our view is a transfer appropriate processing explanation (Morris et al., 1977). We see the two types of tests as generally recruiting different types of encodings. Direct tests recruit the more extensive elaborative encodings that we undertake once we have registered a stimulus and made a quick first pass at interpreting it. The most typically used forms of these tests (recall and recognition) are primarily sensitive to how we think about the meaning of the stimulus on the two encounters and to the extent that these extended semantic processing episodes overlap in their memory representations. Moreover, these tests ordinarily allow processing at test to go on for as long as the subject requires, either with a complete stimulus (recognition) or with no stimulus at all (recall). When a complete or partial stimulus is available as a cue, as in the recognition test, recruitment of prior interpretive encoding operations is also likely to be involved. We suggest that the recruitment of interpretive and of elaborative aspects of a prior encoding form the basis of familiarity and recollection processes that appear to determine performance on recognition tests (Jacoby, 1991).

Under our view, indirect tests that involve identification of a stimulus call forth the initial interpretive encoding of the item and do not ordinarily draw upon prior elaborative encoding operations (conceptually driven indirect tests such as those involving general knowledge questions would be an exception to this characterization). Interpretive encoding includes both perceptual and conceptual components. Because the goal when this encoding was formed was to interpret the stimulus, this is the encoding most likely to be helpful when faced with a degraded test stimulus or the requirement for a rapid response. Here, recollection is not required but interpretation is. Although it remains to be discovered how the weighting of the conceptual and perceptual elements works in various indirect tests, we are beginning to see some consistent patterns across tests and situations.

Remembering is a process of mapping past experience onto present experience, sometimes consciously, sometimes unconsciously. Conscious recollection can be seen as a construction that optionally accompanies the fluent, skilled performance that is supported by prior experience. To the extent that elements of prior episodes come to mind fluently and can be distinguished from other episodes, we can (re)construct an earlier episode and conclude that this construction is an accurate account of the past. Either interpretive or elaborative encoding episodes can support fluent performance, depending on the kind of task. However, recruitment of elaborative encoding episodes is more likely to be accompanied by construction of awareness of prior occurrence. This is because elaborative encoding creates greater distinctiveness and offers more convincing evidence regarding the source of the episode.

There are no doubt myriad ways to use memory. The indirect/direct dichotomy helps to capture one dimension of the experience of remembering, but it only scratches the surface. Our goal must be to understand the procedures that we use when we process information both the first time and subsequently, usually expressed in terms of the encoding/retrieval distinction. Yet thinking in terms of that distinction may actually undermine our ability to understand how prior processing connects with subsequent processing. In the end, encoding and retrieval may have much more in common than there is to separate them. They are simply names for an earlier processing episode and a later processing episode, but it is the processing overlap, not the temporal sequence, that must be emphasized.

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