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How Priming Affects Two Speeded Implicit Tests of Remembering: Naming Colors versus Reading Words

COLIN M. MACLEOD[1]

Division of Life Sciences, University of Toronto, Scarborough Campus, Scarborough, Ontario M1C 1A4 Canada

Three experiments investigated two timed implicit tests of memory—word reading and color naming. Using the study–test procedure, Experiments 1 and 2 showed that studied words caused reliable facilitation in word reading but no interference in color naming relative to unstudied words. Indeed, there was a small amount of facilitation in color naming as well. Experiment 3 further explored the color naming task by alternating shorter study and test intervals and adding control trials consisting of letter strings. Although both studied and unstudied words showed interference relative to the control letter strings, the amounts of interference they showed did not differ. Overall, word reading consistently displayed facilitation whereas color naming never exhibited increased interference due to word priming. Priming appears to be process-specific: It is restricted to facilitating repetition of processing previously applied to a stimulus and does not extend to influencing performance on a different task involving the same studied materials.

For decades, the bulk of the research on memory investigated remembering in the ''everyday'' sense of the word: the conscious recovery of prior experience. But over the past 15 years or so, cognitive psychologists have turned their attention to what is undoubtedly an even more prevalent and fundamental use of memory: remembering without awareness. Recognition of these two ways of remembering is now often captured as the distinction between explicit remembering (with awareness) and implicit remembering (without awareness), terms introduced by Graf and Schacter (1985).

The study of implicit remembering has now gained a central place in efforts to understand memory, as attested to by the increasing number of edited books (Lewandowsky, Dunn, & Kirsner, 1989; Graf & Masson, 1993), and special issues of journals such as this one and others (see also the *Canadian Journal of Experimental Psychology*, 1996, **50**). Today, implicit tests such as word fragment completion, word stem completion, and masked word identification, among others, are accepted and frequently used tools for studying how memory works without the need for awareness. Cognitive psychologists have unambiguously shown that prior processing of a stimulus such as a word frequently makes subsequent reprocessing of that stimulus more fluent, a phenomenon widely referred to as *priming.*

The experiments to be reported in this article have two points of origin, one in research on memory and one in research on attention. The first grew directly out of

[1]Address correspondence and reprint requests to Colin M. MacLeod at Division of Life Sciences, University of Toronto, Scarborough Campus, Scarborough, Ontario M1C 1A4 Canada. E-mail: macleod-@lake.scar.utoronto.ca.

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my interest in the study of implicit remembering (e.g., MacLeod, 1989; Masson & MacLeod, 1992, 1996). The impetus was simply an observation about the priming literature: All of the existing studies report instances of *facilitation* due to prior occurrence (with the exception of negative priming, see Fox, 1995; May, Kane, & Hasher, 1995). If you are currently processing a stimulus, it often helps to have processed that same stimulus in the not-too-distant past, particularly if the processing is similar on the two occasions. The second impetus stems from my interest in the domain of attention and automaticity, particularly in the context of the Stroop (1935) color–word task (see, e.g., MacLeod, 1991; MacLeod & Dunbar, 1988; MacLeod & Hodder, in press). In the Stroop situation, the emphasis is on the *interference* we suffer as a result of a well-learned color word making it more difficult to name the incompatible color in which the word is printed (e.g., the word RED in blue, say ‘‘blue’’). My goal was to bring these two areas of research together. Would it be possible to develop a Stroop-like measure of implicit remembering wherein priming would take the form of interference rather than facilitation? Such a test would also have the advantage of being an especially indirect measure of implicit remembering, in that the priming would apply to the irrelevant dimension of the task.

The kernel of the experimental idea was to have people study a list of unrelated words with the goal of remembering them for an anticipated (explicit) test. They would then go on to an implicit test where, on each trial, a word would be presented in color and the participant would have to name the color, ignoring the word. Unannounced to the participants, some of the to-be-ignored words would be the very ones they had just studied, whereas others would be new, unstudied words. The prediction was that the studied words should be primed and should therefore disrupt color naming due to an increased disposition to respond to the word instead. This would constitute a rare instance of an implicit task that displays interference, not facilitation, due to priming. Such a finding would make this Stroop analog a valuable addition to the implicit test arsenal, given the exceptionally indirect nature of the measure. After all, the participant has been told *not* to attend to the word. Indeed, this is the very type of argument that underlies the now prevalent use of the so-called ‘‘emotional Stroop task’’ to measure chronic states of activation in the clinical literature (see Logan & Goetsch, 1993, for a review). Thus, for example, spider phobics are thought to have chronically primed spider concepts, such that they are slower to say ‘‘green’’ to the word WEB printed in green than to a suitable control item such as WET printed in green (Watts, McKenna, Sharrock, & Trezise, 1986).

The idea of melding implicit priming and the Stroop task is not without precedent. In fact, there already were several well-known studies in the Stroop literature that made my expected outcome seem quite probable, although this work was not done in an implicit remembering context, taking instead a traditional lexical priming perspective. The best known of these earlier studies was that of Warren (1972; see also Warren, 1974). On each trial in his experiment, participants studied three words from a single category (e.g., AUNT, UNCLE, COUSIN). Immediately thereafter, a critical test item appeared in color. For example, this might have been the word AUNT or RELATIVE (related) or DOG or ANIMAL (unrelated), presented in the color blue. The task was to ignore the word and to name the color as quickly as possible. Compared either to the unrelated control words or to a nonword control such as XXXX, both of which served as baselines, considerable interference was observed when the word in color was identical to or related to a just studied word. Thus, in an immediate prime-target situation like the then new semantic memory tasks (see, e.g., Meyer & Schvaneveldt, 1976), Warren showed that priming a word enhanced its capability to produce interference with color naming.

Shortly thereafter, Conrad (1974) reported a related result. On each trial, she had people read a sentence like ''The toy cost a nickel'' and then tested them by having them color name a to-be-ignored word. Words that were related to the meaning of the sentence (e.g., NICKEL, MONEY) interfered with color naming relative to unrelated control words (e.g., CHAIR). Thus, immediate priming once again led to enhanced interference in color naming, a result which has since been reported in the sentence priming literature on several occasions (e.g., Whitney, 1986; see MacLeod, 1991, pp. 173–174, for a review).

At the outset, these findings seemed to bode well for extension to the implicit remembering situation, although Burt (1994) has recently shown that the situation may be more complicated (see the General Discussion). The only real concern was whether the enhanced interference effect required the kind of adjacency inherent in the procedures used by Warren and Conrad. My hope was that the interference would survive the transition to the greater lag in the study–test procedure, the procedure that is more characteristic in the domain of implicit remembering. In large part, it was with this concern in mind that the current experiments emphasized identity priming, which has been shown to span quite long intervals (e.g., Scarborough, Cortese, & Scarborough, 1977; Smith, MacLeod, Bain, & Hoppe, 1989).

This article reports three experiments aimed at studying the impact of priming a word on subsequent ability to ignore that word and name the color in which it is printed. In addition, though, the first two experiments included another implicit measure, that of word reading. In this task, sometimes called ''naming'' or ''pronunciation,'' the goal is simply to say a word aloud as soon as possible after it is displayed. Attempting to make explicit reference to an earlier studied word is neither called for nor necessary and would probably just slow down responding. Thus, word reading seems to be a fine candidate as an implicit measure, as indicated by previous studies (e.g., Carr, Brown, & Charalambous, 1989; den Heyer, Goring, & Dannebring, 1985; Durgunoglu, 1988; Logan, 1990).

There are several virtues to including the word reading task in the present experiments. First, this task is a common one in the word recognition literature (e.g., Balota & Chumbley, 1984; Forster & Chambers, 1973; Meyer, Schvaneveldt, & Ruddy, 1975) and readily reveals facilitation both for semantically related words (e.g., Joordens & Besner, 1992; Lupker, 1984) and for repeated words (e.g., Durso & O'Sullivan, 1983). In the case of repeated words, the facilitation can span quite long intervals filled with intervening words. Furthermore, as a sensitive index of facilitation for repeated words, word reading is an excellent candidate to provide a benchmark that priming indeed occurred and was measurable in these experiments. And finally, it seemed worthwhile to ascertain the degree to which these two implicit measures of memory—color naming and word reading—responded correspondingly to the experimental manipulations. There is relatively little work using such speeded measures of implicit remembering, so a careful comparison of the tasks would be instructive.

In the interest of brevity, I will describe the experiments first before considering a possible explanation, although the elements of that explanation will begin to emerge along the way. Each experiment will be introduced with the specific hypothesis that pertained to it, and then the General Discussion will be used to connect the findings in a single explanatory framework. Experiment 1 begins this process by attempting to demonstrate in an implicit test situation the basic empirical phenomenon: enhanced interference in color naming for previously studied versus unstudied words.

EXPERIMENT 1

The first experiment was modeled after the basic study–test procedure so often used in memory research (see, e.g., most of the studies described in the Richard-Klavehn & Bjork, 1988, or Roediger & McDermott, 1993, reviews). Here, participants study a relatively long list of words and then do a memory test. If explicit, the test usually requires discrimination of the studied words from other, unstudied words. If implicit, however, the test allows comparison of studied and unstudied words without informing the participant of this dichotomy.

Both the color naming and word reading tests can be seen as implicit in that neither requires intentional recovery of the words from the studied list. Put another way, both tests could readily be performed without any prior study episode. The test of primary concern was the Stroop analog in which noncolor words were presented in color and participants were required to name the color aloud, ignoring the word. An example would be the word CHAIR in green, to which the correct response would be ''green.'' Would CHAIR interfere more with color naming when it was primed rather than unprimed? As already discussed, studies by Warren (1972, 1974), Conrad (1974), and others (see MacLeod, 1991, pp. 173–174) suggest that priming might be expected to increase the interference in color naming caused by noncolor words. Such an effect would be particularly interesting because it would provide a rare instance of an *inhibitory* impact of priming on an implicit measure of memory, a measure that was also unusually indirect.

The other test was word reading, wherein participants simply said each word aloud as quickly as possible, ignoring the print color. Using the same example of CHAIR in green, the correct response would now be ''chair.'' It is well established in the semantic memory and word recognition literature that priming leads to faster pronunciation of studied words than of unstudied words (e.g., Durso & O'Sullivan, 1983; Logan, 1990). Thus, the word reading task was expected to show reliable facilitation due to priming and can be seen as a ''manipulation check'' that the prior study of the word list did have an influence. Furthermore, as it constitutes a second implicit measure, the word reading test results can also be compared to those observed in color naming.

Method

Participants. For taking part, 47 undergraduate students at the University of Toronto, Scarborough Campus, received bonus points toward their grade in Introductory Psychology. Note that a different sample from this same pool was used in each of the experiments.

Materials. The stimulus pool consisted of the 200 high-frequency words used by MacLeod (1989, see Appendix). Each participant saw a randomly selected subset of 96 of the words in the pool. All words were from the A and AA frequency range in the Thorndike and Lorge (1944) norms and varied in length from four to eight letters.

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. Item displays were in white or in one of four colors—red, blue, green, or yellow—against a black background. Vocal responses were collected using a microphone positioned directly below the screen in front of the participant. Response times were recorded as the time between the stimulus onset on the screen and the oral response into the microphone, which triggered a voice key connected to the computer. The same apparatus was used in all of the experiments.

Procedure. The 200 words were read into the program and randomized, after which 96 were selected for use with the current participant. This set of 96 was broken into two sets of 48, one set to be studied and one set not to be studied. For the study phase, the 48 items were randomized again and then presented one by one at the center of the screen in lowercase letters. Each word was on the screen for 1500 ms, followed by a 250-ms blank before the next word. The instructions presented just before the study phase stated that the words would be common words and that each would be presented for 1.5 s. The task instructions stated that the participant should ''try to remember the words for a later memory test'' and should ''study them quietly and try to learn as many of them as possible.'' When the participant indicated that the instructions were understood, the experimenter pressed a key to begin the study phase.

The first test phase immediately followed the study phase; the second test phase immediately followed the first. Order of test administration was counterbalanced, with 24 participants doing the color naming task before the word reading task and 23 participants performing the tests in the opposite order. The two tests contained the identical word–color combinations, but in two different random orders. In addition to the test-specific instructions, the instructions preceding the first test explained how to respond aloud into the microphone, with the emphasis on speaking loudly and avoiding false starts.

Consider first the color naming test. The participant was told that a series of words would be presented one at a time and that there were only four colors: red, blue, green, and yellow. The task was to ''name the color in which a word appears, ignoring the word,'' and to do so as rapidly as possible, avoiding errors. The participant was discouraged from reading the word. An example was given, and the participant was warned that the stimuli were randomized so that the color of a given stimulus word did not depend on that of preceding words. Once the participant indicated that the instructions were understood, the experimenter then pressed a key to go on to the color naming trials.

There were 96 color naming trials, made up of the 48 studied and the 48 unstudied words, randomly intermingled. Within each of the studied and unstudied sets, 12 words were presented in each of the four colors, with no constraints on the randomization. A 500-ms blank screen preceded presentation of each item. Then the item was

TABLE 1
Experiment 1—High Frequency Words: Mean Response Time in Milliseconds and Mean Proportion of Errors in the Color Naming and Word Reading Tasks as a Function of Whether the Target Word was Studied or Unstudied

	Color naming		Word reading	
	Studied	Unstudied	Studied	Unstudied
Correct latency	642 (11.46)	647 (11.03)	553 (11.38)	562 (12.38)
Error proportion	.017 (.001)	.044 (.005)	.017 (.001)	.046 (.006)

Note. The value in parentheses below each mean is the standard error for that mean.

presented at the center of the screen until the participant responded aloud, after which there was an 800-ms blank interval. Then the word ''Ready?'' appeared at the center of the screen as a cue both for the participant to prepare for the next trial and for the experimenter to input a keypress indicating the response accuracy of the just completed trial. The experimenter accomplished this by folllowing along on a protocol sheet that indicated the correct response for each trial, responding ''/'' for a correct response or ''z'' for an error. The computer then proceeded to the next trial. The experimenter also wrote down all errors on the protocol sheet.

The word reading test was carried out in exactly the same way as the color naming test phase, using a different randomization of the same 96 test items. The only difference was in the instructions: The participant was told to ''read each word aloud as fast as you can, ignoring the color in which it is printed.'' The participant was discouraged from attending to the color in which the word was printed and was given an example trial before beginning the 96 word-reading trials. The experimenter again scored accuracy on a trial-by-trial basis with the aid of a protocol sheet.

Results and Discussion

Preparation for the analyses. The mean response times for the correct responses appear in the top row of Table 1, with proportions of errors shown below the corresponding times. The value in parentheses below each mean is its standard error. Inspection of individual trial data revealed that participants occasionally had one or two very long response times. The first trial in particular was likely to be exceptionally long, perhaps because the participant was not yet used to the test format. Such outliers can seriously distort the estimated mean response time for a condition. To reduce such distortion, response times longer than 2000 ms were excluded from the correct response times and were counted as errors. For most participants, this resulted in no data trimming; for the rest, it required elimination of at most three trials. This same trimming procedure was used in all of the experiments reported in this article.

Separate analyses were conducted on both the error proportions and the correct latencies for both the color naming and the word reading tasks. Note that the reported analyses used data collapsed over test order. A critical decision in presenting the data for the first two experiments was what to do with the counterbalancing variable of test order—whether color naming or word reading was the first task administered to a given participant. All of the data were also analyzed including test order as an independent variable, but presentation of all the main effect and interaction terms involving test order would have greatly increased the length and complexity of the Results and Discussion without adding much of value. Basically, test order had no effect on either the accuracy or the latency of color naming in either Experiment 1 or 2. For the word reading task, both experiments showed a slightly stronger priming effect on both dependent measures when word reading was done first (i.e., when it was uncontaminated by a preceding color naming test), but the interaction of order with whether the word was studied or not was only reliable in Experiment 1. Perhaps test order had little influence because both tests were implicit tests, and people treated them as such.

Color naming and word reading. For color naming, the 5-ms advantage for studied words over unstudied words was marginally significant, $F(1, 46) = 3.64$, $MS_e = 204.99$, $p = .06$, but in the unpredicted direction: Studied words interfered with color naming a little less than unstudied words. Of the 47 participants, 28 (60%) were faster for studied words and 19 (40%) were faster for unstudied words. The error rate was correspondingly higher on the unstudied words than on the studied words, $F(1, 46) = 33.71$, $MS_e = .001$, $p < .001$, indicating both facilitation and the absence of any speed–accuracy tradeoff. Apparently, priming the words in the study phase was not sufficient to increase the amount of interference those words caused during color naming. If anything, priming actually *facilitated* color naming both in latency and in accuracy, surprising given that the task was color naming and not word reading.

Of course, the possibility exists that the priming manipulation was too weak to exert any real interference in the experiment. Fortunately, there is a ‘‘manipulation check’’ on this: the word reading task. The 9-ms difference in word reading time between studied and unstudied words was quite reliable, $F(1, 46) = 10.48$, $MS_e = 183.39$, $p < .01$. Of the 47 participants, 32 (68.1%) were faster for studied words and only 15 (31.9%) were faster for unstudied words. The difference in errors was also reliable for word reading, $F(1, 46) = 22.10$, $MS_e = .001$, $p < .001$, with fewer errors on studied words, again demonstrating facilitation and also opposing a speed–accuracy tradeoff.

Not surprisingly, priming of a word assisted subsequent processing directed at the word itself. However, that same priming also had a slight facilitating effect on subsequent processing of a nonverbal dimension of the stimulus (its color), a result in the unanticipated direction. Priming clearly affected performance on an implicit test when that test required *direct* processing of the item, but its effect was only slight on a test requiring *indirect* processing, and then apparently in the same direction. The primed word was itself faster to read but, if anything, that same priming actually reduced the time to name the color in which the word was printed.

EXPERIMENT 2

Given the well-known results of Warren (1972, 1974) and Conrad (1974) demonstrating increased interference in a Stroop analog as a consequence of priming the

TABLE 2
Experiment 2—Low Frequency Words: Mean Response Time in Milliseconds and Mean Proportion of Errors in the Color Naming and Word Reading Tasks as a Function of Whether the Target Word was Studied or Unstudied

	Color naming		Word reading	
	Studied	Unstudied	Studied	Unstudied
Correct latency	639	643	579	594
	(13.59)	(13.12)	(13.03)	(13.94)
Error proportion	.018	.062	.018	.076
	(.001)	(.008)	(.001)	(.008)

Note. The value in parentheses below each mean is the standard error for that mean.

words, the preceding results were surprising. Possibly the choice of high frequency words in Experiment 1 was not an ideal testing ground: High-frequency words are faster to process than low frequency words on first encounter in an experiment (e.g., Monsell, Doyle, & Haggard, 1989), presumably because the benefit of one additional presentation is less for the high frequency words. In turn, this makes it harder for high frequency words to show priming. Larger priming effects are typically observed with low frequency words than with high frequency words (see, e.g., Jacoby & Dallas, 1981; MacLeod & Kampe, in press; Scarborough et al., 1977). To take advantage of this fact, Experiment 2 was a replication of Experiment 1 using low frequency words. Such words should show more priming in the word reading task and hence provide a fairer test of whether there is also priming in the color naming task. If so, will that priming now lead to increased interference in color naming?

Method

Participants. Twenty-two people performed color naming before word reading; 16 performed the tests in the opposite order.

Materials. The low frequency items were the 120 words shown in the Appendix. All were selected from the Kucera and Francis (1967) norms and had a frequency of either 1 or 2 occurrences per million. There were 40 four-letter, 40 five-letter, and 40 six-letter words. Each participant saw a randomly selected subset of 96 of the 120 words in the pool.

Procedure. The procedure of Experiment 2 was identical to that of Experiment 1; the only change was the switch to low frequency words.

Results and Discussion

The mean response time data for Experiment 2 are presented in Table 2, with the error proportions shown below the corresponding times. The value in parentheses below each mean is its standard error. The color naming data for low frequency words again showed no interfering effect of priming, $F < 1$. Averaging over testing order, there was only a 4-ms effect of priming on color naming, again in the direction of facilitation rather than interference. Of the 38 participants, 22 (58%) were faster on the studied words, 15 (39%) were faster on the unstudied words, and 1 (3%) had identical times regardless of priming. As in Experiment 1, reliably more color naming errors were made on the unstudied words than on the studied words, $F(1, 37) = 33.60$, $MS_e = .001$, $p < .001$, again indicating a small trend toward facilitation of color naming for primed words in both the latency and the error data. Thus, the color naming pattern for low frequency words was very similar to that for high frequency words.

As in Experiment 1, there was reliable evidence of priming on the word reading task in Experiment 2, with studied words read on average about 15 ms faster than unstudied words, $F(1, 37) = 15.21$, $MS_e = 283.03$, $p < .001$. Of the 38 participants, 27 (71%) were faster on the studied words, whereas only 10 (26%) were faster on the unstudied words, with 1 (3%) unaffected. Once again, the error rate data were consistent in also showing facilitation: Reading unstudied words showed a higher error rate than did reading studied words, $F(1, 37) = 52.34$, $MS_e = .001$, $p < .001$.

This reliable priming for reading low frequency words aloud is consistent with prior results and, as in Experiment 1, provides a manipulation check that the study trial did indeed have an impact. Thus, the absence of enhanced interference for primed words in color naming is not the consequence of inadequate study of the primed words, whether those words are high or low in frequency.

The pattern across these two experiments is very consistent. Word reading time was primed by prior study. Although this effect was smaller for high frequency words, it was nonetheless apparent over both high and low frequency words. Studying words facilitated the reading of those same words on an implicit test. Of course, studying entailed reading, so process repetition necessarily occurred in the word reading task. This process repetition was not required by the other implicit task, color naming, although the existence of the standard Stroop effect clearly indicates that people normally must process the word to some extent or Stroop interference would not occur at all. Yet priming the words did not cause interference in color naming. Regardless of word frequency, studied words did not interfere more than unstudied words when they made up the irrelevant dimension of the task. In fact, for both error and latency data, there was evidence of facilitation over the first two experiments. The question now is why this Stroop-like implicit measure does not evidence the predicted increased interference for previously studied words. Experiment 3 took a new tack in attempting to explore this question.

EXPERIMENT 3

The problem with obtaining an interfering effect of priming on color naming may have to do with the long delay between the study and test of an individual item in Experiments 1 and 2. Although the study–test procedure has been used extensively—and successfully—to investigate priming on a variety of implicit tests involving individual words (Richardson-Klavehn & Bjork, 1988; Roediger & McDermott, 1993), it may not be appropriate when the measure is both indirect and different in quality, like color naming. In color naming, the primed word is not responded to at test; rather, it serves as a distractor, which makes the color naming task distinctly different from other implicit tests.

Reexamination of the Warren (1972, 1974) and Conrad (1974) studies, and of other priming studies using the Stroop task, reveals an interesting commonality: These studies were set up such that the priming event occurred immediately before the Stroop-like trial. In the Warren (1972) study, three categorically related words (e.g., AUNT, UNCLE, COUSIN) were presented and then the target item (e.g., AUNT or RELATIVE or DOG) was presented in a color which the person had to name. There was no intervening activity between the three primes and their corresponding target. Roughly the same time frame was used in the Conrad study: The sentence prime (e.g., The toy costs a nickel) immediately preceded the target word (e.g., NICKEL or MONEY or METAL or CHAIR). All of the subsequent studies that have examined indirect priming using the Stroop task (see MacLeod, 1991, pp. 173–174, for a review) have also adopted short time lines. Perhaps this prime–target proximity is critical.

In Experiment 3, the study phase was brought much closer to the test phase. The experiment was modelled after the procedure used by McKoon and Ratcliff (1979) and more recently by Smith et al. (1989), where the study of a short list of unrelated word pairs was followed by a lexical decision test. For present purposes, the details and findings of those studies are not relevant; instead, the general procedure is what matters. They broke their set of materials into a number of blocks, with each block containing a brief study list (7 pairs) followed by a brief lexical decision test (10 prime–target pairs). In this way, study and test occurrences of individual items were brought quite close together within each block. Unfortunately, the greater number of study and test trials involved in this procedure resulted in there being time for only the color naming task in a single session, so the word reading test was omitted in Experiment 3.

This procedure was adapted for the present study. During each block, participants studied a short list of single words and then immediately did a short sequence of Stroop-like color naming trials, some of which contained the studied words. Both the study lists and the test lists were only 9 items long. The color naming test trials were equally divided into studied words, unstudied words, and control simuli (xxxx). The inclusion of the control condition afforded the opportunity of examining whether noncolor words produced any interference at all relative to a nonword baseline. Klein's (1964) classic study of the Stroop interference caused by words having different degrees of relation to colors suggested that noncolor words produced relatively little interference relative to a nonword control. However, his study was done using the traditional procedure of naming a long sequence of colors on a single stimulus card. There is reason to believe that his result may not generalize to the item-by-item procedure in more common use today. As one illustration, Grant, Dunbar, and MacLeod (1995) obtained considerable interference for noncolor words using the single-item procedure.

In addition to this supplementary question of whether noncolor words do cause interference, the present experiment also permits further exploration of the specific question of concern in this article: Can priming increase Stroop interference caused by noncolor words? (Indeed, it might now be appropriate to ask whether priming words facilitates their color naming, given the outcomes of Experiments 1 and 2.) If priming has a negative impact here, then the implication must be that the time between the priming event and the corresponding color naming test is critical and that this time cannot be too long. Thus, Experiment 3 addresses both (1) the extent to which noncolor words interfere when unstudied and (2) whether that interference is increased for recently studied noncolor words.

Method

Participants. Twenty new students were selected from the same pool.

Materials. The design required 240 words. For ease of construction and correspondence to Experiments 1 and 2, the items consisted of 120 low frequency words and 120 high frequency words. The low frequency words were the same as those used in Experiment 2 and presented in Appendix A. The high frequency words were a subset of the 200 words used in Experiment 1 and derived from the list used by MacLeod (1989).

Procedure. A QuickBASIC 4.5 program prepared the sequence of materials for each participant. This consisted of 20 blocks. For half of the participants, the first 10 blocks were constructed from the high frequency words and the second 10 blocks used the low frequency words; for the other half of the participants, this order was reversed. Given the highly similar results as a function of word frequency in the first two experiments, the word frequency variable was treated as a counterbalancing variable and was not included in the analysis.

Each block consisted of 9 study words and 9 color-naming test words. Because no repetition was allowed, the 10 study blocks of a given word frequency used 90 of the available 120 words in the file. The construction of the 9 test items in each of the 10 test blocks was more complicated. First, 3 of the 9 studied words were chosen at random from among the positions 3 through 7 in the study order; this avoided primacy and recency serial positions. These words constituted the primed, or studied, set. Then, a further 3 words were selected from the original stimulus file, consuming the remaining 30 words over the 10 blocks. These constituted the unstudied set. Finally, three test trials were assigned the xxxx control stimulus. The order of these 9 test items was then randomized.

In this way, each participant saw a unique ordering of items during study and test. A separate program ran the experiment, controlling stimulus presentation and data collection. Here is how the timing and presentation appeared for every block. First, the warning ‘‘WORD STUDY PHASE b’’ appeared at the center of the screen, where ‘‘b’’ stands for the block number. This stayed on the screen for 1.5 s, followed by a 250-ms blank interval. Then each of the study words for that block appeared one at a time at the center of the screen in lower case for 1.5 s, each followed by a 250-ms blank interval.

The test phase was next, prefaced by the warning ‘‘COLOR NAMING PHASE b,’’ where ‘‘b’’ again stood for block number. This message stayed on at the center of the screen for 1.5 s followed by a 250-ms blank interval. Before the test words appeared, the program randomly assigned a color to each test word with the constraint that three of the four colors were used twice each and the remaining color was used three times. As previously, the four colors were red, blue, green, and yellow. Each test word was presented at the center of the screen until the participant responded

TABLE 3
Experiment 3—Short Study–Test Sequences: Mean Response Time in Milliseconds and Mean Proportion of Errors in the Color Naming Task as a Function of the Studied, Unstudied, and Control (xxxx) Conditions

	Studied	Unstudied	Control
Correct latency	880	876	759
	(31.08)	(28.77)	(24.13)
Error proportion	.033	.024	.018
	(.006)	(.004)	(.005)

Note. The value in parentheses below each mean is the standard error for that mean.

aloud into the microphone with its color, at which point the screen was cleared and a 250-ms blank intervened before the next test item. After each test block, participants were asked to recall aloud as many of the 9 studied words as possible, in an effort to ensure attention to and rehearsal of the words during study. However, these recall efforts were not actually recorded.

Prior to the experiment, participants were given a skeleton outline of how each block would proceed in terms of timing, but without any mention of the priming manipulation. They were told that there would be 20 blocks and that the first 10 would involve low (or high) frequency words and the second 10 would involve high (or low) frequency words. They were then told their primary tasks. During the study phase, this was to remember the 9 words in the block until after the color naming task, when the words were to be recalled aloud. During the color naming phase, their primary task was to ignore the word on each trial and to name its color as quickly as they could, avoiding errors. No explanation was given for any of these stages prior to the experiment.

Results and Discussion

Table 3 presents the mean response times and error proportions for color naming, the only test in Experiment 3. The value in parentheses below each mean is its standard error. A one-way ANOVA was conducted on each of the dependent variables, the independent variable being Study Status (studied, unstudied, or control).

The analysis of the error data revealed a marginally significant effect of Study Status, $F(2, 38) = 2.75$, $MS_e = .0004$, $p = .08$. This was due to the control condition showing a lower error rate than the two conditions involving words, $F(1, 19) = 4.20$, $MS_e = .002$, $p = .05$, with the latter two not differing from each other, $F(1, 19) = 1.55$, $MS_e = .001$, $p > .20$. Errors were a little higher in the conditions with the longer latencies, indicating that there was no speed–accuracy tradeoff.

The ANOVA on latencies revealed a reliable effect of Study Status, $F(2, 38) = 73.24$, $MS_e = 1283.49$, $p < .001$. Comparisons showed that the effect of study status was entirely due to the difference between the control xxxx stimuli and the two conditions involving words (studied and unstudied), $F(1, 19) = 94.12$, $MS_e = 11976.35$, $p < .001$; there was virtually no difference between studied and unstudied words in the extent of interference they caused with color naming, $F < 1$. Thus, consistent with both of the preceding experiments in this article, priming some of the words did not lead those words to produce more interference in color naming than their unprimed counterparts. Notice, though, that there was no hint of facilitation due to study in this experiment.

There are two main messages to be drawn from the results of Experiment 3. The first is that Experiments 1 and 2 are again corroborated in showing that priming one subset of words does not increase the interference those words will cause when the task at hand is naming the colors of studied and unstudied words. This appears to be true even when the proximity of the study and test of each word is increased substantially, as was done here. Rather, priming words may facilitate naming the colors in which they are printed. In fact, when Burt (1994) increased proximity of study and test to its maximal level by switching to the prime–target procedure (in which a studied word immediately preceded the color naming test), she obtained quite large and reliable facilitation.

The other main message is not the focus of the present work, but is relevant to the use of the Stroop task with words other than color words, as in the burgeoning clinical literature (see Logan & Goetsch, 1993, for a review). The received wisdom is that noncolor words produce relatively little interference relative to control stimuli such as xxxx. This belief derives largely from the landmark study by Klein (1964) and from its successors (e.g., Dalrymple-Alford, 1972). However, it would appear that the belief does not accord with all of the data. In particular, when an individual-trial procedure is implemented using computer-controlled displays, there appears to be fairly substantial interference due to noncolor words. In the present case, this amounted to about 119 ms on average. Although this may be a rather high estimate, it nevertheless points to a topic worthy of further study. Elsewhere (Grant et al., 1995), we have been attempting to explore this question more thoroughly, consistently finding that noncolor words produce strong interference relative to a neutral baseline.

GENERAL DISCUSSION

Over the first two experiments, prior presentation of a word faciliated subsequent pronunciation of that word on a word reading task, replicating prior studies (e.g., den Heyer et al., 1985; Durso & O'Sullivan, 1983; Logan, 1990). Furthermore, this facilitation changed in an orderly way, increasing as words moved from high to low frequency. Word reading would appear to be an exemplary implicit measure of memory in that it is very easy for the participant to do—perhaps even automatic (Posner & Snyder, 1975)—and this rapid speeded character of the measure discourages any temptation to switch to an explicit retrieval strategy. Word reading also has the virtues of being a very sensitive measure and of providing a bridge to the large literature on word recognition (cf. Besner & Humphreys, 1990).

The story is quite different for color naming. Most crucial, the anticipated enhancement of interference for studied words over unstudied words never materialized in any of the three experiments. Instead, there appeared to be a little facilitation of color naming due to prior study of the words. Thus, at least in the common study–test setting, color naming would not appear to be a good candidate as an implicit measure of memory. This particular effort to develop an indirect implicit measure that reveals priming through interference rather than facilitation has therefore been unsuccessful.

The remaining question is why color naming of words shows not interference but facilitation, albeit only a small amount. In fact, recent work (MacLeod, 1992; Burt, 1994) makes it clear that when a prime–target procedure is used, such that the word to be color named is immediately preceded by itself vs. an unrelated word (analogous to the studied vs. unstudied manipulation here), there is reliable and consistent *facilitation* of color naming for studied words, in sharp contrast to the results of Warren, who found interference for both identical and categorically related words in one study (Warren, 1972) and for associatively related words in another study (Warren, 1974). Thus, the pattern in the prime–target situation remains to be clarified and is apparently not as straightforward as has long been believed. I am currently attempting to replicate the Warren (1972) study and to locate the source of this disparity.

For the study–test procedure used here, however, it would appear that color naming of words is only slightly sensitive to whether those words are primed, despite word reading showing a distinct advantage for the same primed words following the same study episode. Difficulty in understanding this pattern may stem from a bias to think in terms of the words themselves rather that the processes applied to those words. During study, the words were read and then processed further in whatever way(s) the participants chose to use toward their goal of remembering the words. But the key fact is that the words were read at the time of study. At the time of test, that initial reading was directly relevant to the rereading required by the word reading task, so priming in the form of facilitation was evident on that test. In contrast, the initial reading was not directly relevant in the color-naming task where people are discouraged from rereading the words. Of course, the existence of standard Stroop interference tells us that people do read the words during a color-naming task, and so it may be that priming word reading helps them to do this a little more easily, producing a small amount of facilitation. Facilitation is less in color naming than in word reading because word reading plays less of a role in the color-naming task.

The search for an implicit measure that is very indirect and that reveals interference, rather than facilitation, may be more difficult than might previously have been thought, given that color naming does not produce such a result. The Stroop phenomenon is the best known and most robust task of its kind; if it does not show an inhibitory effect, finding a situation that does will require considerable ingenuity. The argument offered here is that there is no additional interference in color naming of studied words because the priming of those words is process-specific. Reading a word at study will prime reading that word again at test, and this will be seen as facilitation. But the primed word does not gain the capability of further disrupting a task in which reading the word is irrelevant.

This is not an isolated result. MacLeod et al. (1995) have reached the same conclusion from data in the flanker task, where participants must attend to a target item and ignore a distractor item on each test trial (e.g., Eriksen & Eriksen, 1974; Dallas & Merkle, 1976; White, 1995). Our experiments demonstrate that a primed flanker word does not interfere any more with a lexical decision about the target word than does an unprimed flanker word. Taken together, these two sets of data converge to the strong conclusion that priming is specific not to the studied item, but to the interplay between the item and the process applied to it on its prior occurrence. If a previously studied word is not in the focus of attention when next it reappears, the fact that it was recently primed appears to be much less influential. The critical factor is not whether an item has been previously processed, but whether that previous processing is relevant to the current situation.

APPENDIX: THE 120 LOW FREQUENCY WORDS USED IN EXPERIMENT 2

Four-letter words		Five-letter words		Six-letter words	
aura	lull	abbot	joust	adverb	medley
boar	malt	annex	knoll	almond	mildew
cask	mend	arbor	ladle	bedlam	morgue
clan	moth	basil	mirth	beggar	nugget
cuff	omen	bicep	molar	bridle	oblong
drip	pawn	brawl	navel	cavern	octave
duct	perk	caddy	patio	coyote	pelvis
dune	quiz	chive	plaid	crease	podium
fawn	rash	cocoa	polka	duplex	poplar
feud	romp	croak	robot	dynamo	quartz
gull	silo	drawl	rodeo	enamel	rascal
harp	soot	ether	shrub	faucet	rumble
hive	swig	felon	sleet	fungus	safari
jade	thug	flake	snout	gambit	sequel
jest	tote	foray	tonic	giggle	splice
jinx	tuck	gauze	trash	hearse	tartar
kite	veal	gorge	usher	heresy	tinsel
knob	wand	hedge	valet	icicle	tycoon
leak	whim	hinge	vigil	lament	visage
lily	yawn	icing	waltz	lesion	wallop

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