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Prime Validity Affects Masked Repetition Priming: Evidence for an Episodic Resource Account of Priming

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Masked repetition priming in the lexical decision task was found to be greater when prime validity, defined as the proportion of repetition versus unrelated primes, was high (0.8) rather than low (0.2), even though primes were displayed for only 45 or 60 ms. Prime validity effects did not obtain when targets varied markedly from trial to trial with respect to processing difficulty. This variation appears to cause extensive prime recruitment even when prime validity is low. Reducing variability in target processing difficulty restored the influence of prime validity. Prime validity effects are anticipated by an episodic account of masked priming in which a prime event creates a resource that can be recruited to aid word identification. These effects support the idea that resource recruitment is more likely to occur when the validity of the resource is high, which creates a context that supports prime recruitment. Implications for lexical accounts of masked repetition priming are discussed.

Key Words: episodic memory; masked priming; prime validity; repetition priming; word identification.

Consciously and unconsciously, we rely on our memories of prior experiences to help us recognize the people, places, and things we encounter every day. Whether we recognize something depends not only on our learning experiences with similar things in the past but also on the context in which the recognition attempt is being made. Stated this way, it seems obvious that recognition is a memory phenomenon that reflects an interaction between memory for prior experience and current encoding conditions. In contrast to this idea, the dominant view of how people recognize words is that we rely on activation of special representations that are entirely distinct from our memories for particular prior experiences with words. The ultimate goal of the present research is to examine more closely the possibility that word recognition occurs in the same general way as recognition of any other object in the world, namely, through the recruitment of prior processing episodes from memory.

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An effective tool for studying word recognition involves assessing the influence of a prior presentation of a single context word, a *prime*. By determining the types of primes that facilitate responding to a target, and by varying the stimulus onset asynchrony (SOA) between the prime and the target, inferences may be drawn about the nature and time course of word recognition. In repetition priming, the type of priming examined in the experiments reported here, subjects are faster or more accurate at responding to a word if it is preceded by the same word (a *repetition prime*) than if it is preceded by a different, unrelated word (e.g., Scarborough, Cortese, & Scarborough, 1977).

In the word recognition literature, priming effects are often interpreted from an activation perspective that assumes the existence of an abstract representation for each word and that a word's representation is automatically activated when it is encountered. In repetition priming, presentation of a prime word automatically causes its lexical entry (Forster & Davis, 1984) or logogen (Morton, 1969) to be activated, so that if the subsequent target is the same as the prime word, less target processing has to be done before a response can be initiated.

The present work diverges from this perspective and instead builds on the notion that priming effects may reflect a form of episodic learn-

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ing (e.g., Becker, Moscovitch, Behrmann, & Joordens, 1997; Jacoby & Dallas, 1981; Joordens & Becker, 1997; Ratcliff & McKoon, 1988; Rueckl, Mikolinski, Raveh, Miner, & Mars, 1997). On this account, a priming event is a learning episode that leads to some form of change in episodic memory (e.g., a change in connection weights or an additional episode represented in memory). More generally, we suggest that presentation of a prime creates a processing skill that enables more fluent processing of that or a similar stimulus in the future (e.g., Kolers, 1979).

Although a number of researchers representing diverse theoretical perspectives have advocated the notion that there is an episodic basis for repetition priming when the prime event permits easy identification of the prime word (e.g., Becker et al., 1997; Forster & Davis, 1984; Jacoby & Dallas, 1981), Forster and his colleagues (e.g., Forster, 1998, 1999; Forster & Davis, 1984, 1991) have argued that an activation process makes additional contributions to priming. To demonstrate these contributions, primes were briefly presented (60 ms) and masked to prevent their conscious identification and hence presumably to prevent the formation of an episode. Using this masked priming paradigm, Forster and Davis (1984) obtained a form of repetition priming that was dissociated from priming obtained with clearly visible primes. For example, whereas easily identified primes can produce priming for both words and nonwords, Forster and Davis (1984) found masked priming only for words. Also, low-frequency words often benefit more than high-frequency words from clearly presented primes, but Forster and Davis showed that masked primes produce equal priming for low- and high-frequency words. They proposed that a masked prime opens the lexical entry for the corresponding word. When the same word subsequently appears as a target, its entry is already open; thus less time is needed to identify the target.

In contrast to the Forster and Davis (1984) lexical account of masked priming, Bodner and Masson (1997; see also Masson & Isaak, 1999) have argued that masking primes does not prevent the construction of a priming episode. Instead, we suggested that episodes are formed for masked primes, but are not consciously accessible. The proposal that episodes can be formed for very briefly presented stimuli is consistent with findings from the mere exposure paradigm (e.g., Kunst-Wilson & Zajonc, 1980; Seamon, Brody, & Kauff, 1983; Whittlesea & Price, in press), in which brief (sometimes masked) exposure to a stimulus leads subjects to prefer that stimulus to a novel one in a subsequent preference judgment task. This preference effect appears even though subjects are at chance when making explicit recognition memory judgments for the same stimulus pairs.

Bodner and Masson's (1997) account was inspired by Whittlesea and Jacoby's (1990) demonstration that use of prime episodes can vary as a function of the difficulty of the subsequent item that is processed. A briefly presented prime (e.g., GREEN) was more likely to be used to help identify a briefly presented second item if that second item was degraded (e.g., pLaNt) rather than nondegraded (e.g., PLANT). The priming advantage following degradation was revealed by faster naming latencies for a third item that was a repetition of the prime (e.g., GREEN). By Whittlesea and Jacoby's (1990) retrieval view of priming, a degraded second item was more likely to recruit the prime, making it more available to help guide recognition of its subsequent re-presentation (i.e., repetition priming). In contrast, by prospective accounts of priming (e.g., spreading activation), the influence of a prime cannot be made conditional on whether or not a subsequent item turns out to be degraded.

LIST CONTEXT EFFECTS IN WORD RECOGNITION

An important implication of the proposal that priming effects—even those based on masked primes—have an episodic origin is that these effects should be susceptible to manipulations of context. There is ample evidence that both single word identification and priming are influenced by list context (i.e., the mixture of items included in the stimulus list). For example, the characteristics of a set of filler words used in the naming task (e.g., words with regular vs irregular pronunciations) affect how long subjects take to read critical words aloud (Jared, 1997; Lupker, Brown, & Columbo, 1997). Similarly, lexical decisions are influenced by whether low- and high-frequency words are presented in separate blocks or are mixed together within blocks (e.g., Gordon, 1983). Lexical decisions are more difficult when the nonword targets sound like real words such as “brane” and “phort” (e.g., Davelaar, Coltheart, Besner, & Jonasson, 1978; Joordens & Becker, 1997). In addition, the amount of benefit derived from a prime depends not only on the nature of targets but also on the nature of the primes (Smith, Besner, & Miyoshi, 1994; Stolz & Besner, 1997). For example, Smith et al. (1994) found that semantic priming occurred for shorter duration primes only when these were presented in a list that did not contain any longer duration primes. Finally, McKoon and Ratcliff (1995) showed that even with SOAs of 250 and 300 ms, priming in lexical decision and in word naming was greater if the primes were predominantly of one type (antonym vs synonym). Thus, the primes and the other targets in a stimulus list act as a type of context that can influence how each word target is recognized.

The particular aspect of list context we chose as the primary basis for examining context effects in masked priming was the proportion of repetition primes in the stimulus list. Although no published studies have specifically examined whether repetition proportion effects occur in the masked repetition priming paradigm, Cheesman and Merikle (1986) reported an experiment in which a color-word prime was presented below the subjective identification threshold prior to naming the color of a rectangle. When the identity of the color word was congruent with the color of the rectangle on 75% of the trials, color naming was faster than when the word and color were congruent on only 25% of the trials. In addition, a manipulation related to repetition proportion has been used in long-term repetition priming studies (Allen & Jacoby 1990; Jacoby, 1983). In these experiments, subjects studied a set of words and then were given a masked word identification task, in which subjects attempted to identify briefly presented masked words. The proportion of targets that had been previously studied (proportion overlap) was varied (e.g., 0.1 vs 0.9). Jacoby (1983) found that prior study increased target identification and that this benefit was greater when a high rather than a low proportion overlap was used. Allen and Jacoby (1990) showed that this proportion overlap effect was not due to use of deliberate strategies because it was equally strong for words that were studied as anagrams as for words that were simply read at study, even though the former were more likely to be recognized in a subsequent recognition test. Instead, the effect was attributed to higher similarity between study and test context when a high proportion of test items had been studied.

Another important aspect of the Allen and Jacoby (1990) results is that although studied words were more likely to be identified when the proportion overlap was higher, nonstudied words on the test list were less likely to be identified. The implication of this finding is that proportion overlap, at least in this task, has its effect on bias rather than on sensitivity (see also, Ratcliff, McKoon, & Verwoerd, 1989). Thus, there is evidence to suggest that context manipulations such as proportion overlap can bias performance on tasks in which aware uses of memory have been minimized.

If the overlap between study and test contexts can influence priming in masked word identification, we reasoned that a comparable manipulation in the masked priming task could have a similar effect. In particular, the proportion of repetition versus unrelated masked primes might influence the size of masked priming effects on the lexical decisions. When repetition proportion is high, the prime is a more valid and helpful source of information about targets than when repetition proportion is low. Therefore, recruitment of the prime resource to assist target processing should be more likely when the repetition proportion (i.e., prime validity) is higher. If so, then a group of subjects receiving a higher repetition proportion, by relying on primes to a greater extent, should show more priming for word targets than a group of subjects receiving a lower repetition proportion—a repetition proportion by priming interaction, or *prime validity effect*.

Moreover, if repetition proportion, like proportion overlap, has its influence through bias (Allen & Jacoby, 1990; Ratcliff et al., 1989), then enhanced recruitment and use of the prime episode by the high repetition proportion group should generally produce two effects. First, increased prime recruitment should improve target processing when what is recruited is useful. That is, increased reliance on the primes should help performance on the 80% of trials that have repetition primes. Second, increased prime recruitment should impair target processing when what is recruited is not useful and interferes with target identification. Increased reliance on the primes should therefore hurt performance on the 20% of trials that have unrelated primes.

Subjects should not consciously be sensitive to repetition proportion, of course, because they are at least subjectively unaware of the primes' identities and often even of their presence. Instead, the proposal we put forward is that word recognition can become tuned to regularities in the prime context, causing primes to play a larger or smaller role in the identification of targets depending on their validity. This proposal is consistent with results from artificial grammar and implicit learning paradigms in which subjects exhibit sensitivity to regularities in a stimulus set without awareness of those regularities (Reber & Allen, 1978; Vokey & Brooks, 1992; Whittlesea & Wright, 1997).

In the experiments reported below, repetition proportion was systematically manipulated and its effects on masked repetition priming of word and nonword targets in the lexical decision task were observed. An episodic resource account of masked priming provides reason to expect that repetition proportion should influence the amount of priming that is observed.

EXPERIMENT 1

For the initial test of whether repetition proportion modulates masked repetition priming, a low repetition proportion group received repetition primes on 0.2 of the word trials and 0.2 of the nonword trials. A high repetition proportion group received repetition primes on 0.8 of the word trials and 0.8 of the nonword trials. For both groups, unrelated primes preceded the remaining targets.

Method

Subjects. Subjects in these experiments were undergraduates at the University of Victoria who participated for extra credit in an introductory psychology course. Each subject took part in only one of the reported experiments. Subjects always were randomly assigned to either the low group or the high group with respect to repetition proportion. In Experiment 1, there were 40 subjects in the low group and 40 subjects in the high group.

Materials and design. The targets were 220 words and 220 pronounceable nonwords of 3 to 8 letters in length. Twenty targets of each type were used for practice trials. The frequency of occurrence of the 200 critical word targets ranged from 1 to 2,216 per million (median = 31; Kučera & Francis, 1967). The distribution of word frequencies was positively skewed, with 154 of the 200 items having frequencies of less than 100 per million. For each word and nonword target, an additional unique unrelated prime of equal length was selected that shared no more than two letters with the target and had no shared letters in the same position as the target. Each unrelated word prime was paired with a word target of similar frequency. Unrelated primes for nonword targets were pronounceable nonwords.

The critical word and nonword lists were each divided into five blocks of 40 items. In the high group, four blocks of each target type were paired with repetition primes and one block of each type was paired with unrelated primes. The reverse arrangement was used for the low group. The assignment of blocks of items to repetition or unrelated prime conditions was counterbalanced across subjects within the low group and within the high group. The repetition proportion for the practice items matched that of the critical items within each group. The high group received 32 repetition and 8 unrelated practice trials (half words and half nonwords), followed by 320 repetition and 80 unrelated critical trials (half words and half nonwords). The number of repetition and unrelated trials was reversed for the low group. Thus, repetition proportion was 0.8 for both words and nonwords in the high group and 0.2 for both words and nonwords in the low group.

Procedure. Subjects were tested individually. Stimuli were presented in black 12-point courier font against a white background on a monochrome monitor attached to a Macintosh II desktop computer. Stimulus displays were synchronized with the raster scan cycle of the monitor to permit exact timing in increments of 15 ms. The accuracy of the display durations was verified using a light-sensitive diode connected to an electron storage oscilloscope.

Subjects were told that "several briefly displayed items" would be shown on each trial in the center of the screen, and that their task was to respond to the uppercase target that would remain on the screen until they responded. They were not specifically told about the primes. Each trial began with a 495-ms mask consisting of a row of uppercase Xs matched for length with the prime and target. This mask was presented in the center of the computer monitor. The prime was then immediately presented in lowercase letters for 60 ms where the mask had been. The uppercase target then replaced the prime and remained in view until the subject responded. Subjects made a lexical decision as quickly and as accurately as possible by pressing one of two labeled keys on a response box connected to the computer. Subjects used their right index finger to press the YES key if the target was a word and their left index finger to press the NO key if the target was not a word. To encourage conscientious responding, the instructions correctly told subjects they would be shown a summary of their performance at the end of the experiment. In addition, a corrective feedback message appeared on the monitor for 1 s and a tone sounded on trials where the subject made an incorrect response (INCORRECT RESPONSE) or took more than 1,500 ms to respond (TOO SLOW). The next trial began 500 ms after a correct response or corrective feedback.

The 40 practice trials were presented in random order and were followed by a message encouraging subjects to ask questions if they were unclear about the task. Otherwise, they pressed a key and began the 400 critical trials. These trials were presented in an independently determined random order for each subject. Self-paced rest breaks were provided after every 50 critical trials. To assess awareness of the primes, subjects were asked at the end of the testing session what they had seen on each trial, just before the target appeared. If they initially reported seeing only Xs, which was a typical response, they were asked follow-up questions (e.g., "Did you see anything else?"). The experiment took 25–30 min for each subject to complete.

Results

Reported prime awareness. According to their responses to questions about what was displayed during the trials, 77% of subjects across the experiments we report were not aware that anything other than a row of Xs had been presented prior to each target. The remaining subjects were aware that "something" other than a row of Xs had been flashed; the majority of these reported having seen "flickering letters" or "something flashing." A few subjects in each experiment (0–18%) reported noticing that some of the primes were words, but only a few of the 540 subjects we tested reported noticing any sort of relationship between primes and targets. The level of prime awareness implied by these responses is typical of previous masked repetition priming experiments (e.g., Bodner & Masson, 1997; Forster & Davis, 1984) and other experiments using similarly masked primes (e.g., Milliken, Joordens, Merikle, & Seiffert, 1998). Not surprisingly, reports of prime awareness tended to be less frequent in experiments where a 45-ms (5%) rather than a 60-ms (10%) prime duration was used. Across the experiments, the mean percentage of subjects in the high and low groups who did not report seeing anything except a row of Xs was nearly identical (78 vs 77%).

Response latency and errors. In all experiments, the following conventions were used. Trials with response latency shorter than 300 ms or longer than 3,000 ms were excluded from analysis, resulting in less than 0.5% of the trials

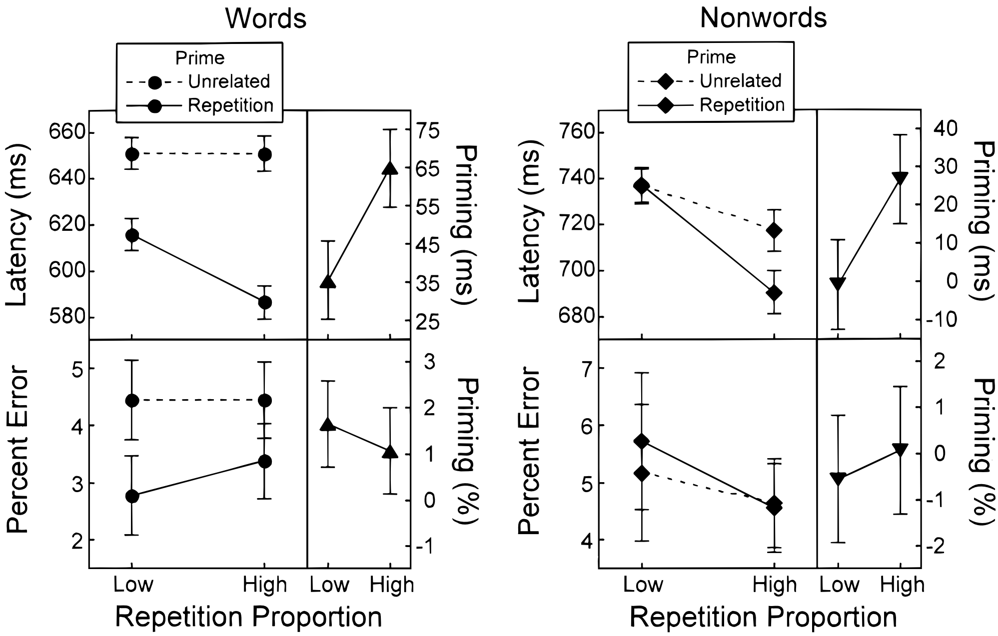

FIG. 1. Mean response latency, percentage error, and corresponding priming effects for words and nonwords in Experiment 1. Error bars for latency and error are 95% within-subjects confidence intervals and are appropriate for comparing means across prime conditions. Error bars for priming effects are 95% between-subjects confidence intervals and are appropriate for comparing means across repetition proportion conditions and against zero.

being eliminated from any single experiment (Ulrich & Miller, 1994). Reducing the upper cutoff to 1,500 ms did not change the pattern of results. Separate analyses of variance (ANOVA) with subjects as the random variable were performed on the mean response latencies and error rates for words and nonwords. Items were never randomly selected, so item analyses are not reported (see Raaijmakers, Schrijnemakers, & Gremmen, 1999). Reported effects were significant at the $p < .05$ level unless otherwise noted. The means and associated confidence intervals (Loftus & Masson, 1994) are displayed graphically. Statistical tests of the main effects and interactions for each experiment appear in the Appendix (Table A1 for Experiment 1). For brevity, only the tests of main theoretical interest—whether priming occurred and whether it interacted with the repetition proportion factor—are reported in the text. In experiments in which word frequency was varied systematically, whether frequency interacted with priming is also reported. Except where noted, priming effects reflected shorter response latencies or fewer errors on repetition prime trials than on unrelated prime trials.

The results reported for Experiment 1 were derived from mixed-factor ANOVAs in which priming (repetition, unrelated) and repetition proportion (low, high) were within- and between-subject factors, respectively. Figure 1 displays the obtained means and priming effects for Experiment 1. In the response latency analysis for word targets, there was a main effect of priming that interacted with repetition proportion. As Fig. 1 (word data, left panel) illustrates, the high group showed substantially more priming than the low group (65 vs 36 ms).[1] In the error rate analysis, only the main effect of priming was significant.

[1]A repetition proportion by priming interaction was also obtained in an earlier version of this experiment in which the frequencies of the unrelated primes were not matched with the frequencies of their corresponding targets. The experiment was otherwise identical to Experiment 1. With 20 subjects in each repetition proportion group, the interaction again reflected more priming in the high than in the low group (69 vs 37 ms), $F(1,38) = 11.16$, $MSE = 464$.

For nonword targets, there was a main effect of priming for nonwords in the response latency analysis that interacted with repetition proportion. Only the high group produced significant nonword priming. There were no reliable effects in the error rates.

Discussion

The results of Experiment 1 support the claim that word recognition can become tuned to regularities in priming stimuli such that when primes are a more valid source of information concerning the target (i.e., when the repetition proportion is high), they exert a greater influence on target processing. The finding of greater priming for both word and nonword targets when repetition proportion was high compared to when it was low is consistent with this claim. Moreover, the finding of nonword priming (when the repetition proportion was high) runs contrary to the proposal that repetition priming of a nonword target inevitably increases the familiarity of that target and biases the subject toward making an incorrect "word" response (e.g., Feustel, Shiffrin, & Salasoo, 1983; Salasoo, Shiffrin, & Feustel, 1985). Instead, Experiment 1 suggests that under some conditions, episodes constructed for nonword repetition primes can be recruited to improve the efficiency of correct "nonword" decisions.

EXPERIMENT 2

Previous experiments have consistently found that masked repetition primes facilitate lexical decisions to low- and high-frequency targets to a similar extent (e.g., Bodner & Masson, 1997; Ferrand, Grainger, & Segui, 1994; Forster, Davis, Schoknecht, & Carter, 1987; Rajaram & Neely, 1992; Segui & Grainger, 1990; Sereno, 1991). In Bodner and Masson's (1997) experiments, a trend toward greater priming for low-frequency words than for high-frequency words was consistently observed, but even a pooling of the data from three of their experiments failed to produce a reliable frequency by priming interaction. Bodner and Masson took the additivity between word frequency and priming as evidence that masked priming episodes contain mostly orthographic or phonological information that is not sensitive to word frequency. Alternatively, Forster and Davis (1984) have taken this additivity as evidence that masked primes open lexical entries, producing equivalent savings for low- and high-frequency targets because frequency effects are assumed to arise from a frequency-ordered search of opened entries.

Experiment 2 provided further tests of whether word frequency and masked priming can interact, this time in the context of the repetition proportion manipulation. On the episodic resource account, masked primes may be more likely to be used to facilitate target processing when they are a valid source of information regarding the target and when the need for such information is high (i.e., when target processing is made difficult, as shown by Bodner & Masson, 1997). The episodes for masked primes become a more valid resource when repetition proportion is high rather than low, and need for this resource may be greater when a low-frequency target is being processed because such targets are less practiced than high-frequency targets. On this account, then, an interaction of frequency and priming may be more likely to be observed when repetition proportion is high (0.8), relative to when it is low (0.2 here; 0.5 in typical experiments).

Earlier failures to obtain a frequency by priming interaction in masked priming may have been due to a relatively weak manipulation of word frequency. For example, in Bodner and Masson (1997) and Forster and Davis (1984), low-frequency words were selected from the 1 to 2 per million range and high-frequency words were selected from the 40 to 60 per million range (Kučera & Francis, 1967). A much more robust frequency manipulation was used in Experiment 2: Low-frequency words were chosen from the 1 to 10 per million range, and high-frequency words were chosen from the 100 to 1,000 per million range. A more powerful frequency manipulation provides a test of the generality of the null interaction observed in previous studies.

Two versions of Experiment 2 were conducted. Experiment 2A was the same as Experiment 1, except target word frequency (low, high) was now systematically varied within subjects. Experiment 2B was the same as Experiment 2A, except targets were presented in case-alternated letters, following Bodner and Masson (1997, Exp. 2B). The idea here was that case-alternated targets, being difficult to process, might increase the word recognition system's reliance on the masked primes. We anticipated that by increasing the reliance on primes, subjects would be more likely to be influenced by prime validity. Also, the prime duration in Experiment 2B was 45 ms instead of 60 ms.

Method

Subjects. There were 40 subjects in each of the two versions of Experiment 2. Half of the subjects in each version were randomly assigned to the low group and half were assigned to the high group.

Materials and design. The critical targets were 100 low-frequency words, 100 high-frequency words, and 200 pronounceable nonwords of 4 to 6 letters in length. An additional 10 low-frequency and 10 high-frequency word targets and 20 nonword targets were used for practice trials. Kučera and Francis (1967) frequencies of the critical low-frequency word targets ranged from 1 to 10 (median = 3), and frequencies for the high-frequency words ranged from 100 to 967 (median = 193). Many of the nonword targets were taken directly from Experiment 1 (some of which were modified to match the length restriction of 4–6 letters) and the rest were newly constructed. Unrelated primes were chosen using the same constraints described in Experiment 1. The design was the same as in Experiment 1, except the critical low- and high-frequency word targets were each divided into five blocks of 20 items for counterbalancing.

Procedure. The testing procedure for Experiment 2A was the same as that used in Experiment 1, including a 60-ms prime duration. In Experiment 2B, all targets were presented in case-alternated letters beginning with a lowercase letter (e.g., *pOwEr*). Also, the stimuli for Experiment 2B were presented using a Macintosh G3 desktop computer rather than a Macintosh II, although the same font and display characteristics were in effect. The display durations on the monitor used with the Macintosh G3 were verified using an electron storage oscilloscope. Nevertheless, casual observation gave the impression that the primes were somewhat easier to detect on the Macintosh G3 monitor, perhaps due to differences in display contrast. To ensure that the primes were not more identifiable in Experiment 2B, primes were presented for 45 ms rather than 60 ms. The effects obtained with 45-ms versus 60-ms primes are directly compared in Experiments 4A and 4B.

Results

The data for Experiments 2A and 2B were separately analyzed as in Experiment 1, except that for the word targets there was a word frequency factor (low, high) in addition to the priming (repetition, unrelated) and repetition proportion (low, high) factors. The means and corresponding priming effects for Experiments 2A and 2B appear in Figs. 2 and 3, respectively. Statistical tests of the main effects and interactions appear in the Appendix (Table A2).

Word targets. In the response latency analyses for Experiment 2A (uppercase targets), a main effect of priming was observed, but contrary to Experiment 1, priming did not interact with repetition proportion. There was, however, a robust interaction of word frequency and priming. As Fig. 2 illustrates, priming effects were almost twice as large for low-frequency targets as for high-frequency targets (71 vs 39 ms). Post hoc tests revealed that this interaction was reliable for both the low group, $F(1,19) = 10.45$, $MSE = 561$, and the high group, $F(1,19) = 7.53$, $MSE = 543$.

The pattern of results in the error rates for Experiment 2A exactly paralleled the pattern in the response latency analyses. There was a main effect of priming that did not interact with repetition proportion but that did interact with word frequency.

The pattern of response latency results for Experiment 2B (case-alternated targets) was the same as in Experiment 2A. There was a main effect of priming that did not interact with repetition proportion, as well as a frequency by priming interaction similar in magnitude to that found with uppercase targets in Experiment 2A. Priming ef-

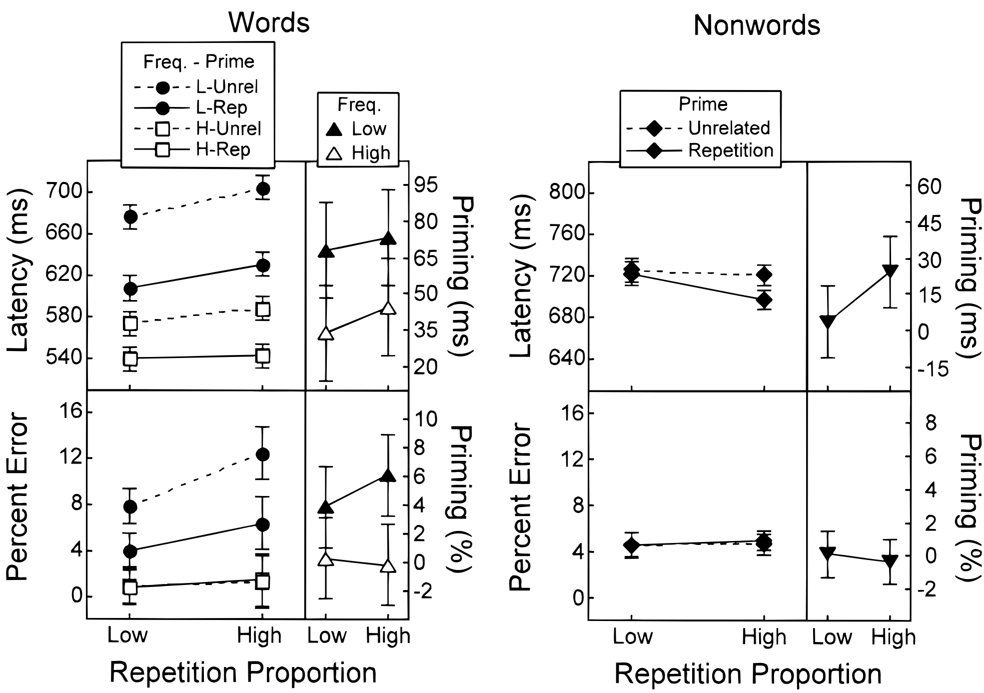

FIG. 2. Mean response latency, percentage error, and corresponding priming effects for words and nonwords in Experiment 2A. Error bars for latency and error are 95% within-subjects confidence intervals and are appropriate for comparing means across prime conditions. Error bars for priming effects are 95% between-subjects confidence intervals and are appropriate for comparing means across repetition proportion conditions and against zero.

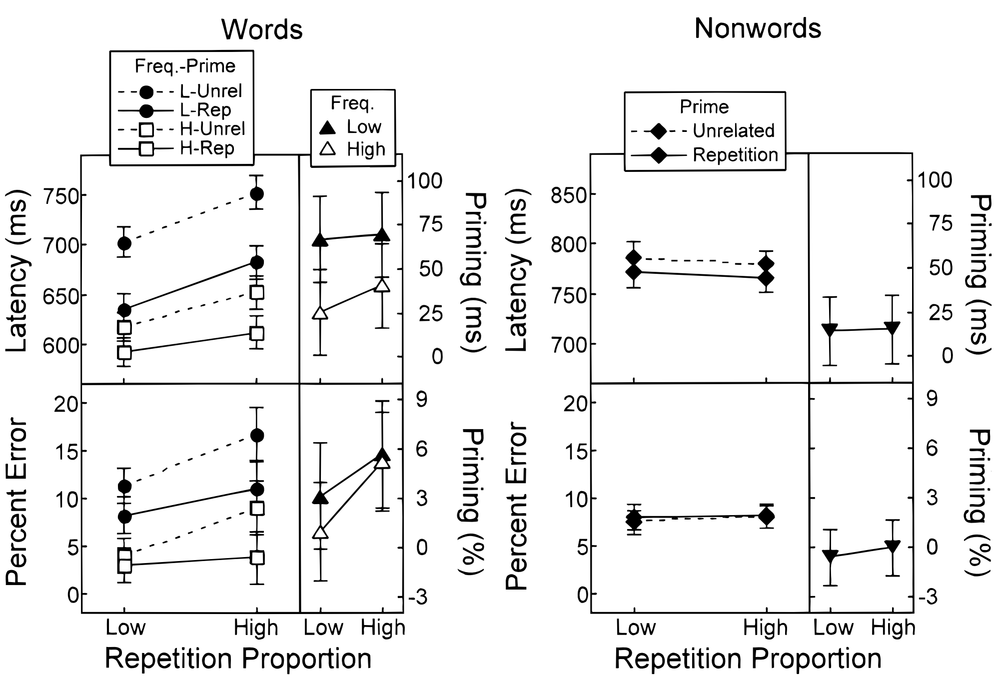

FIG. 3. Mean response latency, percentage error, and corresponding priming effects for words and nonwords in Experiment 2B. Error bars for latency and error are 95% within-subjects confidence intervals and are appropriate for comparing means across prime conditions. Error bars for priming effects are 95% between-subjects confidence intervals and are appropriate for comparing means across repetition proportion conditions and against zero.

fects were twice as large for low-frequency words as for high-frequency words (69 vs 33 ms). As in Experiment 2A, post hoc tests revealed that this interaction was significant both for the low group, $F(1,19) = 9.20$, $MSE = 934$, and the high group, $F(1,19) = 10.26$, $MSE = 410$.

The pattern of error rates in Experiment 2B was somewhat different than the pattern obtained in Experiment 2A. Although the main effect of priming was reliable in both experiments, the repetition proportion by priming interaction was significant in Experiment 2B. That interaction reflected a greater reduction of errors due to repetition primes in the high group than in the low group. There was no frequency by priming interaction in the error rates for Experiment 2B.

Nonword targets. There were reliable nonword priming effects in the response latency analyses for Experiments 2A and 2B. The interaction between repetition proportion and priming observed in Experiment 1 was also observed in Experiment 2A. As Fig. 2 illustrates, reliable nonword priming occurred only in the high group. In Experiment 2B, priming effects were about the same for low and high groups—there was no interaction (see Fig. 3). There were no reliable effects in the nonword error rates for either experiment.

Discussion

Two important results emerged from Experiment 2. First, low-frequency words benefited from repetition primes more than high-frequency words in both Experiments 2A and 2B—an effect not previously reported for masked repetition priming in the lexical decision task. The use of a stronger manipulation of word frequency than usual (cf. Bodner & Masson, 1997; Forster & Davis, 1984) appears to be the basis for the frequency by priming interaction found here. The interaction does not appear to be mediated by prime validity because it was statistically significant in each experiment both when prime validity was high and when it was low. Moreover, the interaction does not appear to be mediated by need for the prime resource, since it obtained both when targets were presented in uppercase letters and when target processing was made more difficult by presenting targets in case-alternation. Note, however, that a shorter prime duration was used in the latter case, which may have worked generally to reduce priming in Experiment 2B.

The second major finding of interest was that a systematic mixed-list manipulation of word frequency appears to have made the prime validity effect found with words in Experiment 1 disappear (except in the error rates of Experiment 2B). The remaining experiments sought to establish the reason for this outcome and to determine whether the prime validity effects occur reliably under specifiable conditions.

EXPERIMENT 3

The purpose of Experiment 3 was to determine why repetition proportion interacted with priming when word frequency varied continuously over a wide range (Experiment 1), but not when word frequency was systematically manipulated in the form of a bimodal distribution of frequency (Experiment 2). One possibility is that subjects' lexical decisions in Experiment 2 were affected by the presence of two distinct bands of word frequency in the stimulus list and that this discontinuity altered their sensitivity to repetition proportion. Having to switch between processing distinctly easy versus hard targets throughout the list may have led subjects consistently to make use of priming resources, regardless of repetition proportion. To explicitly test this idea, word frequency was manipulated between subjects in Experiment 3, so that word targets were selected from a single frequency band for each group.

Method

Subjects. There were 20 subjects randomly assigned to each of four groups defined by a factorial manipulation of repetition proportion (low, high) and word frequency (low, high).

Materials and design. The materials from Experiment 2 were used again, but 100 additional low-frequency and 100 additional high-frequency unrelated prime and target pairs were selected because frequency was now manipulated between subjects. To find enough high-frequency pairs that did not share any letters in common in the same position, some items were chosen from the 80–99 per million range. These items were used as high-frequency practice items and an equivalent number of the high-frequency practice items used in Experiment 2 were used as critical high-frequency items in Experiment 3. Thus, critical high-frequency items in both experiments were selected from the same frequency range. Kučera and Francis (1967) frequencies of the critical targets ranged from 1 to 10 for low-frequency word targets (median = 4), and from 100 to 937 for high-frequency word targets (median = 217). Through an oversight, three low-frequency and three high-frequency targets appeared twice in the stimulus list (paired with different unrelated primes). Also, there were three cases in which a target also appeared as an unrelated prime (two for high-frequency and one for low-frequency targets). Because the duplicates were nearly evenly distributed across the frequency manipulation, they were not omitted from the analyses. There were no duplicates in the remaining experiments.

Procedure. The equipment and procedure used in Experiment 3 were the same as in Experiment 1. A 60-ms prime–target prime duration was used.

Results

The three factors (priming, frequency, and repetition proportion) were analyzed as in Experiment 2, except word frequency was now a between-subjects variable. Statistical tests for the effects reported below appear in the Appendix (Table A3). The means and priming effects for each of the four groups in Experiment 3 appear in Fig. 4.

Word targets. In the response latency analysis, there was a main effect of priming. Critically, manipulating word frequency between subjects, so that each group of subjects saw targets from only one frequency range, allowed the repetition proportion by priming interaction found in Experiment 1 to reemerge. The size of the difference in priming effects for the low and high repetition proportion groups was similar to that found in Experiment 1. The frequency by priming interaction was not significant, but this was qualified by a reliable three-way interaction with repetition proportion. Additional tests revealed that there was reliably more priming for low-frequency than for high-frequency words when repetition proportion was high, $F(1,38) = 5.39$, $MSE = 358$, but no difference when repetition proportion was low, $F < 1$. The three-way interaction can also be interpreted by examining the repetition proportion by priming interaction at each level of the frequency factor. Taking this approach showed that repetition proportion interacted with priming when the list contained only low-frequency words, $F(1,38) = 14.28$, $MSE = 388$, but not when the list contained only high-frequency words, $F < 1.43$. In the error rates, there was a main effect of priming that did not interact with repetition proportion or frequency.

Nonword targets. The pattern of results for nonwords was rather complicated. We emphasize the main effect of priming and its interactions with repetition proportion and frequency. The response latency analysis revealed a main effect of priming that did not interact with repetition proportion, but that did interact with frequency. Nonword priming was present at both levels of the repetition proportion factor, but only when low-frequency word targets were used.

The pattern of results in the error rate analysis differed from that in the response latency analysis in one major respect. Whereas repetition priming typically reduced or had no effect on nonword error rates in earlier experiments, in Experiment 3 there tended to be more errors on repetition than on unrelated prime trials, particularly for the high repetition proportion/low-frequency target group (see Fig. 4). Thus, repetition priming increased the nonword error rate, suggesting a speed–accuracy trade-off.

Discussion

When low and high repetition proportion groups in Experiment 3 were given only low-frequency word targets (hereafter, Experiment 3-LF), there was significantly more priming in the high repetition proportion group, replicating the prime validity effect found in Experiment 1. In contrast, when low and high repetition proportion groups in Experiment 3 were given only high-fre-

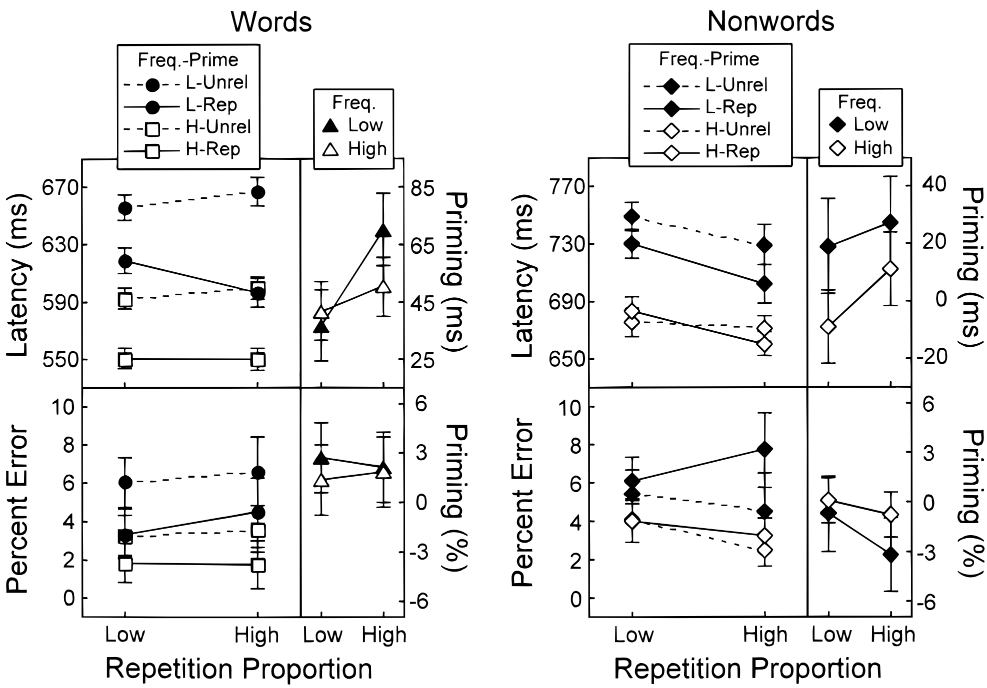

FIG. 4. Mean response latency, percentage error, and corresponding priming effects for words and nonwords in Experiment 3. Error bars for latency and error are 95% within-subjects confidence intervals and are appropriate for comparing means across prime conditions. Error bars for priming effects are 95% between-subjects confidence intervals and are appropriate for comparing means across repetition proportion conditions and against zero. Frequency in the case of nonwords refers to the word-frequency condition in which the nonwords were presented.

quency word targets (hereafter, Experiment 3-HF), the two groups showed similar amounts of priming, as observed in Experiment 2 when subjects were given both low- and high-frequency word targets in a mixed list. Before further examining reasons that the influence of prime validity may be sensitive to the mixture of word frequencies in the stimulus list, it seemed important to establish firmly whether prime validity can modulate priming for low- and high-frequency targets. Experiments 4 and 5 provide the respective tests.

EXPERIMENT 4

In Experiment 4, a replication of the prime validity effect was sought for low-frequency word targets. Moreover, because prime duration in the earlier experiments was sometimes 60 ms and other times 45 ms, this factor was manipulated across Experiments 4A (60 ms) and 4B (45 ms) to examine its possible influence on the pattern of priming effects.

Method

Subjects. There were 20 subjects randomly assigned to the low repetition proportion group and 20 subjects assigned to the high repetition proportion group in Experiment 4A. In Experiment 4B, 30 subjects were randomly assigned to the low group and 30 were assigned to the high group.

Materials and design. The stimuli were the low-frequency words from Experiment 3 with accidentally duplicated items replaced. Four blocks of 50 word and 50 nonword trials were assigned repetition or unrelated primes so that the designated repetition proportion of 0.8 or 0.2 was precisely attained within each block of 100 critical trials. A single random assignment of target items to blocks was used for all subjects, but within a block, assignment of repetition and unrelated primes to targets was counterbalanced across subjects as in the earlier experiments. Counterbalancing of the assignment of primes to targets was applied to the practice items as well.

Procedure. The experiment was run using a Macintosh G3 computer. The prime duration was 60 ms in Experiment 4A and 45 ms in Experiment 4B. The remaining aspects of the procedure were the same as in Experiment 3.

Results

The two versions of Experiment 4 were analyzed separately, and for each mixed-factor ANOVA, type of prime (repetition, unrelated) was the within-subjects factor and repetition proportion (low, high) was the between-subjects factor. Figures 5 and 6 show the means and priming effects for Experiments 4A and 4B, respectively. The Appendix (Table A4) lists the complete ANOVA results for each experiment.

Word targets. There was a main effect of priming in the response latency analysis of each experiment. Priming interacted with repetition proportion in both experiments as well, in the direction of larger priming effects for the high group than for the low group. There was also a main effect of priming in the error rate analysis of each experiment. A repetition proportion by priming interaction was found in the error rate analysis only for Experiment 4A, where 60-ms primes were used.

Nonword targets. In Experiment 4A, with 60-ms primes, there was a nonword priming effect in the response latency analysis that interacted with repetition proportion. Nonword priming was reliable only in the high group. In Experiment 4B, with 45-ms primes, the nonword priming effect was marginal and did not interact with repetition proportion. There were no reliable effects in the error rate analyses of either experiment.

Discussion

Experiments 4A and 4B successfully replicated the prime validity effect for low-frequency targets in Experiment 3. Repetition proportion interacted with priming whether primes were shown for 60 or 45 ms, suggesting that use of different prime durations across earlier experiments did not seriously influence the pattern of results for word targets. Prime duration appears to be a more important factor for nonword tar-

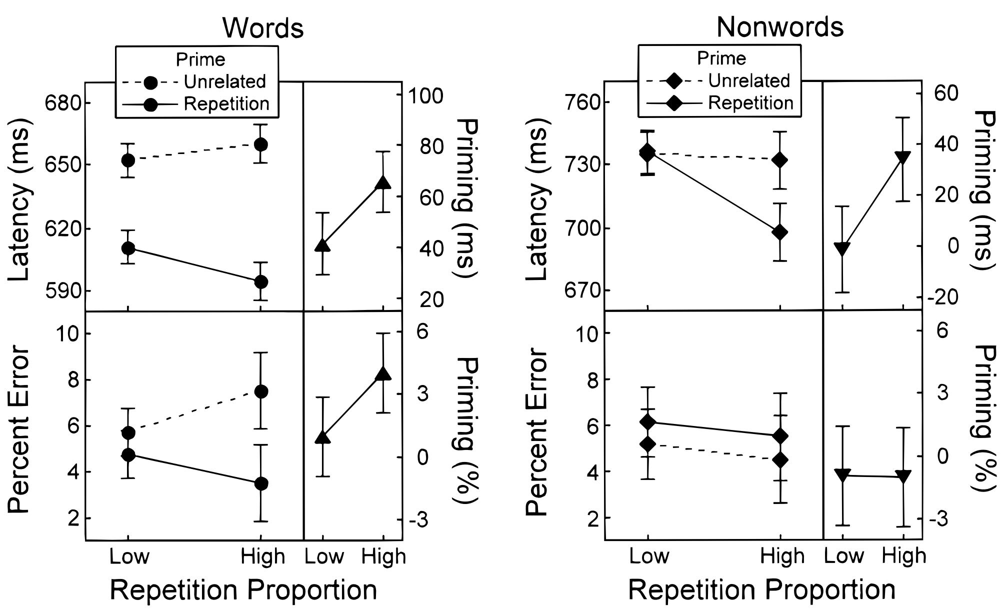

FIG. 5. Mean response latency, percentage error, and corresponding priming effects for words and nonwords in Experiment 4A. Error bars for latency and error are 95% within-subjects confidence intervals and are appropriate for comparing means across prime conditions. Error bars for priming effects are 95% between-subjects confidence intervals and are appropriate for comparing means across repetition proportion conditions and against zero.

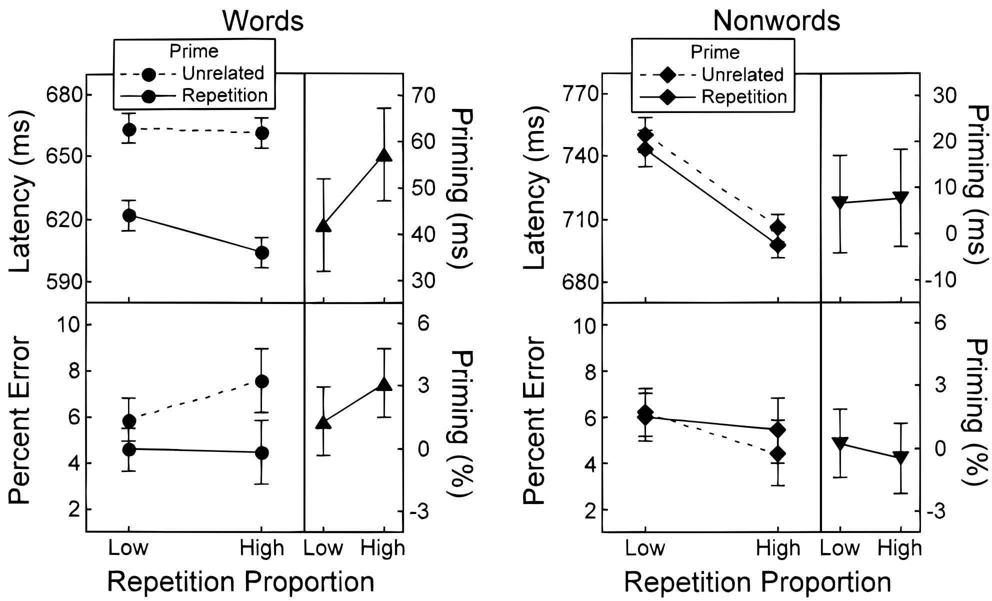

FIG. 6. Mean response latency, percentage error, and corresponding priming effects for words and nonwords in Experiment 4B. Error bars for latency and error are 95% within-subjects confidence intervals and are appropriate for comparing means across prime conditions. Error bars for priming effects are 95% between-subjects confidence intervals and are appropriate for comparing means across repetition proportion conditions and against zero.

gets, as nonword priming and its interaction with repetition proportion emerged only with the 60-ms primes.

EXPERIMENT 5

The purpose of Experiment 5 was to determine whether a prime validity effect could be obtained with the same set of high-frequency targets that failed to produce this interaction in Experiment 3-HF. Experiment 5A was a replication of Experiment 3-HF using a 45-ms prime duration, and Experiments 5B, 5C, and 5D adapted three manipulations of word/nonword discriminability from Bodner and Masson (1997). In Experiment 5B, the high-frequency word targets and the nonword targets from Experiment 5A were presented using case-alternation, as in Experiment 2B. Case-alternated targets make lexical decisions more difficult, which should increase subjects' reliance on masked primes and hence might provide a better chance for observing an influence of prime validity. In Experiment 5C, the same high-frequency targets were mixed with pseudohomophone nonwords which sound like real words but are not spelled like real words (e.g., BRANE). When pseudohomophone nonwords are used, lexical decisions are more difficult because phonology cannot be used as a basis for correct responding. In Experiment 5D, the opposite tack was taken: Lexical decisions were made easier by using consonant string nonwords (e.g., GLDRP). This was done in an attempt to decrease subjects' reliance on the primes. If subjects' reliance on the primes could be sufficiently attenuated, repetition proportion might not interact with priming.

Method

Subjects. There were 20 subjects randomly assigned to the low repetition proportion group and to the high repetition proportion group in each of the four versions of Experiment 5, for a total of 160 subjects.

Materials and design. All four versions of Experiment 5 used the Experiment 3-HF items, with accidentally duplicated targets replaced. Thus, all word targets and their unrelated primes were high-frequency words. Experiment 5A was a replication of Experiment 3-HF. Experiment 5B was the same as Experiment 5A, except targets were presented in case alternation. Targets were presented in uppercase letters in Experiments 5C and 5D. For Experiment 5C, a set of 220 pseudohomophone nonword targets (e.g., BRANE), each with an unrelated pseudohomophone prime, were created and used as the nonwords in the same manner as in earlier experiments. The items were all 4 to 6 letters in length. The frequency of the base words from which pseudohomophones were formed (e.g., BRAIN) and the number of letters shared by a pseudohomophone and its base word were not controlled. For Experiment 5D, a set of 220 consonant-string nonword targets (each with an unrelated consonant-string prime), 4 to 6 letters in length, were constructed and used as the nonwords.

Procedure. The procedure was the same as in earlier experiments, except the lexical decision instructions in Experiment 5C were modified so that subjects were asked to decide whether or not each target "spelled" a real English word. Subjects were tested using a Macintosh G3 computer and a 45-ms prime duration.

Results

Each version of Experiment 5 was analyzed separately, and for each mixed-factor ANOVA, priming (repetition, unrelated) was the within-subjects factor and repetition proportion (low, high) was the between-subjects factor. The obtained means and priming effects for Experiments 5A, 5B, 5C, and 5D appear in Figures 7, 8, 9, and 10, respectively. The complete ANOVA results for each experiment appear in the Appendix (Table A5).

Word targets. The main effect of priming was significant in the response latency analysis of each experiment (only the low repetition proportion group in Experiment 5D, who saw consonant-string nonwords, did not produce a reliable priming effect). Experiment 5A replicated the absence of a repetition proportion by priming interaction for high-frequency targets found in Experiment 3-HF. In contrast, in Experiments

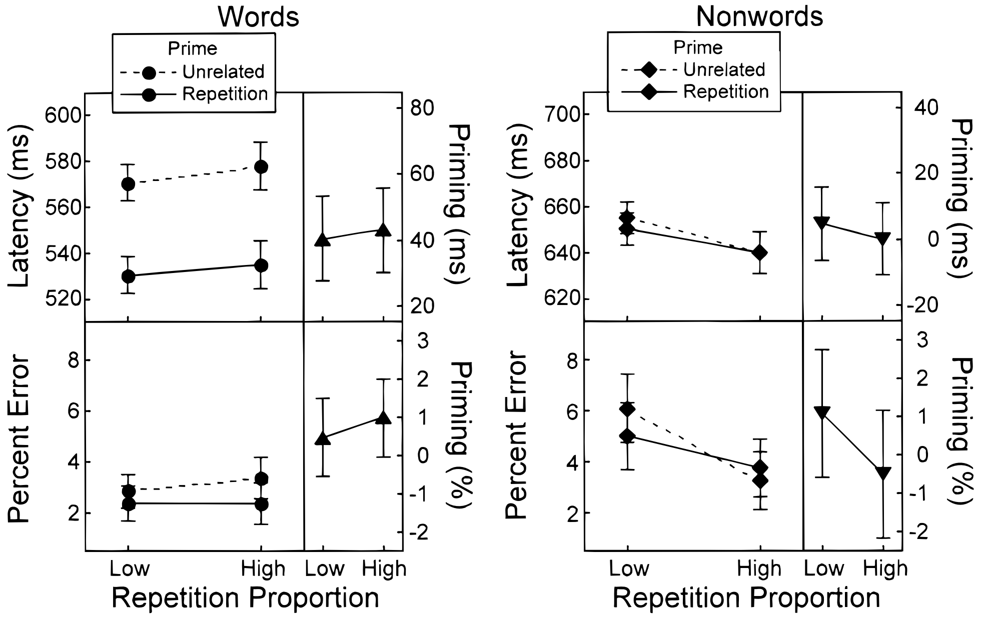

FIG. 7. Mean response latency, percentage error, and corresponding priming effects for words and nonwords in Experiment 5A. Error bars for latency and error are 95% within-subjects confidence intervals and are appropriate for comparing means across prime conditions. Error bars for priming effects are 95% between-subjects confidence intervals and are appropriate for comparing means across repetition proportion conditions and against zero.

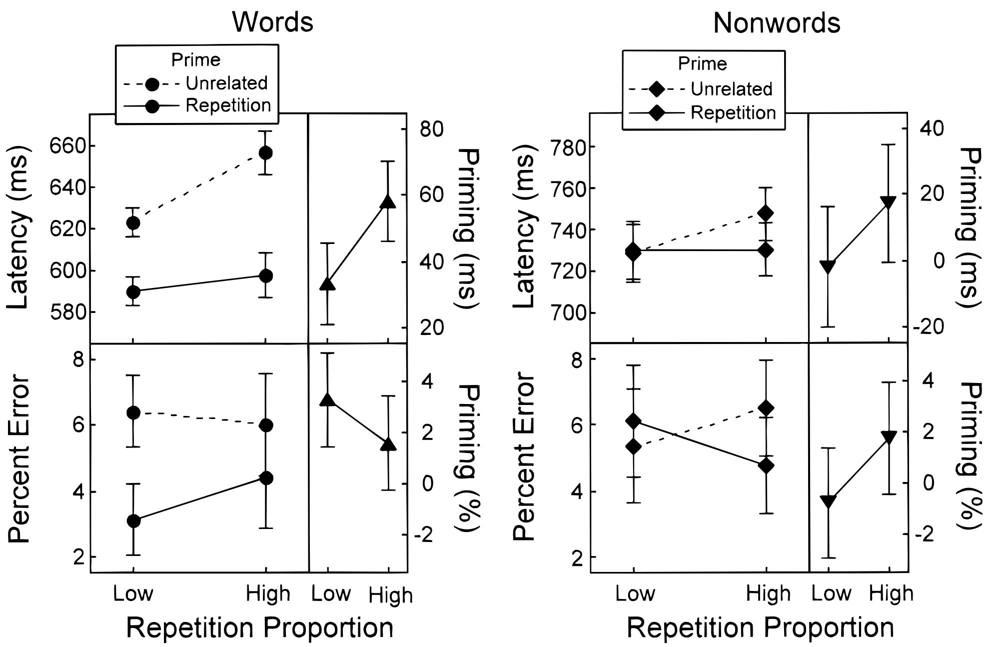

FIG. 8. Mean response latency, percentage error, and corresponding priming effects for words and nonwords in Experiment 5B. Error bars for latency and error are 95% within-subjects confidence intervals and are appropriate for comparing means across prime conditions. Error bars for priming effects are 95% between-subjects confidence intervals and are appropriate for comparing means across repetition proportion conditions and against zero.

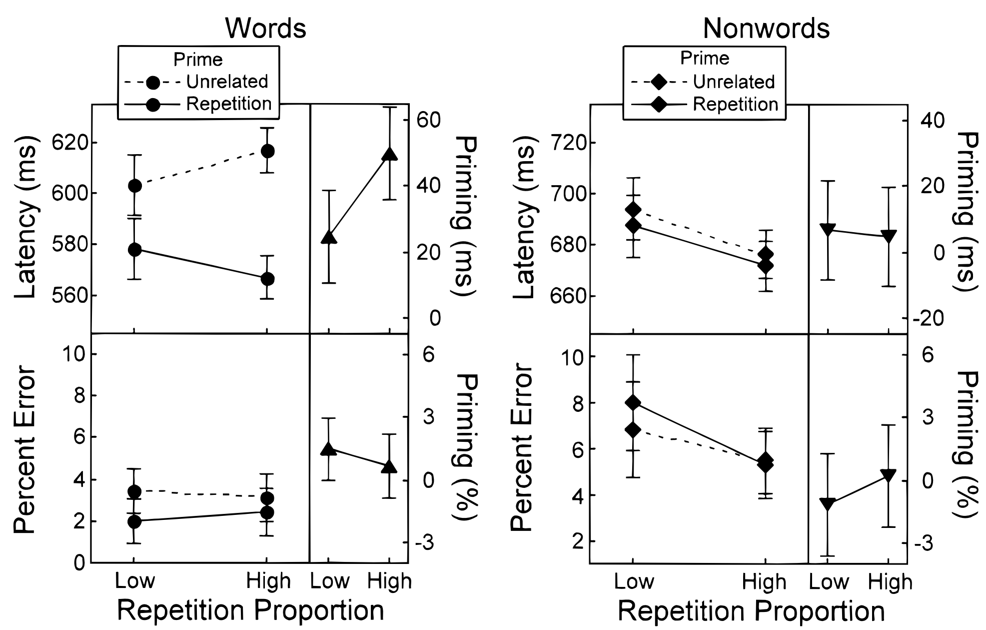

FIG. 9. Mean response latency, percentage error, and corresponding priming effects for words and nonwords in Experiment 5C. Error bars for latency and error are 95% within-subjects confidence intervals and are appropriate for comparing means across prime conditions. Error bars for priming effects are 95% between-subjects confidence intervals and are appropriate for comparing means across repetition proportion conditions and against zero.

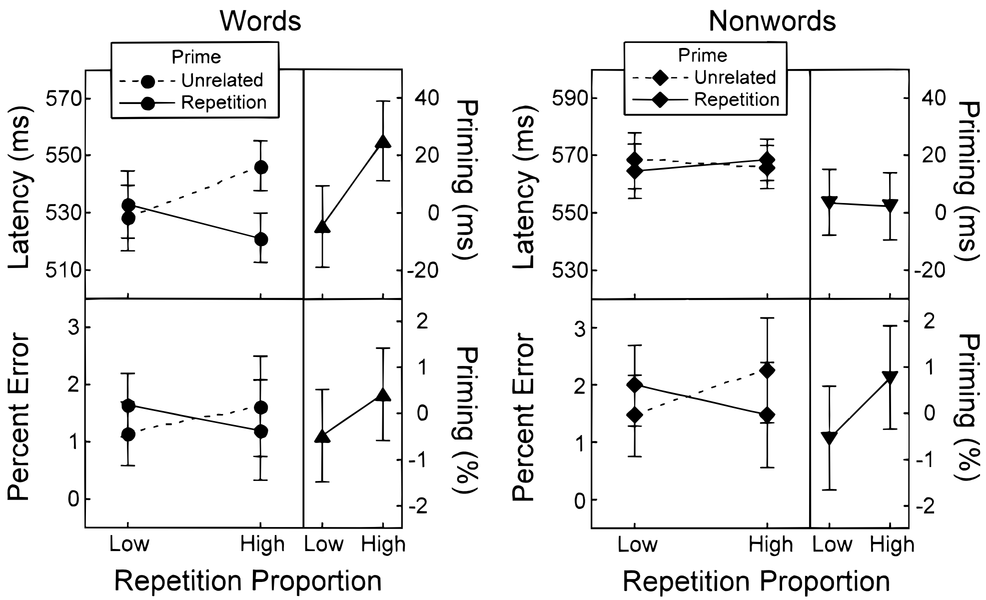

FIG. 10. Mean response latency, percentage error, and corresponding priming effects for words and nonwords in Experiment 5D. Error bars for latency and error are 95% within-subjects confidence intervals and are appropriate for comparing means across prime conditions. Error bars for priming effects are 95% between-subjects confidence intervals and are appropriate for comparing means across repetition proportion conditions and against zero.

5B, 5C, and 5D, priming effects were significantly larger when the repetition proportion was high than when it was low. In the error rate analyses, the only reliable effect was a main effect of priming in Experiments 5A and 5B.

Nonword targets. There were no reliable effects for nonword targets.

Discussion

Priming for uppercase high-frequency words mixed with pronounceable nonwords does not appear to be influenced by repetition proportion. Even when the Experiment 5A data were pooled with the Experiment 3-HF data, creating 40 subjects per repetition proportion group, the 6-ms difference in priming effect between the low and high groups (41 vs 47 ms) failed to approach significance, $F < 1$. In contrast, Experiments 5B–5D make it clear that a prime validity effect can be found for high-frequency targets under other circumstances. The interaction emerged when target processing was made more difficult than in Experiment 5A, either by using case-alternated targets (Experiment 5B) or pseudohomophone nonwords (Experiment 5C). Surprisingly, the interaction also emerged when these targets were made easier to process than in Experiment 5A by using consonant string nonwords (Experiment 5D). Thus, although the absolute difficulty of the lexical decision task may modulate the amount of priming that is observed (see also Bodner & Masson, 1997), it does not appear to determine whether repetition proportion modulates priming.

The lack of nonword priming in Experiments 5B, 5C, and 5D, using the same manipulations that produced nonword priming in Bodner and Masson (1997), suggests that the prime duration may have to be as large as 60 ms for nonword priming to be consistently obtained (see also Experiments 4A and 4B). The inclusion of low-frequency words in the Bodner and Masson experiments, but not in Experiment 5, may also be an important factor. On the episodic resource account, low-frequency targets, being more difficult to process than high-frequency targets, should generally increase reliance on primes (Bodner & Masson, 1997), making nonword priming more likely.

Variation in processing difficulty. The results from Experiments 1 to 5 indicate that prime validity influences masked priming in many—but not all—circumstances. The absence of the effect in Experiments 3-HF and 5A seems problematic, given that the interaction was found when the lexical decision task was made either harder (Experiments 5B and 5C) or easier (Experiment 5D). A promising way of understanding this pattern of results, however, emerges when the experiments are characterized with respect to variation in the processing difficulty of target items. By processing difficulty, we mean the amount of computational work that needs to be accomplished before a target can be correctly classified as a word or a nonword.

More formally, processing difficulty can be defined as the rate of information accumulation in a diffusion model of binary-decision tasks (Ratcliff, 1978, 1988; Ratcliff, Van Zandt, & McKoon, 1999). In the diffusion model, it is assumed that a noisy process accumulates information over time toward one of two boundaries, representing the two possible responses (word vs nonword in the lexical decision task). In this model, a nonword response is based on the accumulation of information that supports that response, rather than on the failure to accumulate positive evidence before a deadline (cf. Grainger & Jacobs, 1996). The rate at which evidence accumulates, the *drift rate*, is larger for easier items, enabling a faster response. Thus, the drift rate for high-frequency words would be higher than for either low-frequency words or, presumably, for pronounceable nonwords.

The idea that subjects react to variation in the difficulty of target processing across successive trials gains credibility from the fact that performance on a trial may be affected by the nature of the stimulus (e.g., its normative frequency) on the preceding trial(s) in tasks such as signal-detection (e.g., Ratcliff et al., 1999), visual search and memory-scanning (e.g., Strayer & Kramer, 1994), lexical decision (e.g., Gordon, 1983), and priming of word reading (Zevin & Balota, 2000). Our suggestion is that large variation in processing difficulty (drift rate in a diffusion model) from trial to trial, even between items requiring opposite responses, implies a high level of noise in the information accumulation process. An adaptive response to a high level of noise may be to rely heavily on recruitment of prime resources at all times, regardless of their validity. To make a crude analogy, if you are descending an unfamiliar staircase and the lights are flickering on and off, you may reach for the banister whether it tends to be sturdy or rickety.

We next show how the concept of variability in processing difficulty provides a reasonable account for the complex pattern of results from Experiments 1 to 5; then we use this concept to make a novel prediction for our last experiment. Table 1 summarizes our account of how variability in processing difficulty appears to determine whether or not a prime validity effect for word targets occurs in each experiment. Consider first the experiments in which prime valid-

TABLE 1

Relation between Variability in Target Processing Difficulty and Prime Validity Effect for Word Targets in Experiments 1–6

Exp.	Word freq.	Characteristics of word and nonword targets	Variability	Validity effect
1	L to H	Continuous range of word frequencies	Low	Yes
2	L, H	Discontinuous bands of word frequencies	High	No
3	L	All targets relatively difficult to process	Low	Yes
3	H	Easy words but difficult nonwords	High	No
4	L	All targets relatively difficult to process	Low	Yes
5A	H	Easy words but difficult nonwords	High	No
5B	H	Case-alternated targets made all targets difficult	Low	Yes
5C	H	Pseudohomophone nonwords made all targets difficult	Low	Yes
5D	H	Consonant string nonwords made all targets easy	Low	Yes
6	L, M, H	Inclusion of medium-frequency items reduced variability	Low	Yes

Note. L, low frequency; M, medium frequency; H, high frequency.

ity did not influence priming. In Experiments 3-HF and 5A there was marked variability in target processing difficulty from trial to trial: High-frequency words are easy to classify as words, but pronounceable nonword targets require more effort to accumulate sufficient evidence to support a nonword decision (as suggested by the large difference in response times). Similarly, in Experiments 2A and 2B, high-frequency word targets were again much easier to classify than the pronounceable nonword targets and, additionally, were easier to classify than the low-frequency word targets. We argue that less variation in processing difficulty was present in the remaining experiments, where prime validity influenced priming. These experiments are considered next.

Although targets in Experiment 1 were selected from a wide range of word frequencies, 77% were lower in frequency than the high-frequency words used in the rest of the current experiments. Hence, there was less variability in target processing difficulty from trial to trial in Experiment 1 than in Experiments 2A and 2B. Experiments 3-LF, 4A, and 4B all used low-frequency targets, which are more difficult to classify as words than are high-frequency words because of their lower familiarity. Low-frequency words are therefore more similar to pronounceable nonwords with respect to classification difficulty than are high-frequency words. Thus, there is less variability in processing difficulty in these experiments than in Experiment 3-HF. Next, although high-frequency targets were used in Experiments 5B, 5C, and 5D, in each case the variability in target processing difficulty between word and nonword targets was reduced relative to Experiment 5A. In Experiment 5B, variability was reduced by presenting all targets in case alternation, an unfamiliar visual format that made the processing of all targets more difficult than in Experiment 5A. In Experiment 5C, variability was reduced by using pseudohomophone nonwords, which ruled out phonology as a basis for lexical decisions and made processing of all targets more difficult than in Experiment 5A. Finally, in Experiment 5D, use of consonant-string nonwords also reduced variability in target processing difficulty by making nonword targets much easier to classify than in earlier experiments. Thus, the subject's task from trial to trial was consistently easy in Experiment 5D, which was not the case in Experiment 5A.

To summarize, in all experiments in which repetition proportion and priming interacted, the majority of word and nonword targets were either relatively difficult (Experiments 1, 3-LF, 4A, 4B, 5B, and 5C) or relatively easy (Experiment 5D) to process, resulting in a low degree of variability in target processing difficulty from trial to trial. In all experiments in which repetition proportion did not interact with priming, there was marked variability in target processing difficulty from trial to trial, either between high-frequency words and pronounceable nonwords (Experiments 2A, 2B, 3-HF, and 5A) or between low- and high-frequency word targets (Experiments 2A and 2B).

The concept of variability in processing difficulty appears to provide a reasonable account of the results of Experiments 1 to 5. A shortcoming of this explanation, however, is that it is post hoc. To address this concern, we conducted a final experiment that tested the prediction that a reduction of variability of target processing difficulty may induce a prime validity effect under conditions that initially failed to generate such an effect.

EXPERIMENT 6

The goal of Experiment 6 was to provide evidence that a strong dichotomy in trial to trial target processing difficulty between low- and high-frequency targets in Experiments 2A and 2B eliminated the prime validity effect in those experiments. To reduce the probability of large trial-to-trial variation in processing difficulty, a subset of the low-frequency words and a subset of the high-frequency words from Experiment 2 were combined with a set of medium-frequency words to create a new list of items. If the processing variability account is correct, reducing the probability of sharp trial-to-trial discontinuities in degree of target processing difficulty should create a situation in which subjects are once again sensitive to prime validity. If so, the interaction of repetition proportion and priming absent in Experiments 2A and 2B should now emerge.

Subjects in each repetition proportion group were also asked during debriefing to estimate the proportion of trials on which a repetition prime had been presented and to rate their confidence in their estimate. If the high repetition proportion group are better able to identify the primes, then these subjects might provide higher or more confident repetition proportion estimates than subjects in the low group.

Method

Subjects. Twenty subjects were randomly assigned to each repetition proportion group.

Materials, design, and procedure. Forty-four of the 110 low-frequency and 44 of the 110 high-frequency prime–target pairs used in Experiment 2 (40 critical and 4 practice per target type) were replaced with a comparable set of 88 (80 critical and 8 practice) medium-frequency prime–target pairs selected from the 30 to 80 frequency range (median = 45; Kučera & Francis, 1967). The assignment of blocks of items to prime conditions was carried out as in Experiment 2. There were five blocks of 16 medium-frequency items and five blocks of 12 items for each of the low- and high-frequency sets. The rest of the design and procedure were the same as in Experiment 2, except that a 45-ms prime duration was used.

During debriefing, subjects were (as usual) asked what they saw on every trial, just before the target was shown. They were then informed that on each trial, a repetition or an unrelated prime had been presented and that even though they may not have seen these primes, they were to pick a number from 0 to 100 to reflect the percentage of trials they thought had repetition primes. Subjects were then asked to rate their confidence in their estimate on a scale from 1 to 10 (1 = completely guessing, 5 = somewhat confident, 10 = completely confident).

Results

Subjects in the high group did not produce significantly higher estimates of repetition prime percentage than subjects in the low group (60 vs 52%), $F(1,38) = 2.20$, $MSE = 314$, $p = .15$, nor were they more confident in the accuracy of their estimates (3.4 vs 3.9), $F < 1$.

Mixed-factor ANOVAs, in which frequency (low, medium, high) and priming (repetition, unrelated) were the within-subject factors and repetition proportion (low, high) was the between-subject factor, were used to analyze the data. The ANOVA results are reported in the Appendix (Table A6) and the means are shown in Fig. 11.

Word targets. The replacement of a subset of the low- and high-frequency items used in Experiment 2 with a set of medium-frequency targets resulted in a significant interaction of repetition proportion and priming, with greater priming in the high group. This effect was present in both the response latency and error rate analyses. Both analyses also revealed a main effect of priming and a priming by frequency interaction in which priming was larger with lower frequency targets.

Nonword targets. There were no significant effects in the analyses of nonword data.

Discussion

In Experiment 1, repetition proportion and priming interacted when targets were selected from a wide, continuous range of frequencies. No such interaction was found in Experiments 2A and 2B when word targets formed two distinct frequency bands. We suggest that large variations in target processing difficulty were less likely in Experiment 1 because most of the targets were lower in frequency than the high-frequency words used in Experiment 2. Consistent with the prediction that this kind of variation interferes with the influence of prime validity, an interaction between repetition proportion and priming emerged in Experiment 6 when the probability of trial to trial discontinuities was reduced, relative to Experiment 2. This was accomplished by replacing some of the low- and high-frequency words with a set of medium-frequency words to create a continuous range of word frequency and reduce the likelihood of sharp trial-to-trial discrepancies in processing difficulty.

Finally, although the repetition proportion estimates and confidence ratings in Experiment 6

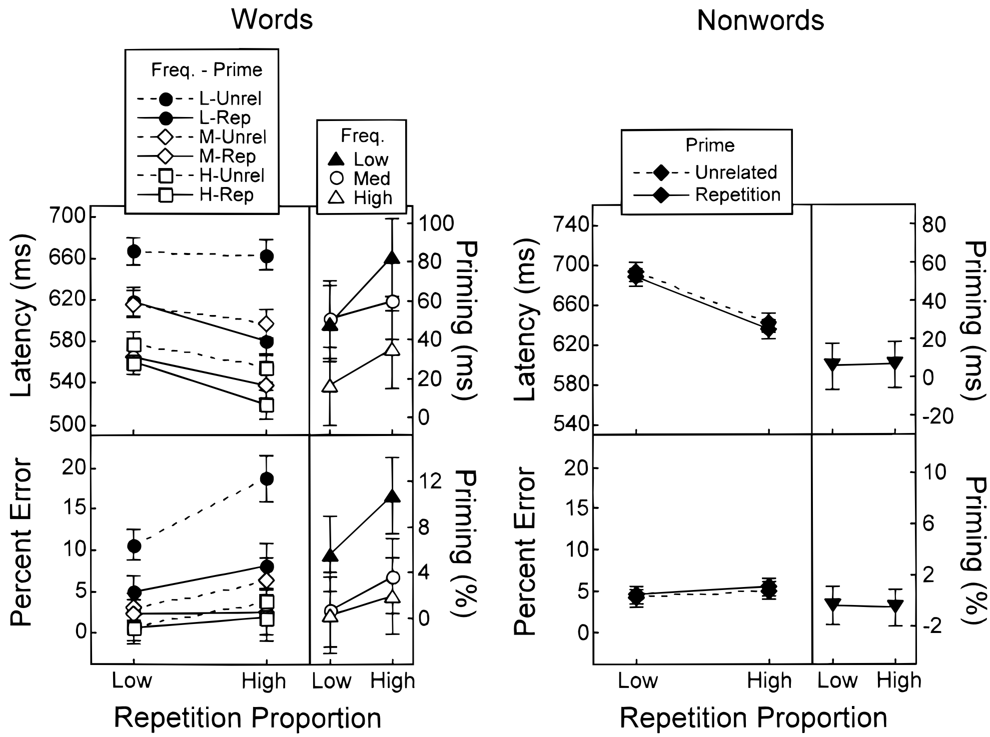

FIG. 11. Mean response latency, percentage error, and corresponding priming effects for words and nonwords in Experiment 6. Error bars for latency and error are 95% within-subjects confidence intervals and are appropriate for comparing means across prime conditions. Error bars for priming effects are 95% between-subjects confidence intervals and are appropriate for comparing means across repetition proportion conditions and against zero.

were equivocal, it may prove informative to obtain such data in future experiments in which masked or unmasked prime proportion manipulations are used (e.g., Milliken, Lupianez, Debner, & Abello, 1999). At this point, however, there is no evidence to suggest that subjects in the low and high repetition proportion groups reliably differ in their awareness of the primes.

COMPARISONS ACROSS EXPERIMENTS

These experiments comprise 12 sets of data from 540 subjects. Such a large data set provides the opportunity for powerful tests of hypotheses by collapsing across experiments. The analyses reported in the next three sections were based on data from selected combinations of experiments and were designed to test specific hypotheses about when and how prime validity affects masked priming in the lexical decision task.

Variability and Prime Validity

We have found it useful to construe masked primes as episodic resources whose recruitment and use is determined by (1) the level of prime validity and (2) the level of task difficulty (Bodner & Masson, 1997; Whittlesea & Jacoby, 1990). To account for the full pattern of results reported here, it seems a third factor must be added to this list, namely, (3) the level of variability from trial to trial in the ease with which targets can be classified. When variability is low, more priming is found with a high repetition proportion than with a low repetition proportion (Experiments 1, 3-LF, 4A, 4B, 5B, 5C, 5D, and 6); when greater variability exists, priming is equivalent for low and high repetition proportion groups (Experiments 2A, 2B, 3-HF, and 5A).

In this section, we examine the proposal that trial-to-trial variability in target processing difficulty can induce a generally high reliance on prime resources, regardless of prime validity. If this proposal is correct, priming should be greater in experiments in which repetition proportion did not influence priming ("no-interaction" experiments), relative to priming found in the low repetition proportion groups in experiments in which repetition proportion and priming did interact. Moreover, priming effects should be of similar magnitude in no-interaction experiments relative to the high repetition proportion groups in experiments in which repetition proportion and priming interacted. These predictions were tested separately for low- and high-frequency words.

For low-frequency targets, the average priming effect found in no-interaction experiments (Experiments 2A and 2B, collapsed across repetition proportion) was compared separately to the priming effects in the low and in the high repetition proportion groups in experiments in which the interaction was obtained (Experiments 3-LF, 4A, 4B, and 6). As predicted, the average no-interaction priming effect (M = 70 ms) was greater than the priming effect in the low repetition proportion groups from experiments in which the interaction obtained (M = 42 ms), $F(1,168) = 23.13$, $MSE = 1{,}375$, and was not reliably different than the priming effect in the high repetition proportion groups from those same experiments (M = 68 ms), $F < 1$.

For high-frequency targets, the no-interaction average was based on Experiments 2A, 2B, 3-HF, and 5A, and it was compared to the mean for Experiments 5B, 5C, and 6. To avoid producing a spurious result, Experiment 5D was not included in the latter set because it produced much less priming than is typically found (e.g., no reliable priming in the low repetition proportion group). As predicted, no-interaction priming (M = 40 ms) was greater than priming for the low repetition proportion groups from experiments in which the interaction obtained (M = 25 ms), $F(1,218) = 9.35$, $MSE = 1{,}098$. This result is particularly striking because the manipulations used in Experiments 5B and 5C typically enhance priming (Bodner & Masson, 1997; Whittlesea & Jacoby, 1990). Thus, variability in processing difficulty may be at least as important a factor as the absolute level of task difficulty in determining the extent to which primes are recruited. Finally, priming for high-frequency targets in experiments in which the interaction did not obtain was not reliably different than priming in the high repetition proportion groups in experiments in which the interaction did obtain (M = 48 ms), $F < 2.13$.

These results are consistent with our claim that large variability in processing difficulty affects prime recruitment and, hence, the extent to which prime validity modulates priming. In particular, high target variability increases priming under conditions of low repetition proportion, but it does not affect priming under high repetition proportion. Goals of future research should be to define more precisely variability in processing difficulty and to elucidate how it interacts with prime validity. For example, although case alternation apparently reduced processing variation between high-frequency words and nonwords to the point that prime validity influenced priming in Experiment 5B, it did not have a similar impact in Experiment 2B. This pattern of results suggests that subjects may be more sensitive to variation in processing difficulty between different classes of words (e.g., between high- and low-frequency targets), which were present in Experiment 2B but not 5B, than to variations in processing difficulty that exist between high-frequency words and nonword targets.

Bias and Prime Validity

Readers appear to rely on a priming resource to a greater extent when that resource is frequently valid than when it is rarely valid. If this proposition is correct, then increased reliance on primes by the high repetition proportion group should improve performance when a repetition prime is presented (80% of the trials) and should impair performance when the prime is unrelated to the target (20% of the trials). This pattern would imply that the influence of masked repetition primes is primarily or exclusively a form of bias effect, as has been argued for repetition priming with unmasked primes (Ratcliff & McKoon, 1997) and for proportion overlap effects in masked word identification (Allen & Jacoby, 1990; Ratcliff et al., 1989).

Figure 12 plots the mean response latencies (left panel) and error rates (right panel) on repetition and unrelated prime trials for the low and high repetition proportion groups collapsed across all the experiments that produced a reliable repetition proportion by priming interaction (Experiments 1, 3-LF, 4A, 4B, 5B, 5C, 5D, and 6; $n = 190$ per group). In the response latency analysis, the high group was indeed faster than the low group on repetition prime trials, $F(1,378) = 4.98$, $MSE = 6,323$, but it was not reliably slower on unrelated prime trials, $F < 1$. By itself, this pattern implies that high repetition proportion produces a genuine improvement in performance. In the error rates, however, the opposite pattern was observed. Relative to the low group, the high group made reliably more errors on unrelated prime trials, $F(1,378) = 4.25$, $MSE = 21.12$, although the groups did not differ on repetition prime trials, $F < 1.34$.

The pattern of latency and error effects shown in Fig. 12 supports the conclusion that the modulation of masked repetition priming by repetition proportion can be characterized as a bias effect. High prime validity appears to increase reliance on the prime, improving performance on repetition-prime trials, but impairing performance on unrelated-prime trials.

Adaptation to Prime Validity

One question we have not yet addressed is how rapidly subjects become sensitive to prime validity as trials progress. The growth of priming effects for word targets in the low and high repetition proportion groups was examined by plotting the size of the priming effect within each block of 100 critical trials, collapsed across all the experiments in which repetition proportion and priming interacted. Plots were prepared for response latencies, as well as for error rates, and are shown in Fig. 13. Two features of the response latency plot stand out: (1) the larger priming effect in the high repetition proportion group appears early, and (2) that advantage does not change systematically across blocks. An ANOVA of mean response latencies that included block as a factor revealed that the influence of repetition proportion on the size of the priming effect did not interact with block, $F < 1$. Unfortunately, data were not collected during the practice trials in most of the current experiments, so we were unable to examine the earliest stage of exposure to the repetition proportion manipulation. Our interim conclusion, then, is that sensitivity to prime validity emerges either during the 40 trials of the practice block or within the first 100 trials of the critical block. There were no reliable effects in the analysis of error rates.

The rapidity and stability with which the influence of prime validity appears in the response latencies suggests two possibilities. One is that manipulating repetition proportion within the 40-trial practice block may have been a critical design element. This sample exposure to low or high repetition proportion may have set a stan-

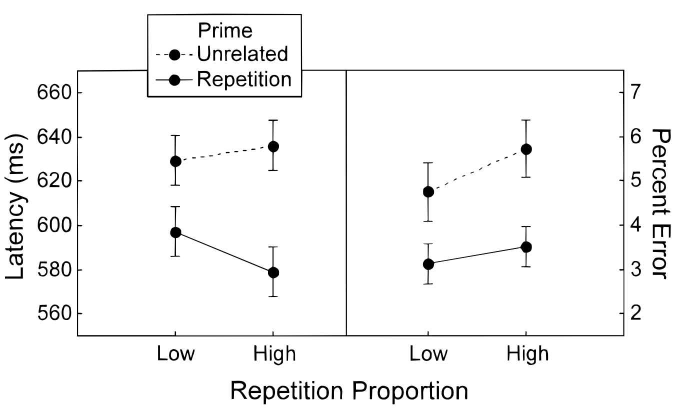

FIG. 12. Mean response latency and error rates for words averaged across all experiments showing a repetition proportion by priming interaction. Error bars are 95% between-subjects confidence intervals and are appropriate for comparing means across repetition proportion conditions.

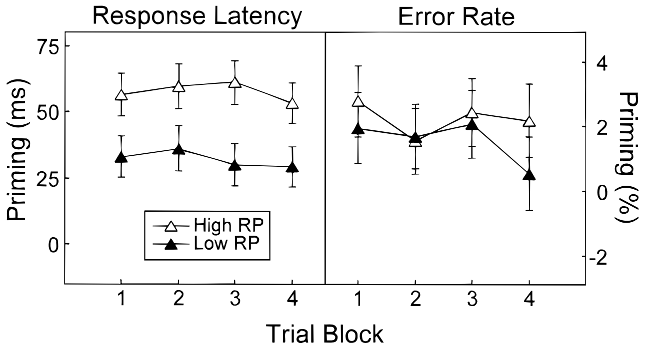

FIG. 13. Mean priming for response latency and error rates for words as a function of trial block averaged across all experiments showing a repetition proportion by priming interaction. Error bars are 95% between-subjects confidence intervals and are appropriate for comparing means across repetition proportion conditions within each trial block and against zero.

dard level of prime use that remained relatively stable across the 400-trial critical block. The second possibility is that use of primes is locally determined, perhaps by the prime validity exhibited on a small run of trials immediately preceding the current trial. Although these possibilities remain to be systematically investigated, evidence from other studies supports the suggestion that adaptation to local list context might occur very rapidly (e.g., Greenwald, Draine, & Abrams, 1996; Ratcliff et al., 1999; Strayer & Kramer, 1994).

GENERAL DISCUSSION

The present experiments introduce a counterintuitive priming result that challenges most theories of how priming affects visual word recognition. In several experiments, we found that repetition priming in the lexical decision task was greater when the proportion of repetition prime trials in the stimulus list was high (0.8) rather than low (0.2), even though primes were masked to prevent their conscious identification. These masked prime validity effects occurred when word target frequency varied continuously over a wide range (Experiment 1), when only low-frequency word targets were used (Experiments 3-LF, 4A, and 4B), when only high-frequency word targets were used (Experiments 5B, 5C, and 5D), and when low-, medium-, and high-frequency word targets were mixed within a list (Experiment 6). This effect obtained with 45- and 60-ms primes, with uppercase and case-alternated targets, and when pseudohomophones, consonant string nonwords, and pronounceable nonwords were used as foils, demonstrating the generality of the effect. Importantly, the present experiments also identify two conditions under which repetition priming was not influenced by prime validity, when word targets consist of two very distinct frequency bands (Experiments 2A and 2B), and when pure lists of high-frequency word targets are distinctly easier to process than their nonword counterparts (Experiment 3-HF and 5A).

This pattern of results provides a compelling illustration of how interactions between prime and target contexts can dramatically affect the extent of a prime's influence on target processing. The involvement of masked primes in target identification appears to depend not only on the validity of the prime context but also on the similarity of the targets with respect to their processing difficulty. Use of the prime resource was not influenced by prime validity when processing difficulty varied substantially from trial to trial. As pointed out in the Introduction, the idea that word recognition is influenced by list context factors is not a novel one, but the present results indicate that this influence extends even to the masked priming paradigm in which subjects are typically unaware that a prime context has been presented (e.g., Bodner & Masson, 1997; Forster & Davis, 1984).

An Episodic Resource Account of Priming

The episodic account described in this paper proposes that word recognition phenomena and memory phenomena may reflect the operation of common underlying mechanisms (e.g., Whittlesea, 1997; Whittlesea & Jacoby, 1990). From this framework, both classes of phenomena require that some processing is applied to an initial stimulus or event, and that this processing can later be used (i.e., retrospectively) to help guide the processing of a subsequent stimulus or event. We have argued that episodic processing resources are constructed even for primes that are masked and presented too briefly for subjects to detect (Bodner & Masson, 1997; Masson & Isaak, 1999). The fact that preference judgments between pairs of novel geometric shapes in the mere exposure paradigm can be influenced by previous 1-ms presentations of one member of each pair (e.g., Kunst-Wilson & Zajonc, 1980; Whittlesea & Price, in press) is consistent with this claim. The present work extends the episodic account by proposing that recruitment of episodic resources can be contingent on their validity—the probability that the primes contain information useful for target processing.

Masked prime validity effects are consistent with an episodic account which posits that more use is made of the prime event when its validity is higher. Moreover, word recognition appears to be highly sensitive to prime validity, as demonstrated by its early and strong influence (Fig. 13). Also in line with this account was the finding that increased recruitment of the prime resource produced a form of bias effect. Relative to the low repetition proportion group, lexical decisions by the high repetition proportion group were facilitated on repetition prime trials (shorter response times), where greater reliance on the prime was an asset, and were impaired on unrelated prime trials (higher error rates), where greater reliance on the prime was a liability (Fig. 12). This bias interpretation of masked prime validity effects fits well with the bias interpretation of proportion overlap effects on priming in studies of episodic effects on masked word identification (Allen & Jacoby, 1990; Jacoby, 1983; Ratcliff et al., 1989).

The most challenging aspect of the present data for any account is that prime validity did not always modulate masked priming. We suggest that the presence or absence of marked variability in target processing difficulty provides a clue regarding conditions under which prime validity matters. Given that the episodic account posits that prime recruitment is dependent on contextual factors such as prime validity and task difficulty, the discovery that another contextual variable affects prime recruitment is not unexpected. Here, we have argued that the presence of marked variability in target processing difficulty, akin to a highly variable drift rate in a diffusion model (e.g., Ratcliff et al., 1999), increases the likelihood of prime recruitment independent of the validity of the primes. At present, we can only speculate as to why subjects rely heavily on the primes, independent of their validity, when target processing variability is high. This is a constraint that poses a challenge not only to an episodic account of masked priming, but to other accounts as well.

In addition to the prime validity results, two other findings from these experiments are compatible with an episodic account. First, word frequency interacted with masked priming in Experiments 2A, 2B, 3 (when prime validity was high), and 6. This outcome was attributed to use of a stronger manipulation of frequency than used in earlier experiments that failed to produce this effect (e.g., Bodner & Masson, 1997; Forster & Davis, 1984). The frequency by priming interaction suggests that prime recruitment is greater when the target is lower in frequency and hence more difficult to process (Bodner & Masson, 1997; Whittlesea & Jacoby, 1990). It is not clear, however, why frequency and priming were additive in Experiment 3 when prime validity was low. One possibility is that power to detect the frequency by priming interaction was not adequate. Indeed, our estimate of the power to detect an interaction in Experiment 3 for subjects in the low repetition proportion group was 0.71, based on the size of the interaction effect seen in Experiment 3 for subjects in the high repetition proportion group. In the five tests of this interaction that we performed across Experiments 2, 3, and 6, four (80%) produced a significant effect.

The other finding of relevance to the episodic account is that nonwords presented in a normal format often showed repetition priming when a 60-ms prime duration and a high repetition proportion were used (Experiments 1, 2A, 4A, 8). Continued demonstrations of masked nonword priming (see also Bodner & Masson, 1997; Forster, 1985, 1998; Masson & Isaak, 1999; Sereno, 1991) suggest that episodes for nonwords can be constructed and recruited even under masked conditions. It must be acknowledged, however, that we do not have a detailed understanding of the conditions that produce nonword priming. For example, nonword priming occurred in Experiment 4B even with a 45-ms SOA, but the nonword priming observed in the response latency analysis of Experiment 3 (where the SOA was 60 ms) was offset by a trade-off with accuracy. Thus, priming of nonwords occurs less consistently than does priming of words in the lexical decision task, perhaps because the task of processing nonwords is a relatively unusual activity that invokes a wider range of processing solutions. Moreover, processing benefits afforded by repetition priming of a nonword may make the nonword seem familiar, and thus impair the subject's ability to classify it as a nonword (e.g., Bodner & Masson, 1997; Salasoo et al., 1985).

Finally, two other ways of casting an episodic account of priming deserve brief mention. First, although Bodner and Masson's (1997) episodic account implies that the construction of the priming episode is terminated when the target is introduced, Masson and Isaak (1999) suggested an alternative—perhaps the masked prime continues to be processed while the target is being encoded. If so, the similarity between the processes applied to the prime and those employed to identify the target may be integrated on repetition prime trials, given their high degree of similarity, producing priming via efficient target processing (e.g., Morris, Bransford, & Franks, 1977). A related idea is that priming may result from fluent reapplication of the processing applied to the prime (Kolers, 1979). The extent to which this reapplication of prior processing occurs is partially stimulus bound, but would also depend on factors such as the instructions, the subject's goals, and—critically for present purposes—the prime and target contexts (e.g., Whittlesea, 1997).

Implications for the Lexical Entry-Opening Account

The lexical entry-opening account maintains that episodic contributions to word identification are eliminated when primes are masked, and that masked priming reflects only the automatic preactivation of the target's lexical entry by a repetition prime (Forster, 1998; Forster & Davis, 1984). The locus of masked priming is thus held to be prospective, revealing itself in the amount of time saved by not having to open the entry "from scratch" when the target word appears. Support for the lexical account has come primarily from four null findings, the lack of repetition proportion effects on masked priming, equivalent masked priming for low- and high-frequency words, the absence of masked nonword priming, and the lack of priming when the prime and target events are temporally separated (Forster, 1998, 1999). Taken together, the repetition proportion by priming and frequency by priming interactions reported here, along with further examples of masked nonword priming, suggest that masked priming effects can no longer be clearly dissociated from long-term priming effects. The question of whether masked primes can exert an influence after a temporal delay is currently under further investigation.

In addition, data from Experiment 6 cast doubt on the lexical account's strong prediction that masked priming should not exceed the prime duration (Forster, 1999). In Experiment 6, the 83-ms priming effect found for low-frequency words when repetition proportion was high was reliably greater than the 45-ms SOA, $t(19) = 3.17$, $SEM = 11.99$. Although one might argue that priming exceeds the SOA for low-frequency words because it is sometimes necessary to make two passes through the lexicon to locate the entry for such words, it is not clear why two passes would be required when repetition proportion is high but not when it is low (where a 48-ms priming effect was observed). This result challenges the view that the effect of a repetition prime is to provide early opening of the target's lexical entry.

Although an adaptive lexical processor could be proposed to account for the effects of prime validity and other results reported here by adding mechanisms, the lexical entry-opening metaphor—having lost much of the basis for distinguishing episodic and lexical effects—will also lose parsimony (Forster, 1999, p .14).

Implications for Accounts of Semantic Priming

Although this work represents the first systematic study of the influence of masked prime validity, there is a substantial literature on proportion effects with plainly visible semantic primes. Semantic priming is often greater when the proportion of related prime–target pairs in the stimulus list is higher (Bushell, 1996; de Groot, 1984; den Heyer, 1985; den Heyer, Briand, & Dannenbring, 1983; Henik, Friedrich, Tzelgov, & Tramer, 1994; Seidenberg, Waters, Sanders, & Langer, 1984; Stolz & Neely, 1995). This relatedness proportion effect, however, appears to occur reliably only when SOAs of 500 ms or more are used, leading researchers to attribute the effect to use of consciously controlled strategies (e.g., Keefe & Neely, 1990; Neely, 1991; Neely & Keefe, 1989; but see Stolz & Neely, 1995). In a companion paper, we show that masked semantic priming can also be modulated by prime validity, leading us to question the claim that relatedness proportion effects in semantic priming are necessarily the product of consciously controlled strategies (Bodner & Masson, in preparation).

Conclusion

Although a detailed process model of episodic influences on priming remains to be developed, the general claim here is that masking and briefly presenting primes may constrain the contents and recruitment of episodic processing resources, but it does not eliminate their creation nor their contribution to the process of recognizing words. These contributions can be modulated by factors such as list context because primes have their influence retrospectively, during processing of the target, rather than via automatic preactivation of a lexical entry or via a consciously deployed strategic process whose effects are exerted at the time the prime is presented. The possibility of episodic influences on masked priming has already been suggested (Forster, Booker, Schacter, & Davis, 1990), but the current experiments indicate that the extent of this episodic influence has been significantly underestimated. As Forster (1998) has pointed out, what constitutes an unwanted effect depends on one's theoretical point of view. From the perspective put forward here, the present demonstrations that masked repetition priming can interact with prime validity and with word frequency, and that masked nonword repetition priming can occur for normally presented nonwords in the lexical decision task, suggest that an episodic account of priming may well be viable.

APPENDIX

ANALYSIS OF VARIANCE SUMMARY TABLES FOR EXPERIMENTS 1–6

TABLE A1

ANOVA Results for Mean Response Latency (ms) and Percentage Error for Words and Nonwords in Experiment 1

	Latency		% Error	
Target and effect	*MSE*	*F*(1,78)	*MSE*	*F*(1,78)
Words				
Repetition prop. (RP)	13,208	0.67	18.0	0.20
Priming	521	194.08*	4.5	16.64*
RP × Priming	521	16.58*	4.5	0.82
Nonwords				
RP	17,060	2.62	44.7	0.65
Priming	689	9.78*	10.0	0.23
RP × Priming	689	10.90*	10.0	0.39

*$p < .05$.

TABLE A2

ANOVA Results for Mean Response Latency (ms) and Percentage Error for Words and Nonwords in Experiments 2A and 2B

	Latency		% Error	
Exp., target, and effect	*MSE*	$F(1,38)$	*MSE*	$F(1,38)$
			Experiment 2A	
Words				
Repetition prop. (RP)	14,694	0.83	30.7	5.18*
Freq.	529	662.55*	17.4	99.74*
RP × Freq.	529	5.74*	17.4	5.25*
Priming	965	124.87*	19.6	12.83*
RP × Priming	965	0.70	19.6	0.40
Freq. × Priming	552	17.89*	20.3	12.19*
RP × Freq. × Priming	552	0.15	20.3	0.86
Nonwords				
RP	12,791	0.36	28.1	0.05
Priming	511	7.64*	4.4	0.07
RP × Priming	511	4.17*	4.4	0.22
			Experiment 2B	
Words				
RP	26,872	2.11	127.4	3.86
Freq.	1569	142.99*	35.2	54.43*
RP × Freq.	1569	2.79	35.2	0.39
Priming	1412	73.28*	26.2	21.34*
RP × Priming	1412	0.53	26.2	4.48*
Freq. × Priming	672	18.47*	21.7	0.84
RP × Freq. × Priming	672	0.58	21.7	0.34
Nonwords				
RP	21,891	0.04	85.2	0.03
Priming	940	4.82*	7.4	0.29
RP × Priming	940	0.004	7.4	0.15

*$p < .05$.

TABLE A3

ANOVA Results for Mean Response Latency (ms) and Percentage Error for Words and Nonwords in Experiment 3

	Latency		% Error	
Target and effect	*MSE*	$F(1,76)$	*MSE*	$F(1,76)$
Words				
Repetition prop. (RP)	7038	0.01	20.5	0.42
Freq.	7038	21.33*	20.5	12.18*
RP × Freq.	7038	0.11	20.5	0.25
Priming	323	308.15*	8.7	19.12*
RP × Priming	323	13.57*	8.7	0.001
Freq. × Priming	323	1.64	8.7	0.70
RP × Freq. × Priming	323	4.75*	8.7	0.29
Nonwords				
RP	13,235	1.05	48.3	0.14
Freq.	13,235	9.10*	48.3	5.06*
RP × Freq.	13,235	0.08	48.3	0.46
Priming	531	11.08*	8.5	6.33*
RP × Priming	531	3.61	8.5	3.30
Freq. × Priming	531	9.12*	8.5	3.05
RP × Freq. × Priming	531	0.66	8.5	0.80

Note. For nonwords, frequency refers to the frequency of the word targets in the stimulus list.
*$p < .05$.

TABLE A4

ANOVA Results for Mean Response Latency (ms) and Percentage Error for Words and Nonwords in Experiments 4A and 4B

	Latency		% Error	
Exp., target, and effect	*MSE*	*F*	*MSE*	*F*
		Experiment 4A (60 ms)		
Words				
Repetition prop. (RP)	6257	0.05	16.6	0.08
Priming	355	161.10*	8.8	14.08*
RP × Priming	355	8.17*	8.8	5.21*
Nonwords				
RP	10,008	0.90	14.9	0.58
Priming	676	8.08*	13.6	1.37
RP × Priming	676	9.35*	13.6	0.002
		Experiment 4B (45 ms)		
Words				
RP	8394	0.56	39.5	0.46
Priming	384	192.04*	10.0	14.82*
RP × Priming	384	4.55*	10.0	2.51
Nonwords				
RP	14,490	4.24*	42.3	1.00
Priming	419	3.57	11.1	0.42
RP × Priming	419	0.03	11.1	1.00

Note. The *df* are 1 and 38 in Experiment 4A; the *df* are 1 and 58 in Experiment 4B.
$^*p < .05$.

TABLE A5

ANOVA Results for Mean Response Latency (ms) and Percentage Error for Words and Nonwords in Experiments 5A, 5B, 5C, and 5D

	Latency		% Error	
Exp., target, and effect	*MSE*	*F*(1,38)	*MSE*	*F*(1,38)
		Experiment 5A		
Words				
Repetition prop. (RP)	5,544	0.13	5.1	0.29
Priming	406	85.93*	2.5	4.18*
RP × Priming	406	0.10	2.5	0.52
Nonwords				
RP	9,415	0.36	27.5	3.02
Priming	305	0.36	6.8	0.24
RP × Priming	305	0.35	6.8	1.88
		Experiment 5B		
Words				
RP	18,086	0.47	16.4	0.26
Priming	365	115.10*	8.3	14.36*
RP × Priming	365	8.60*	8.3	1.76
Nonwords				
RP	25,898	0.07	28.0	0.01
Priming	801	1.50	11.5	0.43
RP × Priming	801	2.33	11.5	2.74

TABLE A5—*Continued*

	Latency		% Error	
Exp., target, and effect	*MSE*	*F*(1,38)	*MSE*	*F*(1,38)
		Experiment 5C		
Words				
RP	9929	0.003	9.9	0.01
Priming	484	57.44*	5.7	4.06
RP × Priming	484	6.40*	5.7	0.56
Nonwords				
RP	12,269	0.45	94.6	0.86
Priming	548	1.17	14.7	0.32
RP × Priming	548	0.04	14.7	0.62
		Experiment 5D		
Words				
RP	9652	0.02	5.2	0.001
Priming	478	4.38*	2.5	0.01
RP × Priming	478	9.26*	2.5	1.70
Nonwords				
RP	10,136	0.001	6.1	0.06
Priming	331	0.02	3.0	0.10
RP × Priming	331	0.55	3.0	2.86

*$p < .05$.

TABLE A6

ANOVA Results for Mean Response Latency (ms) and Percentage Error for Words and Nonwords in Experiment 6

	Latency		% Error	
Target and effect	*MSE*	*F*	*MSE*	*F*
Words				
Repetition prop. (RP)	26,785	1.44	53.8	11.30*
Freq.	1033	127.78*	33.3	53.49*
RP × Freq.	1033	0.76	33.3	2.56
Priming	957	149.21*	26.5	33.79*
RP × Priming	957	6.83*	26.5	5.88*
Freq. × Priming	830	10.35*	25.7	11.14*
RP × Freq. × Priming	830	0.93	25.7	0.59
Nonwords				
RP	9,928	5.39*	15.1	1.14
Priming	375	1.94	5.3	0.74
RP × Priming	375	0.01	5.3	0.03

Note. The *df* are 2 and 76 for effects involving Frequency; the *df* are 1 and 38 for all other effects.
*$p < .05$.

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