Influence of Post-Prime Cues on Masked Repetition Priming

by

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ABSTRACT

I present evidence that masked repetition priming of word identification can be modulated by post-prime cues. Cues consisted of targets presented in black, with repetition and unrelated primes equally likely for such targets, or in a color that was correlated with type of prime (e.g., red = repetition prime, green = unrelated prime). There was an increase in response latency for targets with unrelated primes and a decrease in response latency to targets with repetition primes when target color was correlated with type of prime. In this correlation condition, subjects exhibited a larger reliance on the prime for target processing. In the condition where target color was unrelated to prime type, subjects had less reliance on the prime and processed the target more independently.

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Dedication

I want to give all the appreciation to my supervisor Dr. Masson. I could not have finished this thesis without your instruction.

I also want to thank my officemate, Marnie Jedynak, for her help in checking the experimental materials.

Finally this work is dedicated to my parents. Thank you for all your support.

Introduction

The phenomenon of repetition priming can be observed in both laboratory environments and in real life. It is easier to identify items encountered before than to identify completely new items. In a typical paradigm of repetition priming effect experiments, the first presentation of an item is called prime and the repeated presentation is called target. Researchers have observed long-term repetition priming effects where people process the prime consciously or masked repetition priming effects where people have no conscious awareness of the prime. With word identification tasks such as the lexical decision task, subjects show faster responses or higher accuracy to those target words following a repetition prime than to those targets following an unrelated prime. The speed of processing later occurrences of repeated words is increased compared with that of the first occurrence (Forbach, Stanners, & Hochhaus, 1974; Scarborough, Cortese, & Scarborough, 1977).

One generally accepted theory to account for the mechanism of repetition priming effects is the lexical activation theory. The proposal is that repetition priming effects operate at the lexical level and are based on an assumed lexical entry within the mental lexicon. This theory claims that repetition priming effects are the result of a change in the lexical processing system (Forster, Booker, Schacter, & Davis, 1990). It is assumed that within the language system, there is a logogen (Morton, 1969) or a lexical entry (Forster & Davis, 1984) working as the representation for each word. It is necessary that the activation of a word's representation reach a threshold to enable the identification of that word. When the same word is presented to subjects for the second time and the lexical entry representing the word is still within the activated state, less processing is required to reach the threshold needed for the identification of that word. Therefore, a shorter response latency or higher accuracy will be obtained. By the lexical activation theory, the target is activated proactively by the prime. The direction of repetition priming effects is from the prime to the target and the facilitation produced by the prime is independent of other information in the context of the target's presentation.

The lexical activation theory has some difficulty accounting for long-term repetition priming effects, as these effects can last much longer than an activated state is usually assumed to last (Scarborough et al., 1977; Jacoby & Dallas, 1981; Forster & Davis, 1984).

It has also been observed that long-term repetition priming effects occur with nonwords (Scarborough et al., 1977; Besner & Swan, 1982; Norris, 1984; Kirsner & Smith, 1974; McKone, 1995). Since there is no lexical entry for nonwords, the lexical activation theory cannot explain how priming effects occur for nonwords.

An alternative account interprets repetition priming effects from an episodic memory point of view. As the episodic memory account explains, the event of encountering a word forms an episodic memory event within the memory system and that memory event can be retrieved to facilitate processing of the same word on a later presentation. Kolers (1979) claimed that the processing skill achieved at the first presentation of the word enables more fluent processing when a similar item is encountered later. In McClelland and Rumelhart's model (1986), it is proposed that exposure to each item involves some incremental learning and that learning causes a change in connection weights. The point is that the event of encountering a word sets up an episodic memory trace as a learning episode and the learning episode causes some change in the memory system (e.g. Jacoby & Dallas, 1981; Joordens & Becker, 1997; Ratcliff & McKoon, 1988; Rueckl, Mikolinski, Raveh, Miner, & Mars, 1997). When the same item appears again, people will retrieve the established trace from memory and then the processing of that item will be facilitated. The episodic memory account is based on a retrospective view rather than a proactive view of priming. Consequently, variation of cues presented with the target that can influence the retrieval of the prior event will cause repetition priming effects to vary. Retrieval is not simply a copy of prior experience but a dynamic interaction between the representation in memory and cue properties of the present environment (Masson, Caldwell & Whittlesea, 2000). As a result, the prime's facilitation of a target is dependent on contextual information of both the prior encounter with the prime and the current presentation of the target.

One challenge to the episodic memory account is that it is possible that masked repetition priming effects operate without the involvement of explicit encoding so that no episodic trace is established. Forster and Davis (1984) conducted experiments with masked primes to eliminate the formation of the episodic trace and observed repetition priming effects. Researchers supporting the lexical activation theory accept the proposal that long-term repetition priming effects are based on an episode in memory but claim that masked repetition priming effects operate at the lexical level. It is assumed that there is no memory trace established for the presentation of an item if it is masked such that subjects have no conscious awareness of its presentation. Against this proposal, the phenomenon of mere exposure provides evidence that it is possible that even without full awareness of an item, its presentation will increase people's preference for that item relative to a new one in a subsequent preference judgment, even in the absence of recognition of the stimuli. With a recognition task, briefly presented and masked items show chance performance (e.g. Bonnano & Stillings, 1986; Bornstein, Leone, & Galley, 1987; Kunst-Wilson & Zajonc, 1980; Mandler, Nakamura, & van Zandt, 1987; Seamon, Brody, & Kauff, 1983; Whittlesea & Price, 2001). It is possible that presenting items with a very short duration creates a change in the memory system without conscious awareness. Bodner and Masson (1997; Masson & Isaak, 1999) proposed that even when subjects have no awareness of the presentation of an item, an episodic trace for that item still could be formed but it could not be retrieved consciously. From this perspective, the mechanism of masked repetition priming effects may share some similarities with that of long-term repetition priming effects.

Another challenge to the episodic account is that there is no masked repetition priming effect occurring to nonwords and no significant difference in masked repetition priming between high-frequency words and low-frequency words. From the episodic memory account, the presentation of a low-frequency word is a more salient event than the presentation of a high-frequency word. Therefore, the memory trace established by a low-frequency word should be easier to retrieve than by a high-frequency word and will produce a larger priming. Forster and Davis (1984) found that masked repetition priming effects only occur to words, and there was no difference between the masked repetition priming for high-frequency words and for low-frequency words but long-term priming effect can be modulated by word frequency. It is possible that the lack of masked repetition priming effects for nonwords is due to a trade-off in making a correct response to nonwords because subjects must overcome the tendency (created by a repetition prime) to make a "word" response to a pronounceable nonword. With a naming task or a lexical decision task in which target processing difficulty is increased by using case-alternated targets (Bodner & Masson, 1997; Masson & Isaak, 1999), masked repetition priming effects can be observed to occur to nonwords. Low-frequency words should produce more repetition priming effects than high-frequency words because the occurrence of a low-frequency word is a more salient event for people so that it should be easier to retrieve. It is possible that the lack of interaction between priming and word frequency is due to a weak manipulation of word frequency. With a stronger manipulation of word frequency by using words of very high- and low-frequency as stimuli, the interaction between type of prime and the masked priming has been obtained. Bodner and Masson (1997, 2001) found evidence that the amount of masked repetition priming is modulated by word frequency when there is a large contrast in frequency among the word targets. In this situation, low-frequency words can show more priming than high-frequency words because the presentation of a low-frequency word is a more salient memory event to subjects and this event is easier to be retrieved. This finding also supports the episodic memory account that subjects' tendency to use the prime for target processing results in a change in the amount of priming.

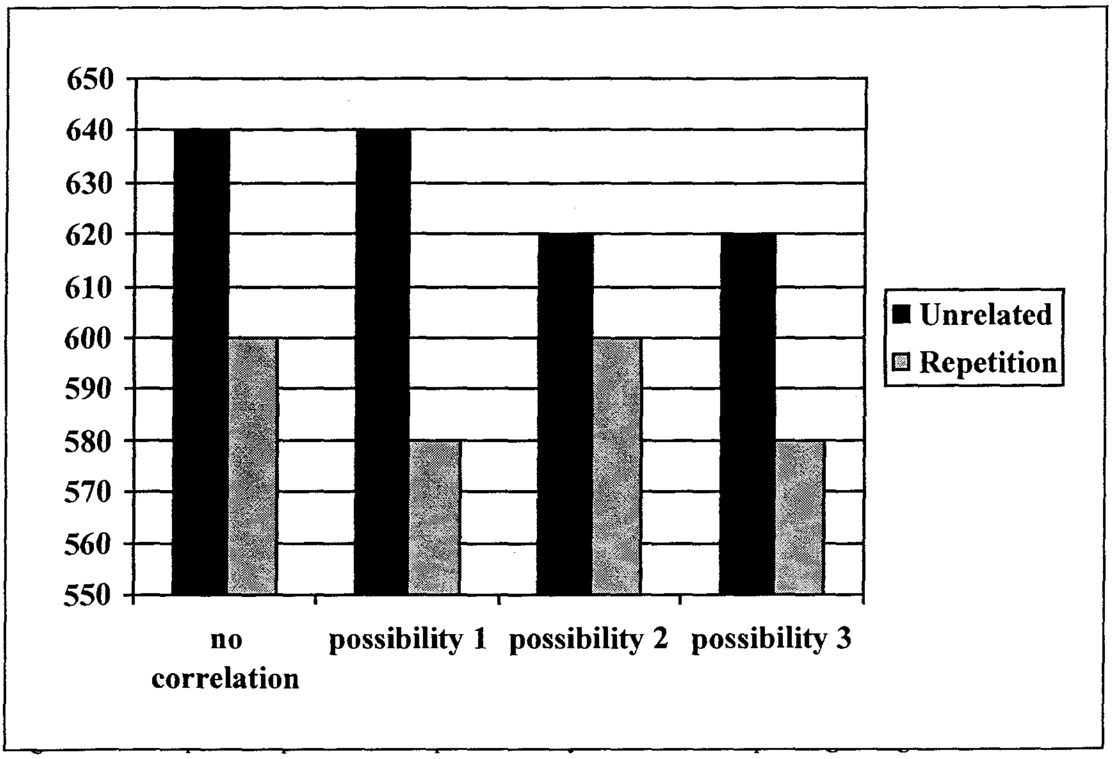
As proposed previously, the episodic memory account claims that the direction of repetition priming is not forward from the prime to the target but backward from the target to the prime (Whittlesea & Jacoby, 1990). Repetition priming effects can last a long time or only for a short period, depending not only on the context of the target but also on the context of the original encounter (Forster et al., 1990; Smith, Besner, & Miyoshi, 1994; Stolz & Besner, 1997). The masked repetition priming effect is sensitive both to the features of the prime and the context of the target. The recruitment of episodic resources can be dependent on their processing context such as whether the primes contain information useful for target processing. Greater reliance on the prime means that subjects are more likely to use the prime to influence the encoding of the target.

Bodner and Masson (2001) observed that repetition priming effects are susceptible to contextual information, which provides evidence for the view that repetition priming effects have an episodic origin. They manipulated contextual information by controlling the repetition proportion (RP) across all trials. The repetition proportion is defined as the proportion of trials in which repetition primes are used. With high repetition proportion, subjects are more likely to recruit information from the prime to facilitate processing of the target. As a result, if the target is a repetition of the target, then greater reliance on information from the prime is useful and identification of the target will be facilitated. If the target is unrelated to the prime, then greater reliance on the prime may interfere with identification of the target. With low repetition proportion, processing of the target should be less likely to rely on the prime because the contextual information is not very useful. In this case, if the target is a repetition of the prime, any tendency to avoid using the prime will reduce the repetition priming effect. The usefulness of the prime can be used as a cue to the extent to which subjects should rely on information from the prime. Bodner and Masson observed that the amount of priming for a high RP group (80% of the targets had a repetition prime) was larger than that for a low RP group (20% of the targets had a repetition prime). These results provide evidence that repetition priming effects reflect a retroactive phenomenon.

The context in which the target is presented and the nature of the task will influence retroactively use of the prime. Cues in the context of the target presentation may influence subjects' reliance on a prime. Whether to use the prime event to assist with the identification of a target may depend on what kind of cue subjects encounter when the target is presented. Besides that, the difficulty of the task also can mediate subjects' reliance on the prime. If the target is hard to identify, subjects will be more likely to recruit the prime information to facilitate target processing. Processing difficulty causes subjects to use resources other than the target. Whittlesea and Jacoby (1990) observed that with an interpolated word between a repetition prime and a target, the amount of priming was larger in a condition where the interpolated word was degraded (i.e., GREEN – pLAnT – GREEN) compared with a condition where the interpolated word was presented in a normal format (i.e. GREEN – PLANT – GREEN). That is because a degraded interpolated word is harder to identify and invites participation of the prime for its identification and this makes the prime more available for the identification of a repeated target. In contrast, a non-degraded interpolated word is processed more dependently and subjects rely to a less degree on the prime. Consequently, relatively less processing of the prime results in less assistance for the target. Similarly, a valid cue should lead subjects to recruit a prime event whereas an invalid cue should reduce the tendency to rely on a prime.

The above findings are all examples that subjects' tendency to recruit prime information is sensitive to contextual information, which provides more evidence to the episodic memory account. The purpose of this thesis is to find more evidence to support the episodic memory account for masked repetition priming effects. In this research, contextual influences on masked repetition priming effects were examined within a retrospective account by manipulating the context of the target's presentation. A correlation was established between target color and type of prime. If the target has a repetition prime then it is presented in a certain color, whereas if the target has an unrelated prime then it is presented in a different color. The correlation between color of the target and type of prime can be used as a cue for prime relevance. Compared with the usual situation in which target color is unrelated to type of prime, it was expected that priming would be modulated by this contextual information. The correlation manipulation was a post-prime cue for subjects and they were not informed of the correlation. If the correlation manipulation is an effective cue to modulate masked repetition priming effects, the retrospective account of priming will be supported. Previous research has provided evidence that the amount of masked repetition priming can be modulated by contextual information of the target's presentation (namely, repetition proportion), which motivates this research using color cues.

It was expected that the correlation manipulation would be another type of contextual information from the target's presentation to modulate subjects' reliance on the prime. This modulation should result in a change in response latency in the repetition prime condition and the unrelated prime condition. Based on the retrospective account, the reliance on the prime can be modulated by the cue properties of the target presentation context. Subjects should be more likely to use the prime if they can obtain an indication from the target that the prime is a useful one and they should be less likely to use the prime if the contextual information of the target suggests that the prime is not useful. The correlation between target color and type of prime was intended to be such a cue. If subjects can get information from the target color about whether or not to use the information of the prime, they can make faster responses to the targets in both the repetition prime and the unrelated prime condition. In this situation, we should observe a decrease in response latency to targets with both repetition primes and unrelated primes and the amount of priming likely would not change. If subjects are cued by the target color to rely on the prime in the repetition prime condition, but do not react to target color in the unrelated prime condition, there will be a decrease in response latency to targets with repetition primes and a larger amount of priming. However, if subjects benefit only when target color indicates an unrelated prime, there should be faster responses to targets with unrelated primes, and there would be a smaller amount of priming. If contextual information benefits response latency to targets with both repetition primes and unrelated primes, the amount of priming may not change but the overall response latency can be reduced. Through these experiments, it should be possible to determine whether the correlation manipulation influences response latency to targets with repetition primes, with unrelated primes, or both.



Seven experiments are reported in this paper. They examined how the correlation manipulation influences the amount of priming. In Experiment 1, we compared the masked repetition priming effect in a condition where there was a correlation between color of the target and type of prime with a condition in which there was no correlation. The correlation condition was manipulated between subjects. In Experiment 2, correlation condition was manipulated within subjects instead of between subjects. Half of the trials presented to subjects had the correlation and the other half of the trials had no correlation.

Experiment 3 was a control experiment. It examined whether the color of the target had any influence on the response latencies and the amount of priming, independent of possible color-prime correlations. Experiment 4 was an attempt to replicate the correlation manipulation using a different method of counterbalancing. Experiment 5 was also a replication experiment with the same design as Experiment 4, except that it used high-frequency words whereas low-frequency words were used in Experiment 4. In Experiment 6, both correlation condition and repetition proportion (RP) were manipulated within subjects at the same time, allowing a comparison between the two manipulations with respect to their effect on the amount of priming. In Experiment 7, the correlation condition was manipulated within subjects but the correlation and no-correlation items were presented in small, alternating blocks of trials. Blocked presentation was used to examine whether the influence of correlation on priming is caused by the local context of the trials immediately preceding a target.

Experiment 1

Experiment 1 was designed to examine whether the color of a target can work as a strong contextual cue to increase the masked repetition priming effect. The correlation between the color of the target and type of prime was manipulated between subjects to make sure that each subject would be exposed to only a single contingency. For those subjects in the correlation condition, the color of the target acted as a cue to the prime type. In such a situation, it was expected people would be more likely to use the information from the prime to facilitate processing of the target if the target is a repetition of the prime. Also, they may avoid using the information from the prime when the target is unrelated to the prime. If both of these influences are at work, we would expect to see a reduction in response latencies in the correlation condition, both for repetition and for unrelated primes. If only one of these influences operates, however, then only the relevant prime condition would show a reduction in response latency because of the introduction of the correlated cue, leading to an increase priming effect.

Method

Subjects. Forty-eight students at the University of Victoria participated for extra credit in an introductory psychology course. Half of subjects were assigned to each of the two groups, correlation and no-correlation. The no-correlation group was presented with a set of trials in which the targets appeared in one of the two colors randomly. In the correlation group, subjects were presented with targets that appeared in one color on repetition prime trials and a different color on unrelated prime trials. No subject took part in more than one of the experiments reported here.

Materials and design. The materials were 440 words and 440 nonwords, four to six letters in length. These items were arranged as 200 word pairs and 200 nonword pairs for critical trials and 20 pairs of each for practice trials. Each word or nonword in a pair was of the same length. The words were low in frequency (below ten occurrences per million, Kucera-Francis, 1967). One member of each pair was used both as the prime item and as the target item with a repetition prime. The other member of each pair, which was orthographically and semantically unrelated to the first member, served as the target in the unrelated prime condition and the first member served as the prime.

The 200 critical word pairs and 200 critical nonword pairs were divided into four blocks with 50 word pairs and 50 nonword pairs in each block. Two blocks of words and nonwords were used in the repetition prime condition and the other two blocks of words and nonwords were used in the unrelated prime condition. Assignment of blocks to prime condition was counterbalanced across subjects so that each block was used equally often in each prime condition. All the primes were presented in black. In the correlation condition, targets were presented in one color (red or green) when a repetition prime was used and in another color (red or green) when an unrelated prime was used. Assignment of color to prime condition was counterbalanced across subjects so that each color assignment (e.g., green = repetition, red = unrelated or green = unrelated, red = repetition) was used equally often. In the no-correlation condition, targets were presented in either red or green randomly, with the constraint that an equal number of targets appeared in each color.

Procedure. Subjects were tested individually in a quiet room. Instructions and stimuli were presented on a G3 Macintosh computer with a color monitor. Subjects were instructed that a row of #s would be displayed, then a target letter string would be presented in uppercase and remain on the screen until a response was made. Their task was to decide whether the letter string was a word or a nonword. If the target was a word, they pressed the "YES" button mounted on a response box. If the target was not a word, they pressed the "NO" button. Subjects were informed that a target was equally likely to be a word or a nonword and was equally likely to be presented in red or in green. They were also told to respond as quickly and as accurately as possible and that if they took too long to make a response or made an error, then the computer would display a message to that effect. Subjects were not informed about the presence of primes in the displays nor were subjects in the correlation condition told of the correlation between the color of the target and type of prime.

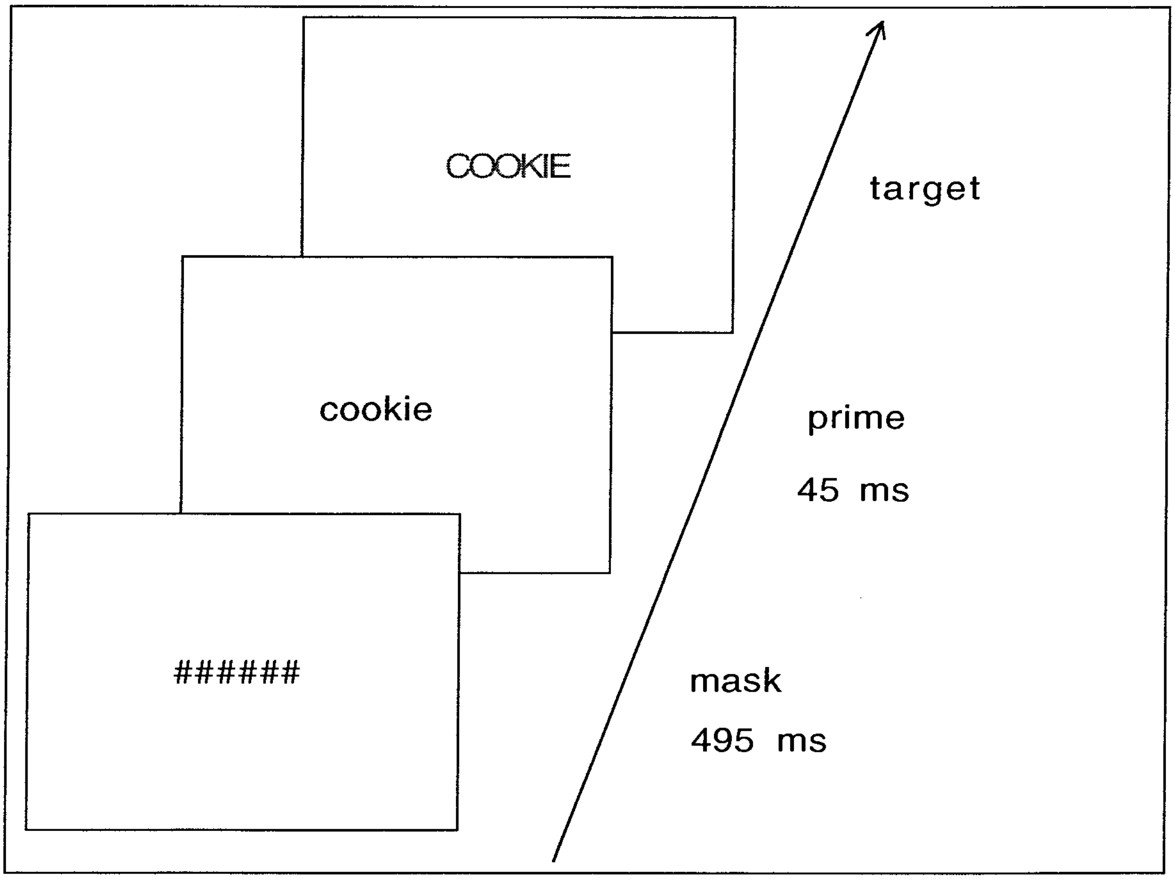


Figure 2. The presentation procedure and duration of the mask, prime, and target.

Forty practice trials were presented in a random order, followed by 400 critical trials. The critical trials were presented to each subject in an independently determined random order. Each trial began with a mask consisting of a row of #s printed in black presented for 495 ms. The mask was the same length as the prime and target, and was followed immediately by the prime printed in lowercase black letters. The duration of the prime was 45 ms. The prime was then replaced by a target printed in red or green uppercase letters.

The target remained on the screen until the subject made a response. After all the trials had been presented to subjects, they were asked several questions to determine whether they had any conscious awareness of the primes. First, they were asked, “What did you see on each word/nonword decision trial just before the target appeared?” If the subject said that all they saw was a row of #s then they were asked, “Did you see anything else?” If they said “no”, they were asked, “Did you see anything after the mask but before the target appeared?” Each subjects’ answer was classified as fitting one of the following three categories: (1) they saw #s only, and did not see prime, (2) they saw something else, like a flash or flicker of letters, but could not identify any primes, and (3) they saw at least some of the primes and could say that some were related to the targets.

Results

For all the experiments in this article, response latencies shorter than 200 ms or longer than 1500 ms (1600 ms for nonwords) were classified as outliers excluded from the analyses. These criteria were selected so as to keep the percentage of excluded trials at or below 0.5% (Ulrich & Miller, 1994).

Prime awareness. Thirty-four of the forty-eight subjects reported they did not see anything between the mask and the target letter string. The remaining fourteen subjects reported that something after the mask flashed between the mask and the target. But they could not identify what the flash was and none reported noticing any relationship between the flash and the target.

Word targets. The mean response latencies and error rates for word targets are shown in Figure 3 with 95% between-subject confidence intervals (Loftus & Masson, 1994; Masson & Loftus, 2003). A two-factor mixed analysis of variance (ANOVA) was conducted on response latencies, with type of prime (repetition vs. unrelated) and correlation (correlation vs. no-correlation) as the independent variables. Another ANOVA was conducted with the same independent variables and error rate as the dependent variable. The significance level was set at .05 for all the experiments in this article.

In the analysis of response latencies, there was a reliable priming effect, $F(1, 46) = 277.21$, $MSE = 68{,}320$. Response latencies to targets with a repetition prime were significantly shorter than to targets with an unrelated prime. The correlation manipulation showed no significant main effect, $F < 1$, and did not interact with type of prime, $F < 1$.

Thus, the priming effects for the correlation and no-correlation conditions were very similar (51 ms vs. 56 ms, respectively).

There was also a significant main effect of the priming in the error rates, F(1, 46) = 31.83, MSE = 299.27. Subjects made more errors when the targets had an unrelated prime than when they had a repetition prime. In contrast to the results of response latencies, there was a main effect of correlation in the error rates, F(1, 46) = 12.12, MSE = 388.41. The error rate was lowerer in the correlation condition than in the no-correlation condition. There was no interaction between prime and correlation, F < 1.

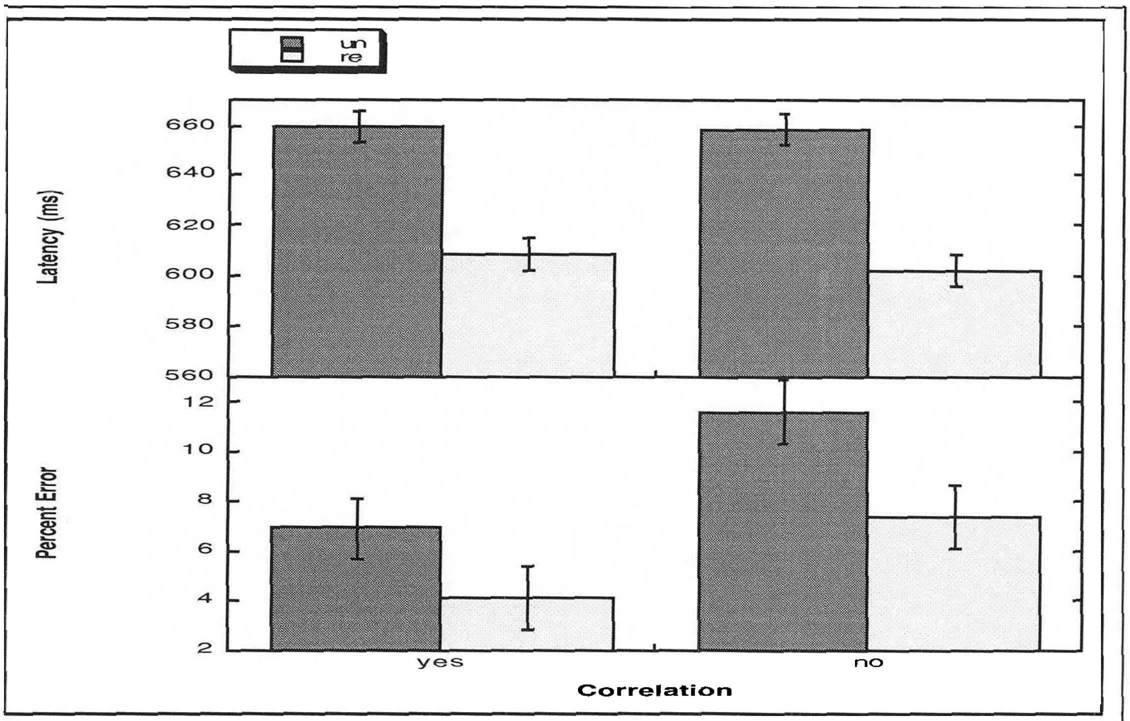


Figure 3. Mean response latencies (RT, in ms) and error rates (%E) for words in Experiment 1.

Nonword targets. The mean response latencies and error rates for nonword targets are shown in Figure 4. Response latencies and error rates were analyzed with ANOVAs in the same way as the word data.

There were no significant effects in the analysis of response latency. The analysis of error data revealed a reliable priming effect, F(1, 46) = 6.198, MSE = 65.175, with lower error rates for targets with unrelated primes. There was no reliable main effect of correlation and no interaction.

The priming effect on the error rates for nonword targets may be interpreted as follows: The presentation of the nonword also can set up an episodic memory event within the system. When that nonword is presented for processing again, the established episode can be retrieved and causes a sense of familiarity because of the previous encountering. Such a sense of familiarity may bias subjects towards classifying it as a word. Subjects must overcome this tendency so to make a correct response, creating the possibility for error (Bodner & Masson, 1997, 2001).

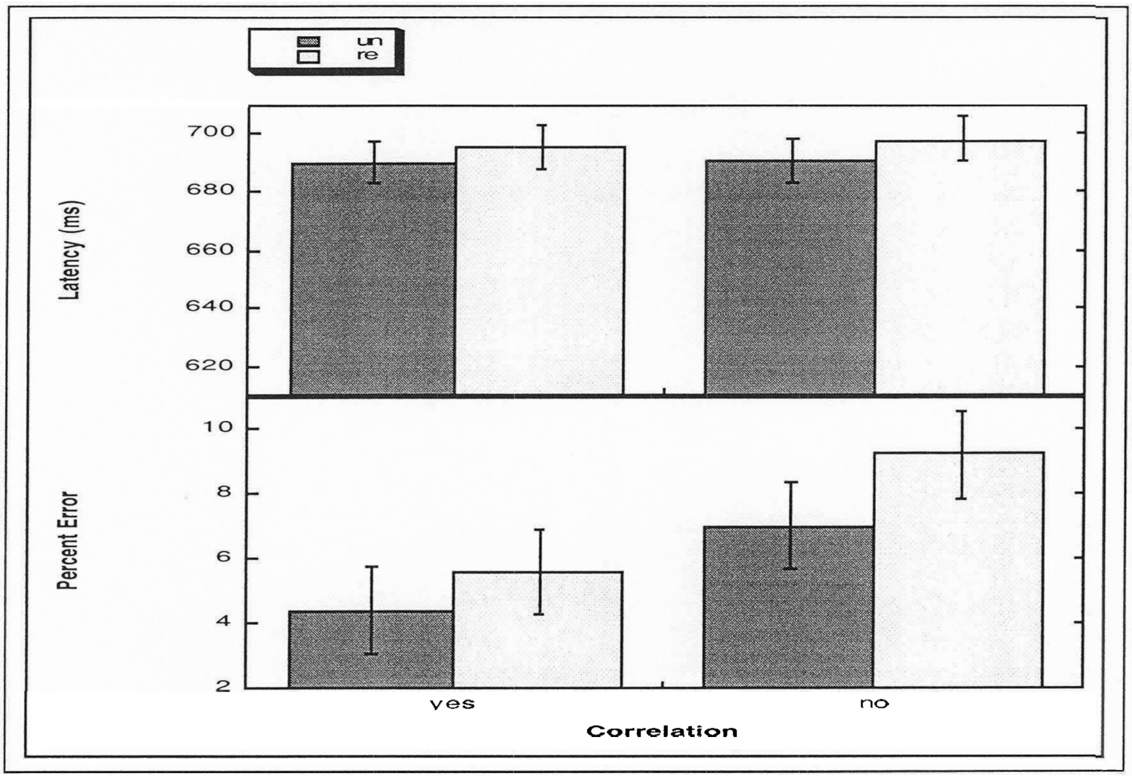


Figure 4. Mean response latencies (RT, in ms) and error rates (%E) for nonwords in Experiment 1.

Discussion

The results of Experiment 1 did not confirm the expectation that cues correlated with prime type would lead to more efficient responding. Overall response latency and priming effects were almost equal in both the correlation condition and the no-correlation condition for word targets. It may be that the correlation manipulation was not strong enough to increase subjects' reliance of the prime and produce a change in response latency.

Experiment 2

Color correlation was manipulated within subjects instead of between subjects in

Experiment 2. The purpose of this experiment was still to compare the masked repetition priming effect in a condition where there is a correlation between the color of the target and type of prime with the other condition in which there is no correlation. It was expected that power would be increased by this within-subject design. Besides that, subjects would experience a contrast between correlation and no-correlation through which the correlation manipulation might be more easily experienced. To distinguish between trials with and without the correlation, we presented targets in the no-correlation condition in black and targets in the correlation in red or in green. The correlation manipulation was expected to modulate subjects' reliance on the prime. More reliance on a useful prime should result in a decrease in response latency for targets with repetition primes and less reliance on an unrelated prime should lead to a decrease in response latency for targets with unrelated primes. Half of the black targets appeared with repetition primes and half with unrelated primes. All targets of one color (red or green) appeared with repetition primes and targets of the other color appeared with unrelated primes. In this experiment, subjects would be exposed to these two different contingencies. Since the materials for Experiment 2 were the same as in Experiment 1, any difference in outcome between the two experiments could be attributed to differences in the nature of the correlation manipulation.

Method

Subjects. Forty students from the same source as Experiment 1 were tested in Experiment 2.

Materials and design. The same 220 low-frequency word pairs and 220 pronounceable nonword pairs as Experiment 1 were used for practice trials and critical trials for Experiment 2. As in Experiment 1, the critical 200 word pairs and 200 nonword pairs were divided into four word blocks and four nonword blocks with fifty word pairs and fifty nonword pairs in each block. Two blocks of words and nonwords were used in the repetition prime condition and the other two blocks of words and nonwords were used in the unrelated prime condition. One member of each pair was used both as the prime and as the target for the repetition prime condition. That item also served as the prime in the unrelated condition. The other member of each pair, which was orthographically and semantically unrelated to the first member, served as the target in the unrelated condition.

This arrangement meant that targets with repetition primes were always drawn from one set of items and targets with unrelated primes were always drawn from another set of items. Thus, interpretation of the size of the priming effect must be made with caution, but any interaction between priming and correlation condition should not be compromised by this method of assigning items to prime condition because the assignment of blocks to prime and correlation conditions was counterbalanced across subjects.

For trials in the no-correlation condition, all the targets were always presented in black. For trials in the correlation condition, the target was printed in red or in green depending on what type of prime it had. For example, the target was presented in red when it had a repetition prime and presented in green if it had an unrelated prime. Assignment of color to prime condition was counterbalanced across subjects. Subjects were presented with 40 practice trials and 400 critical trials. Half of the trials of each type were in the correlation condition and half were in the no-correlation condition. Thus, 50% of the targets were presented in black, 25% were presented in red and the remaining 25% in green.

Procedure. The procedure was the same as in Experiment 1. Forty practice trials were presented in random order, followed by 400 critical trials. The critical trials were presented to subjects in an independently determined random order. Subjects were asked to classify each target letter string as a word or a nonword. They were instructed that the letter string might be presented in greed, red, or black but not told of the possible color correlation. After subjects completed the experiment, they were asked the same three questions as in Experiment 1 to examine conscious awareness of the prime.

Results

Prime awareness. Thirty-six of the forty subjects of Experiment 2 reported they did not see anything between the mask and the target letter string. The remaining four subjects reported that there was something flashing between the mask and the target, but they could not identify what the flash was and none reported noticing any relationship between the flash and the target.

Word targets. Response latencies were filtered as in Experiment 1. Figure 5 illustrates the mean response latencies and error rates for word targets of Experiment 2 with 95% within-subject confidence intervals. A two-factor within-subject ANOVA was conducted with type of prime (repetition vs. unrelated) and correlation (correlation vs. no-correlation) as the independent variables and response latency as the dependent variable. Another two-factor within-subject ANOVA was conducted on error rate with the same independent variables.

There was a reliable priming effect on response latency, $F(1, 39) = 152.41$, $MSE = 88{,}501$. The correlation manipulation had no main effect on response latency ($F < 1$), but the correlation manipulation did interact with priming effect, $F(1, 39) = 8.704$, $MSE = 4{,}442$. Subjects made faster responses to targets with a repetition prime and the priming effect was larger in the correlation condition than in the no-correlation (58 ms vs. 37 ms).

There was also a significant priming effect on the error rates, $F(1, 39) = 23.14$, $MSE = 154.84$, but no effect of the correlation manipulation and no interaction between type of prime and the correlation was observed ($F < 1$ in both cases). Subjects made more errors when the target had an unrelated prime than when the target had a repetition prime.

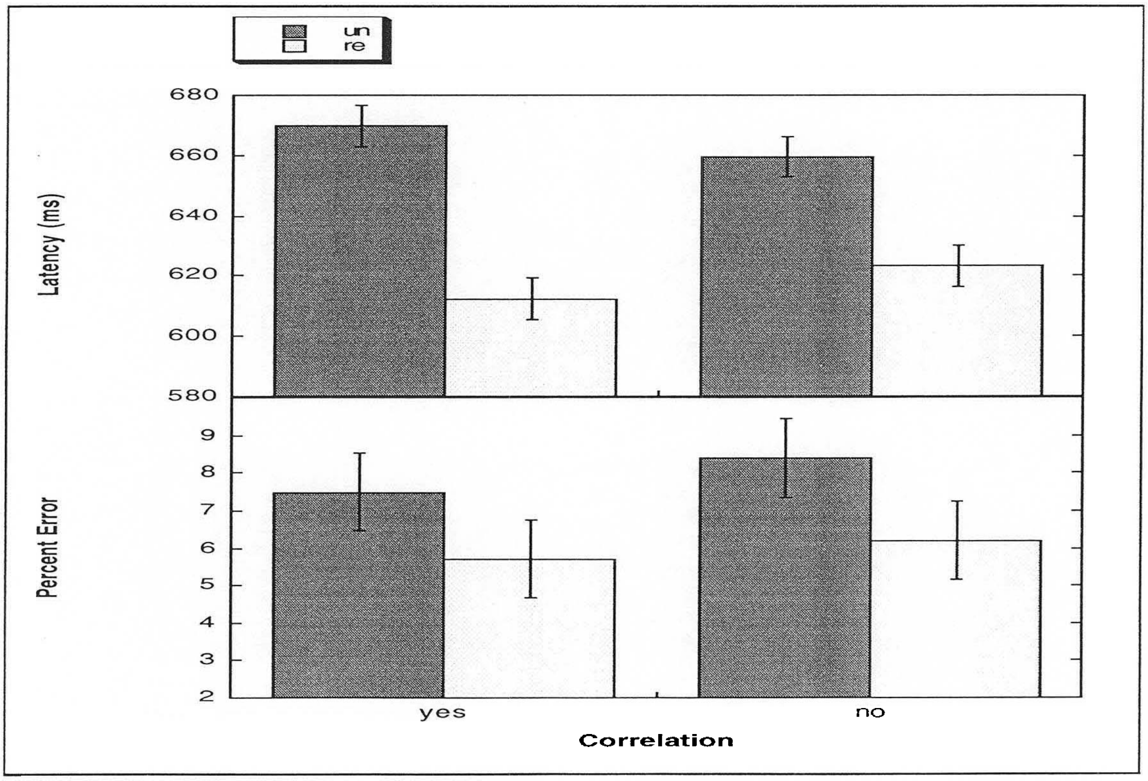


Figure 5. Mean response latencies (RT, in ms) and error rates (%E) for words in Experiment 2.

Nonword targets. The mean response latencies and error rates for nonword targets of Experiment 2 are shown in Figure 6. A two-factor within-subject ANOVA was conducted on response latencies with type of prime (repetition vs. unrelated) and correlation (correlation vs. no-correlation) as the independent variables. The effects on the error rates were examined by another ANOVA with the same independent variables.

For nonword targets, a significant priming effect on response latency was observed, F(1, 39) = 16.59, MSE = 10,774. Subjects made faster responses to nonwords when the target nonword had an unrelated prime than when it had a repetition prime. The correlation manipulation had no significant main effect on response latency, nor did it interact with priming. There were no priming effects in the analysis of the error rates.

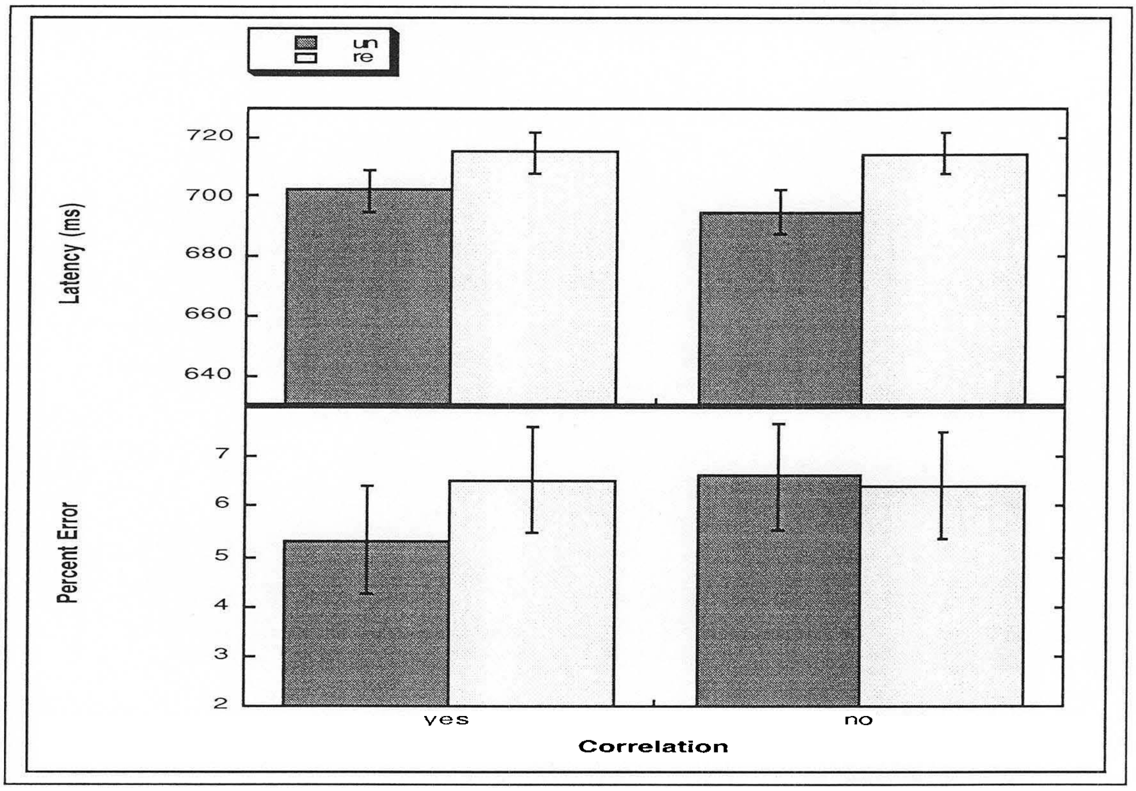


Figure 6. Mean response latencies (RT, in ms) and error rates (%E) for nonwords in Experiment 2.

Discussion

A within-subject manipulation of correlation was used for Experiment 2, in which both trials with the correlation cue and without the correlation cue were presented to subjects. A larger priming effect for trials with the correlation cue was observed. We conclude that only in the case where subjects are presented with trials with and without the correlation, allowing subjects to experience a contrast between the two conditions, will the correlation manipulation function to modulate subjects' tendency to recruit the prime for target processing. From the pattern of response latency changes, we find an increase in response latency for targets with unrelated primes and a decrease for targets with repetition primes in the correlation condition compared with the no-correlation condition. Priming in the correlation condition was larger than that in the no-correlation condition. This finding supports the episodic memory account that subjects' reliance on the prime is sensitive to the context of target presentation.

Experiment 3

In Experiment 2, we found a larger priming effect for trials with a correlation between the color of the target and type of prime than for trials without the correlation cue. It may be that subjects' response latencies to targets printed in different colors might differ from response latencies to black targets or that colored targets might be differentially effective as post-masks of primes, relative to black targets. To demonstrate that the amount of priming for colored versus black targets was not an artifact of target color, we conducted Experiment 3. Targets were printed in red, green, or black and the proportions of targets printed in red, green, or black were equal to the proportions in Experiment 2. In Experiment 3, however, the color of the target was unrelated to type of prime -- each target color appeared equally often with a repetition and with an unrelated prime. It is assumed that the length of response latencies to targets presented in red, green, and black are not different from each other and that color has no influence on the amount of priming. If such results can be found, then we can draw the conclusion that the larger amount of priming on trials with the correlation in Experiment 2 did not result from artifactual influences of the color of the target but rather was due to the correlation manipulation.

Method

Subjects. Twenty-seven students from the same source as Experiment 1 were tested in Experiment 3.

Materials and design. The same 220 low-frequency word pairs and 220 pronounceable nonword pairs used in Experiment 1 were used in Experiment 3 but a different method of counterbalancing was used. We randomly assigned each target to the repetition prime condition or the unrelated prime condition with equal numbers of targets in each condition. One member of each pair was used both as the target item and as the repetition prime. The other member of each pair, which was orthographically and semantically unrelated to the target member, served as the unrelated prime. All the subjects were given the same set of target items no matter whether it had a repetition prime or an unrelated prime. By this method of prime and target assignment, the counterbalancing problem in Experiment 2 was eliminated. The independent random assignment targets to prime conditions for each subject was used in the remaining experiments in this article. All the masks and primes were presented in black. Half of the targets were presented in black and 25% in red, and 25% in green. Each target was randomly assigned a color and there was no correlation across all the trials. Half of the targets of each color were presented with a repetition prime and the other half were presented with an unrelated prime, so there was no correlation between any target color and type of prime.

Procedure. The procedure was the same as in Experiments 1 and 2. Forty practice trials were presented in a random order, followed by 400 critical trials, which were presented to subjects in an independently determined random order. Subjects were asked to make a response to the letter string displayed on the screen whether it was a word or a nonword. They were told that the letter string might be presented in green, red or black. Subjects were asked the same set of questions as in Experiment 1 to examine conscious awareness of the prime after they completed the experiment.

Results

Prime awareness. Twenty-three of the twenty-seven subjects reported they did not see anything between the mask and the target letter string. The remaining four subjects reported something flashed between the mask and the target but they could not identify what the flash was and nobody reported noticing any relationship between the flash and the target.

Word targets. Figure 7 shows the mean response latencies and error rates for word targets. A two-factor within-subject ANOVA was conducted with type of prime (repetition vs. unrelated) and the color of the target (red vs. green vs. black) as the independent variables and response latency as the dependent variable. The same ANOVA was conducted with error rate as the dependent variable.

For word targets, the color of the target had a reliable main effect, $F(2, 52) = 3.65$, $MSE = 1,707$. Post-hoc tests indicated that subjects made slower responses to targets printed in green than targets printed in red or in black. Response latencies were not significantly different between targets printed in red and in black. There was a reliable priming effect with repetition primes leading to shorter response latencies than unrelated primes, $F(1, 26) = 131.36$, $MSE = 77{,}137$. The color of the target did not interact with type of prime, $F < 1$. Masked repetition priming was the same no matter what was the color of the target (45.0 ms vs. 42.6 ms vs. 43.3 ms). The analysis with error rate as the dependent variable showed no significant effects.

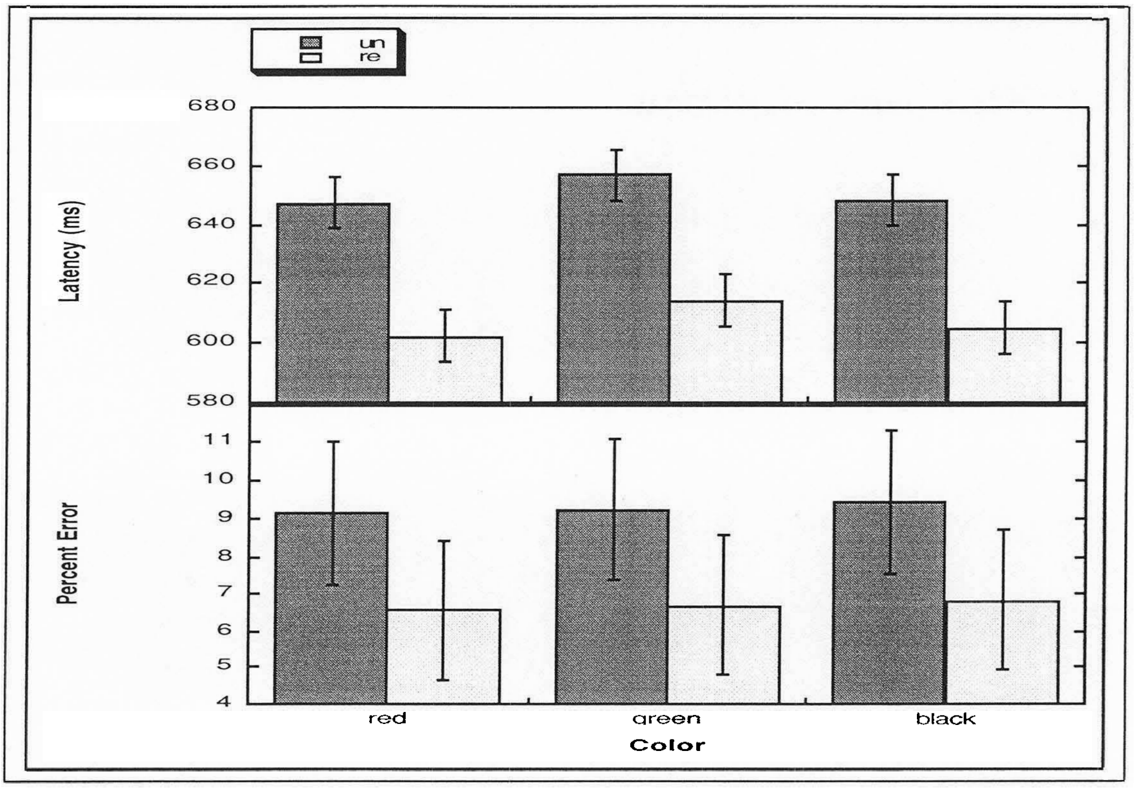


Figure 7. Mean response latencies (RT, in ms) and error rates (%E) for words in Experiment 3.

Nonword targets. Figure 8 shows the mean response latencies and error rates of nonword targets. A two-factor within-subject ANOVA was conducted with type of prime (repetition vs. unrelated) and the color of the target (red vs. green vs. black) as the independent variables and response latency as the dependent variable. Another ANOVA was conducted with the same independent variables and with error rate as the dependent variable. In the analysis of response latencies, there were no significant effects. The analysis with error rate as the dependent variable also showed no significant effects.

Unlike Experiments 1 and 2, there were no significant priming effects for nonwords. In general, masked priming of nonwords in the lexical decision task tends to be inconsistent and susceptible to changes in the extent to which subjects rely on feelings of processing fluency to make their decisions. Repetition priming may facilitate or interfere with responses to nonword targets in the lexical decision task (Bodner & Masson, 1997, 2001; Zeelenberg, Wagenakers, & Shiffrin, 2004).

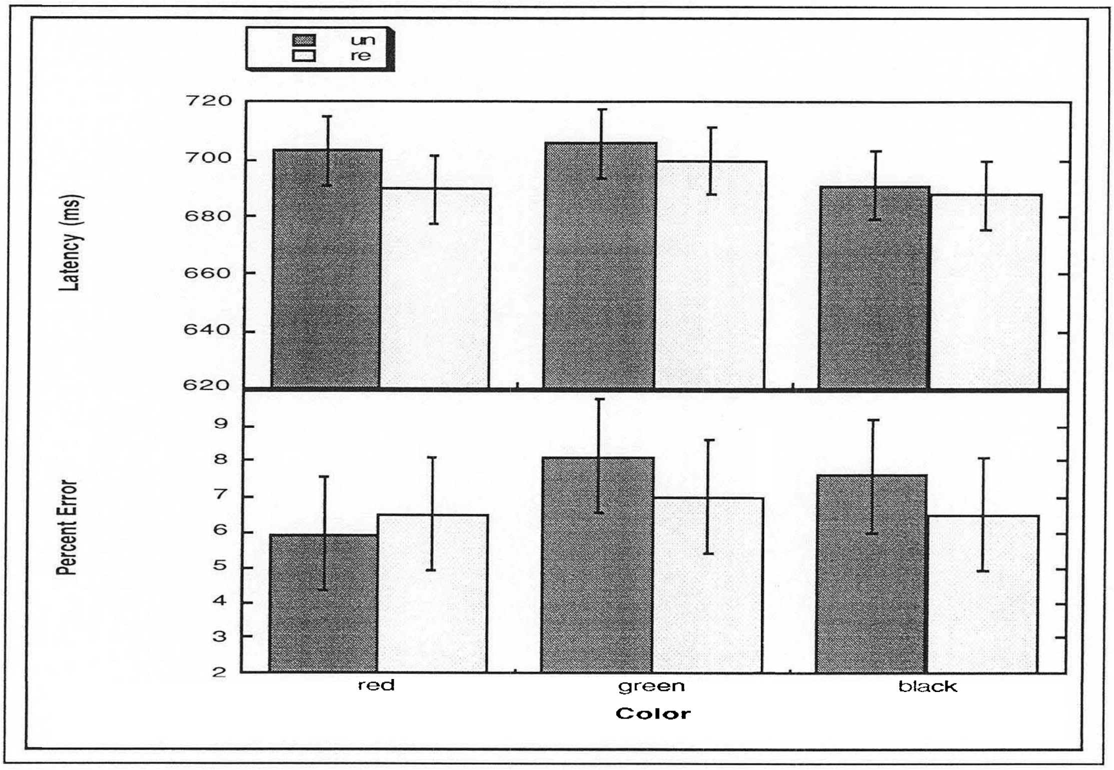


Figure 8. Mean response latencies (RT, in ms) and error rates (%E) for nonwords in Experiment 3.

Discussion

The results of Experiment 3 provide evidence that the amount of priming is unaffected by the color of the target when no correlation between type of prime and target color is present. Although green targets led to somewhat longer latencies overall, there was no indication that this tendency interacted with the influence of masked primes. The suggestion that the larger amount of priming in the correlation condition of Experiment 2 may have been due to artifacts of target color can be refuted.

Experiment 4

Experiment 2 provided evidence that the correlation between target color and type of prime increases the priming effect compared with the no-correlation condition. Experiment 3 showed that the larger priming in the correlation condition is not induced simply by the target color. However, there was a counterbalancing problem in Experiment 2 and the observed correlation manipulation effect might be suspect because different targets were used for repetition versus unrelated prime trials. It might be claimed that the larger priming in the correlation condition was induced by different response latencies to this set of words but not by the correlation between the target color and type of prime. The purpose of Experiment 4 was to replicate the correlation manipulation effect without the counterbalancing problem in Experiment 2. If a larger amount of priming in the correlation condition than the no-correlation condition is found, those results would support the episodic memory account of masked repetition priming.

Method

Subjects. Fifty-one students from the same source as Experiment 1 were tested in Experiment 4. Fifteen students were tested with a program error so those 15 subjects' data were excluded and 36 subjects' data were used for analysis.

Materials and design. The same 220 low-frequency word pairs and 220 pronounceable nonword pairs used in Experiments 1-3 were used in Experiment 4. For each subject, targets were randomly assigned to the repetition prime condition or the unrelated prime condition with equal numbers of targets in each condition in the same way as in Experiment 3.

In Experiment 4, half of the trials were in the no-correlation condition and the targets were always presented in black. The other half of the trials were in the correlation condition and the target color was dependent on prime type. All the masks and primes in the two conditions were presented in black. Assignment of red or green as the target color for repetition versus unrelated prime conditions was counterbalanced across subjects. Equal numbers of word and nonword targets were assigned to the repetition and unrelated prime conditions, and to the correlation and no-correlation conditions.

Procedure. The procedure was the same as in Experiment 1. The 400 critical trials were presented to subjects in an independently determined random order after forty randomly presented practice trials. Subjects' task was to make a response to the target whether it was a word or a nonword. They were not told of the possible correlation between the target color and type of prime. The same three questions as in Experiment 1 investigating subjects' prime awareness were asked to subjects after they completed the experiment.

Results

Prime awareness. Thirty-two of the 36 subjects of Experiment 4 reported that they did not see anything between the mask and the target letter string. Four subjects reported that there was a flash between the mask and the target but they could not recognize which word or nonword the flash was and nobody reported noticing any relationship between the flash and the target.

Word targets. Figure 9 illustrates the mean response latencies and error rates of Experiment 4. A two-factor within-subject ANOVA with type of prime (repetition vs. unrelated) and the correlation (correlation vs. no-correlation) as the independent variables and response latency as the dependent variable was conducted. A similar analysis of error rates was conducted.

For word targets, a significant priming effect on response latency was found in Experiment 4, $F(1, 35) = 121.833$, $MSE = 61{,}380$. Subjects made faster responses to word targets with a repetition prime than with an unrelated prime. The correlation manipulation had no effect in the analysis of response latencies and there was no type of prime by correlation manipulation interaction, $F < 1$. The amount of priming in the correlation condition was not significantly larger than in the no-correlation condition (44 ms vs. 39 ms). Based on the size of the priming by correlation condition interaction in Experiment 2, the estimated power to detect an interaction of that size in Experiment 4 was .83.

The pattern of the results in the error rate was as follows. There was a reliable priming effect, $F(1, 35) = 9.342$, $MSE = 158.131$. Subjects made more errors for targets with an unrelated prime than targets with a repetition prime. Correlation had no effect on error rate, $F < 1$. A marginally significant interaction between type of prime and correlation manipulation was observed, $F(1, 35) = 3.545$, $MSE = 27.475$, $p < .07$. The priming effect on error rate in the correlation condition was somewhat larger than that in the no-correlation condition (3.0% vs. 1.2%). Post-hoc comparisons showed that in the correlation condition, there was a reliable priming effect on error rate, $F(1, 35) = 20.477$, $MSE = 158.717$. Subjects made fewer errors with a repetition prime than with an unrelated prime if the target color was dependent on what type of prime the target had. In the no-correlation condition, there was only a marginally significant effect of priming on error rate, $F(1, 35) = 3.469$, $MSE = 26.889$, $p < .08$. Subjects tended to make fewer errors to word targets with a repetition prime than with an unrelated prime when the target color was unrelated to type of prime. The correlation manipulation did cause a more obvious priming effect but not enough to reach the standard significance level. With a medium effect size, the power to detect the type of prime by correlation manipulation on error rate was .71.

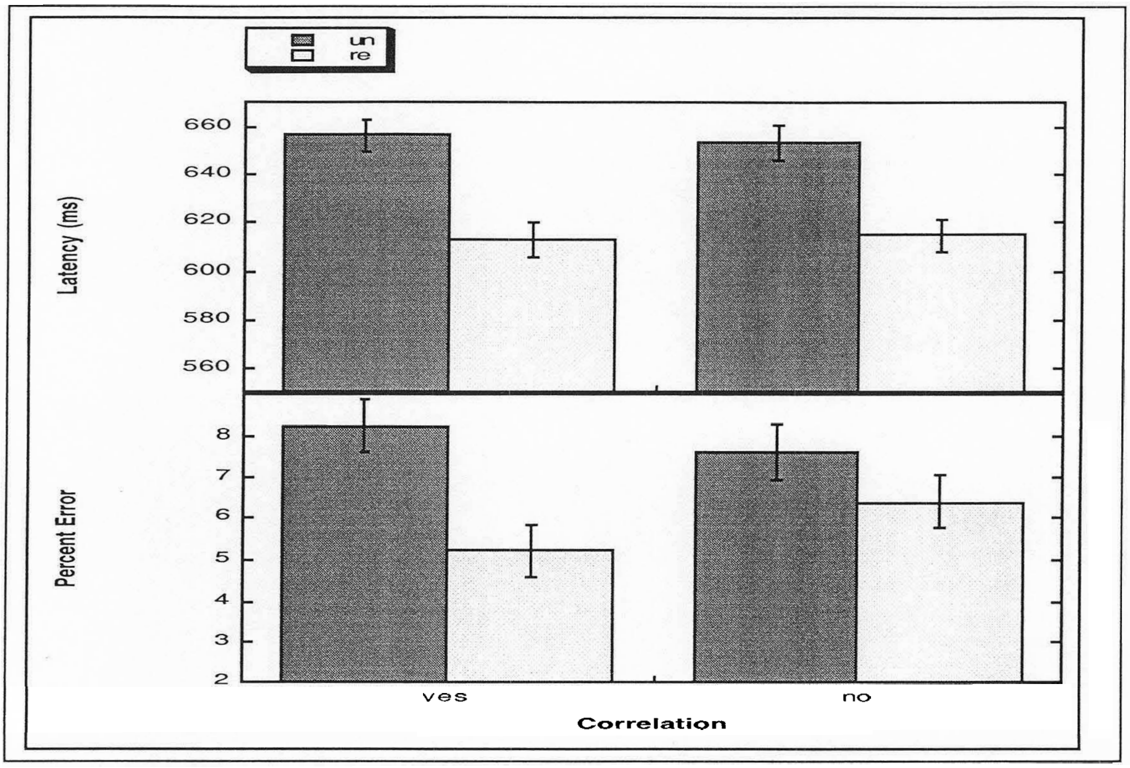


Figure 9. Mean response latencies (RT, in ms) and error rates (%E) for words in Experiment 4.

Nonword targets. Figure 10 shows the mean response latencies and error rates for nonword targets of Experiment 4. A two-factor within-subject ANOVA with type of prime (repetition vs. unrelated) and correlation (correlation vs. no-correlation) as the independent variables and response latencies as the dependent variable was conducted for nonword targets. Another ANOVA with the same independent variables and with error rate as the dependent variable was also conducted.

There was no reliable priming effect on response latencies for nonword targets, $F < 1$. Subjects' response latencies to nonword targets with a repetition prime and with an unrelated prime were not significantly different with each other. The correlation manipulation had a marginally significant effect, $F(1, 35) = 3.036$, $MSE = 1,863$. Subjects tended to make slower responses to targets presented in the correlation condition than to targets presented in the no-correlation condition. The type of prime did not interact with the correlation manipulation, F < 1. The analysis of the error rates showed no main effects of type of prime or correlation manipulation, or interaction.

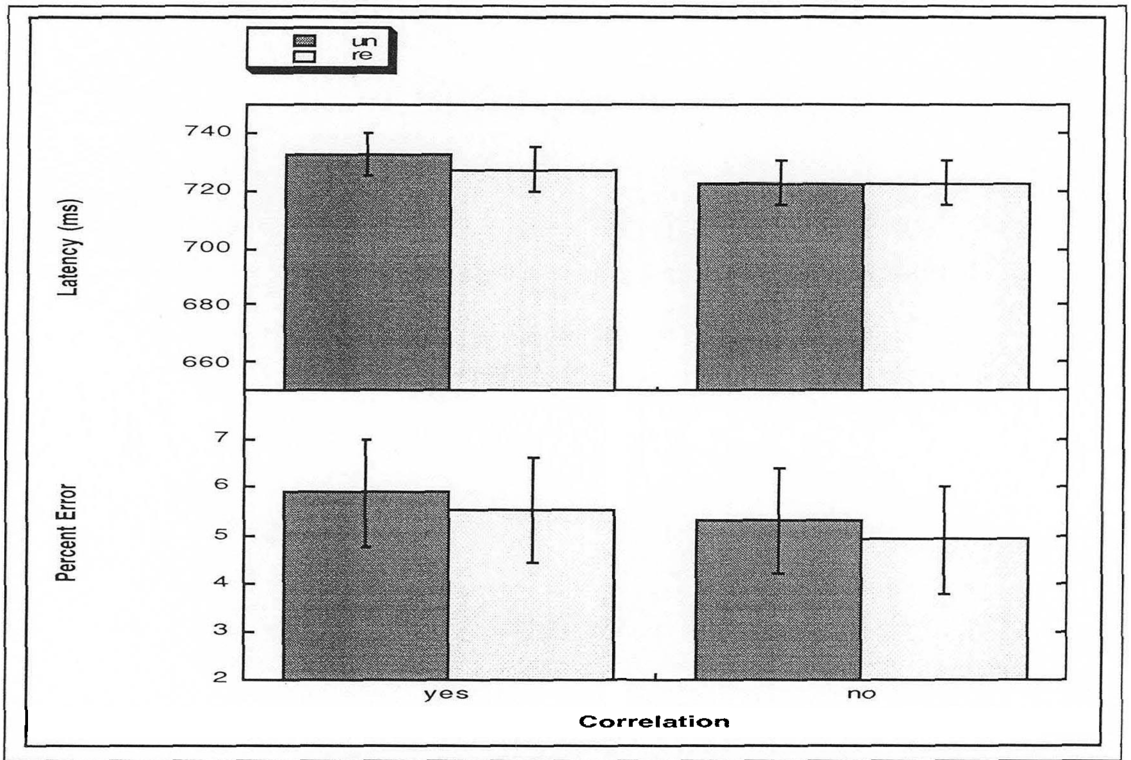


Figure 10. Mean response latencies (RT, in ms) and error rates (%E) for nonwords in Experiment 4.

Discussion

The influence of correlation cue on repetition priming was not replicated in Experiment 4. With target color as the post-prime cue, subjects showed almost equal amounts of priming on response latency in the correlation condition and in the no-correlation condition. However, the correlation manipulation did have some influence on the amount of priming in the error rate analysis. The correlation between target color and type of prime resulted in a relatively larger priming effect on error rate compared with the trials in the no-correlation condition. In the correlation condition, target color is an indication of type of prime and causes subjects to be more likely to rely on the prime for target processing. Consequently, subjects will get more facilitation from a repetition prime and more interference from an unrelated prime, so a relatively larger priming effect can be observed. When there is no such a cue that follows the prime, subjects show less reliance on the prime. However, the correlation manipulation was not found to affect response latency in this experiment. Further evidence, therefore, is needed to establish the correlation manipulation effect and to support the episodic memory account.

Experiment 5

Since Experiment 4 failed to replicate the correlation manipulation effect on response latency, Experiment 5 was conducted in an attempt to replicate the correlation manipulation effect. Experiment 5 was the replication of Experiment 4 with the post-prime cue of the target color. One possible reason for the failure to find a correlation manipulation effect on response latency is that the word targets in Experiment 4 were low-frequency words and there was a large variation in response latencies. High-frequency words instead of low-frequency words were used as word targets for Experiment 5 and more stable response latencies were expected.

Method

Subjects. Thirty-nine students from the same source as Experiment 1 were tested in Experiment 5. Nine subjects were tested with a program error so their data were excluded. Thirty subjects' data were used for analysis.

Materials and design. The difference in materials for Experiment 5 relative to the previous experiments was that high-frequency words instead of low-frequency words were used as word targets in this experiment. Two hundred and twenty pairs of high-frequency words with a familiarity rating between 400 and 700 were selected for Experiments 5. The two words in each high-frequency word pair were of the same length. All these high-frequency words were four- to six-letter words. These 220 pairs of high-frequency words and the same 220 pairs of nonwords as Experiment 3 were used to create practice trials and critical trials for Experiment 5. Half of the trials were in the repetition condition and the other half were in the unrelated prime condition. One item in each pair was used as both the target and the repetition prime and the other item was used as the unrelated prime. The correlation manipulation of Experiment 5 was the same as in Experiment 4, where the correlation was between the target color and type of prime. Half of the trials were in the correlation condition and the other half were in the no-correlation condition. Assignment of each target and the color of the target to prime condition was arranged in the same way as in Experiment 4.

Procedure. The procedure was the same as in Experiment 1. Forty practice trials were presented randomly, followed by 400 critical trials presented to subjects in an independently determined random order. Subjects were instructed to classify the target letter string as a word or a nonword. They were not told of the possible correlation between the target color and type of prime. The same three questions as in Experiment 1 investigating subjects' prime awareness were asked to subjects after they completed the experiment.

Results

Prime awareness. Twenty-five of the 30 subjects of Experiment 5 reported they did not see anything between the mask and the target letter string. Five subjects of Experiment 5 reported that something flashed between the mask and the target but they could not recognize which word or nonword the flash was and nobody reported noticing any relationship between the flash and the target.

Word targets. The mean response latencies and error rates of word targets of Experiments 5 are illustrated in Figure 11. Two two-factor within-subject ANOVAs with type of prime (repetition vs. unrelated) and the correlation (correlation vs. no-correlation) as the independent variables and response latency and error rate as the dependent variables were conducted separately.

There was a reliable priming effect on response latencies of Experiments 5, $F(1, 29) = 110.347$, $MSE = 41{,}925$. Subjects had shorter response latencies to targets with a repetition prime than with an unrelated prime. The correlation manipulation had no effect on response latencies and did not interact with priming effect, $F < 1$. The amount of priming in the correlation condition and in the no-correlation condition was nearly equal (39 ms vs. 36 ms). Based on the size of the interaction in Experiment 2, the estimate of power for this experiment to detect an interaction was .86.

The analysis of error rate also found a reliable priming effect, $F(1, 29) = 21.659$, $MSE = 93.633$. Subjects made more errors to targets with an unrelated prime than with a repetition prime. There was no effect of the correlation manipulation and no interaction between type of prime and correlation manipulation, $F < 1$. With a medium effect size, the estimated power to detect the type of prime by correlation manipulation interaction on error rate was smaller than .47.

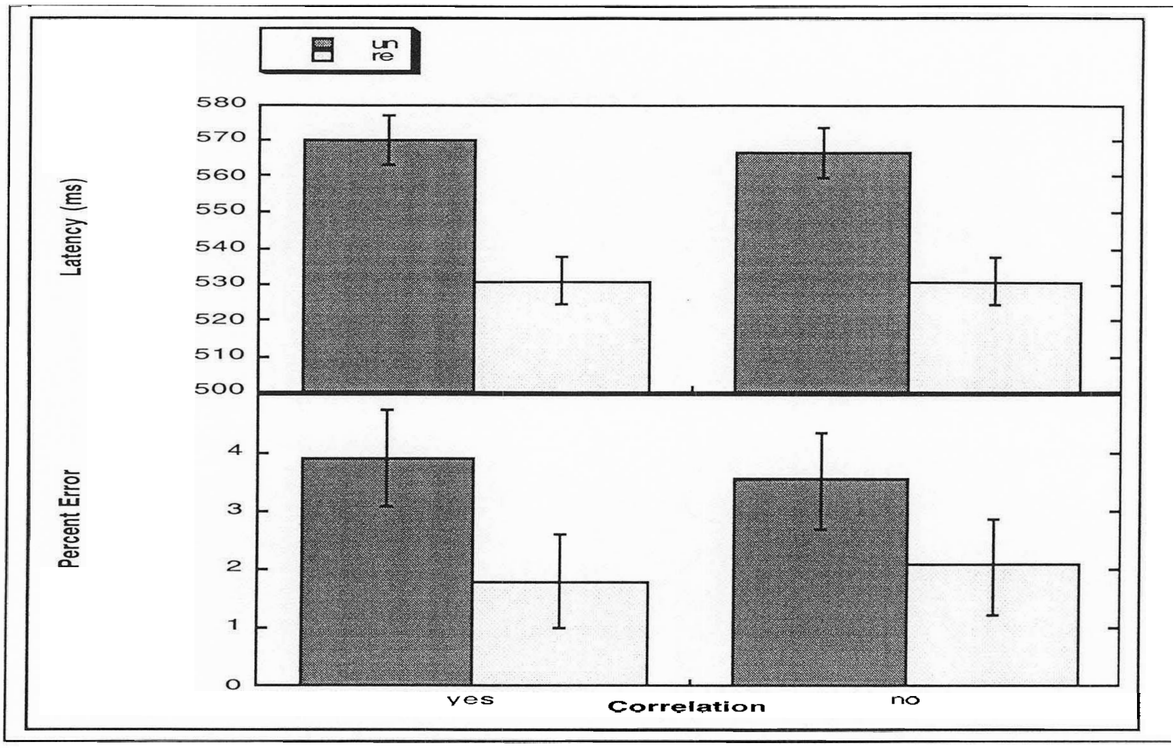


Figure 11. Mean response latencies (RT, in ms) and error rates (%E) for words in Experiment 5.

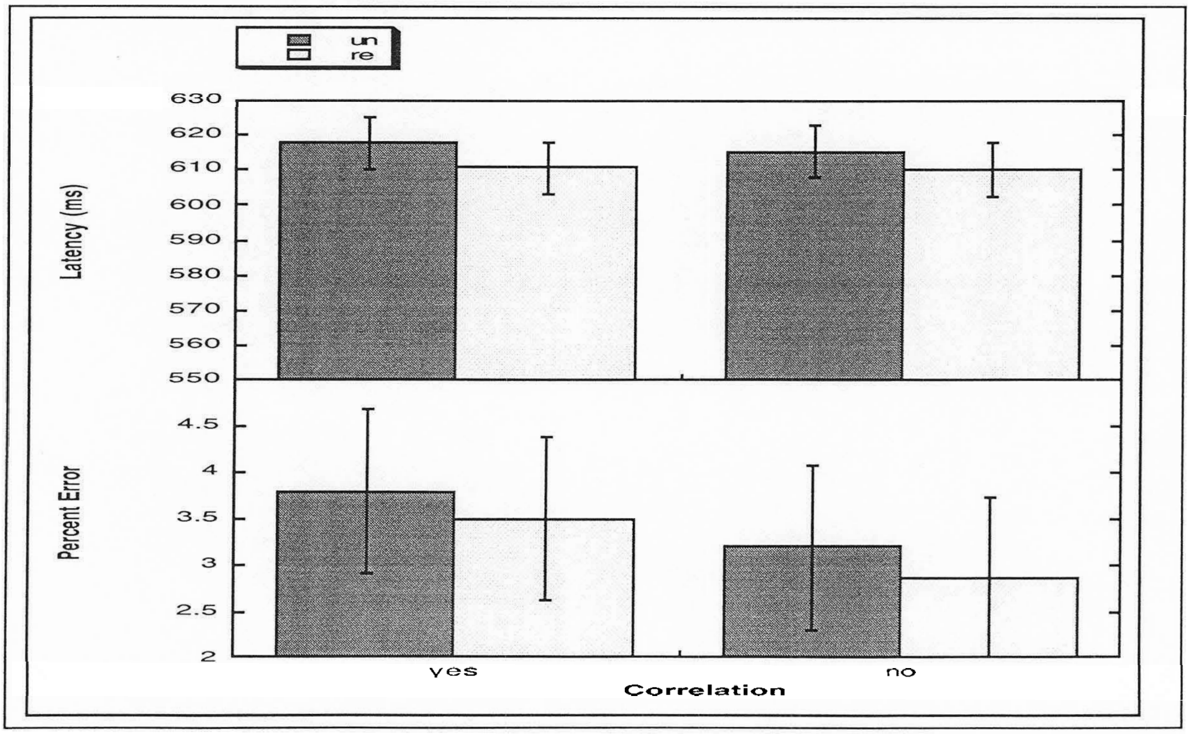


Figure 12. Mean response latencies (RT, in ms) and error rates (%E) for nonwords in Experiment 5.

Nonword targets. The mean response latencies and error rates for nonword targets in Experiments 5 are shown in Figure 12. A two-factor within-subject ANOVA with type of prime (repetition vs. unrelated) and correlation (correlation vs. no-correlation) as the independent variables and response latency as the dependent variable was conducted. Another ANOVA was conducted with error rate as the dependent variable.

No reliable priming effect on response latency was found for nonword targets. There was no effect of the correlation manipulation. No priming effect on error rate was found either. However, the correlation manipulation showed a marginally significant effect on error rate, $F(1, 29) = 3.765$, $MSE = 12.288$, $p < .07$. The error rate in the correlation condition tended to be higher than the error rate in the no-correlation condition.

Discussion

A reliable priming effect was found to occur on both response latency and error rate with high-frequency words but the expected larger priming effect in the correlation condition was not observed. The amount of priming was very similar between the correlation condition and no-correlation condition. Subjects process a high-frequency target with less reliance on a prime than when they process a low-frequency target and obtain a smaller priming effect for high-frequency words (Bodner & Masson, 1997, 2000). Therefore, the correlation manipulation may not have as strong an influence on high-frequency words as it does on low-frequency words. This may be the reason for the absence of correlation manipulation effect in this experiment.

Experiment 6

One previous experiment has found the correlation manipulation effect but this effect was not consistently observed in the replication experiments. In Experiment 6 an additional attempt to replicate the correlation effect was made by manipulating correlation and repetition proportion (RP) at the same time. There has been evidence that high RP can increase subjects' recruitment of the prime for the processing of the target and results in a larger priming (e.g., Bodner & Masson, 2001). A question addressed in Experiment 6 was whether the correlation manipulation or the RP manipulation is stronger. In this experiment, the correlation manipulation and the RP manipulation were set up to work in opposition to one another. In the correlation condition, in addition to setting up a correlation between the color of the target and type of prime, an RP of .5 was used (50% repetition prime trials and 50% unrelated prime trials). In the no-correlation condition, a higher RP of .8 was used. Both the correlation manipulation and the RP manipulated were carried out within subjects. In this way, it was possible to determine whether correlation is a stronger cue than RP and whether the correlation effect is strong enough to overcome the influence of RP.

It was expected that both correlation and a high RP could increase priming. With a relatively low RP assigned to the correlation condition and a high RP assigned to the no-correlation condition, a trade-off effect was expected. In previous research showing the RP effect, RP was manipulated between subjects. In present within-subject manipulation, RP may not be as salient as the correlation manipulation and the influence of high RP on target processing may be counteracted by the benefit from the correlation manipulation. If so, the advantage of a higher RP may be overridden by the lack of correlation in the no-correlation condition. Therefore, when both the correlation and the RP are manipulated within subjects, the effect of RP may not be found and only the correlation manipulation effect may be observed. If the RP effect is found even when it is manipulated within subjects, we expected that an equal amount of priming in the correlation and no-correlation conditions or a larger amount of priming in the no-correlation (.8 RP) condition would be found, dependent how strong is the RP cue.

Method

Subjects. Twenty-eight students from the same source as Experiment 1 were tested in Experiment 6.

Materials and design. For Experiment 6, the same 220 low-frequency word pairs and 220 pronounceable nonword pairs from Experiment 3 were used to construct practice trials and critical trials. Half of the trials were in the correlation condition and the other half were in the no-correlation condition. For the trials in the correlation condition, 50% of targets were paired with a repetition prime and the other 50% were paired with an unrelated prime. The color of the target was dependent on whether it had a repetition prime or an unrelated prime. The assignment of color (red or green) to prime condition was counterbalanced across subjects. For the trials in the no-correlation condition, 80% of the targets had a repetition prime and 20% had an unrelated prime. All the targets were presented in black and there was no correlation. Thus the colored targets had .5 RP and the black targets had a higher RP of .8. The assignment of each target to prime condition was randomly determined across subjects.

Procedure. The procedure was the same as in Experiment 1. Forty practice trials were presented in a random order. The critical trials were presented to subjects in an independently determined random order following the practice trials. Subjects were asked to classify the letter string as a word or a nonword as quickly and as accurately as possible. There was no information about the correlation manipulation or the RP manipulation in the instructions. The same questions as in Experiment 1 were asked to examine the prime awareness after subjects completed the experiment.

Results

Prime awareness. Twenty-five of twenty-eight subjects of Experiment 6 reported they did not see anything between the mask and the target letter string. Three subjects in this experiment reported that there was a flash between the mask and the target but they could not identify what the flash was and nobody reported noticing any relationship between the flash and the target.

Word targets. Figure 13 illustrates the mean response latencies and error rates of word targets in Experiments 6. A two-factor within-subject ANOVA was conducted with type of prime (repetition vs. unrelated) and the correlation (correlation and .5 RP vs. no-correlation and .8 RP) as the independent variables and response latency as the dependent variable. Another ANOVA was conducted with the same independent variables and error rate as the dependent variable.

A significant priming effect was observed on response latency, $F(1, 27) = 144.82$. Subjects made faster responses to targets with a repetition prime than with an unrelated prime. Correlation had no significant main effect. The priming by correlation manipulation interaction was significant, $F(1, 27) = 6.81$, $MSE = 2{,}911$. A larger priming effect was found in the correlation and .5 RP condition than the no-correlation and .8 RP condition (57 ms vs. 37 ms). Even though RP was higher in the no-correlation condition than in the correlation condition, the RP manipulation did not work to increase the amount of priming.

There was also a reliable priming effect on the error rates, $F(1, 27) = 9.01$, $MSE =$

232.01. Subjects made fewer errors when responding to targets with a repetition prime than to targets with an unrelated prime. The correlation manipulation had no significant effect on error rate and there was no interaction between type of prime and the correlation manipulation, F < 1

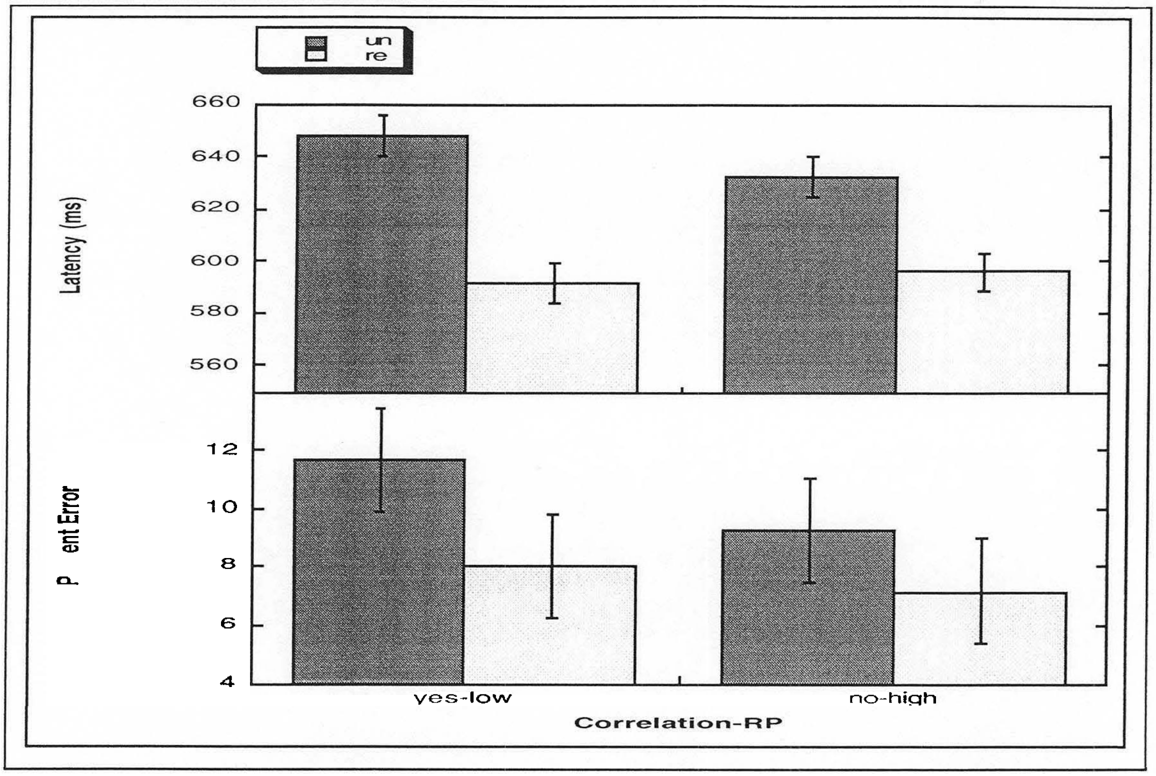


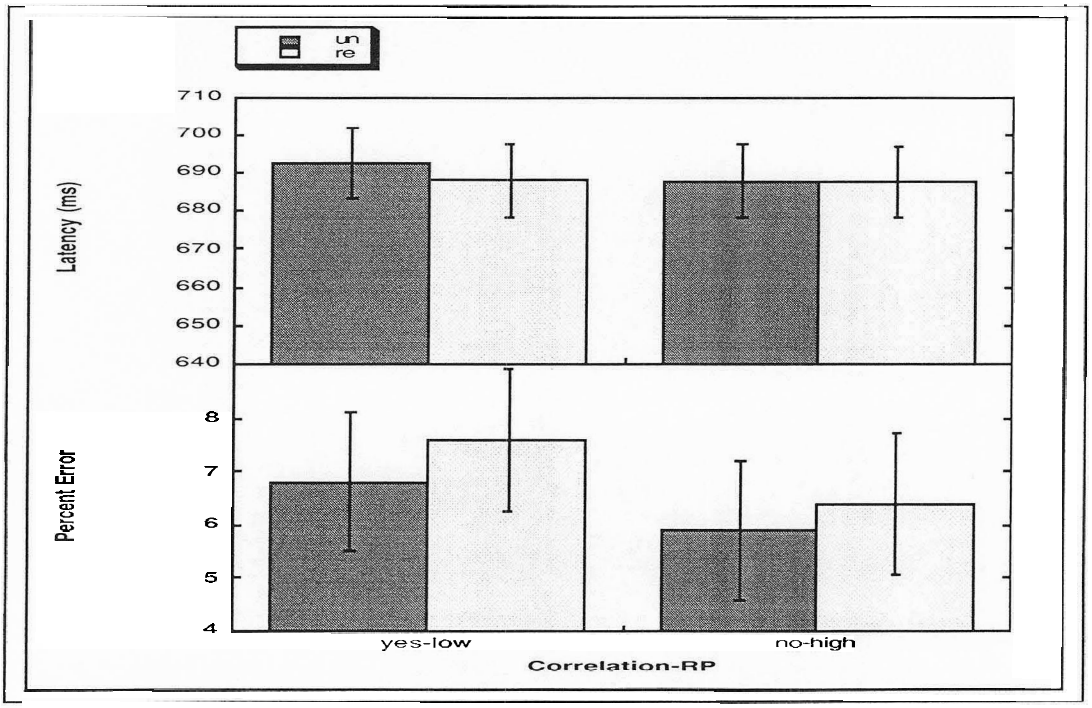
Figure 13. Mean response latencies (RT, in ms) and error rates (%E) for words in Experiment 6.

Nonword targets. Mean response latencies and error rates of nonword targets are shown in Figure 14. A two-factor within-subject ANOVA was conducted with type of prime (repetition vs. unrelated) and correlation manipulation (correlation and .5 RP vs. no-correlation and .8 RP) as the independent variables and response latency as the dependent variable. A similar analysis of error rate was also conducted.

There was no priming effect, correlation effect, or interaction in the analysis of response latencies or on error rates.

Combined analysis. Experiments 2 and 6 showed a correlation effect. The data of these two experiments were combined to investigate how the color correlation influenced response latencies and then resulted in a difference in the amount of priming between correlation and no-correlation conditions.

A two-factor within subject ANOVA was conducted on the combined data with type of prime (repetition vs. unrelated) and correlation manipulation (correlation vs. no-correlation) as the independent variables and response latency and error rate as the dependent variables. The priming effect on response latencies was reliable, $F(1, 67) = 294.436$, $MSE = 149{,}555$. The correlation manipulation had no effect on response latency, $F < 1$. There was a significant type of prime by correlation interaction, $F(1, 67) = 15.66$, $MSE = 7{,}351$. The amount of priming on trials in the correlation condition was significantly larger than in the no-correlation condition. A priming effect was found to occur to the error rates, $F(1, 67) = 25.781$, $MSE = 373.184$ but the correlation had no effect and it did not interact with priming, $F < 1$ in both cases.



igure 14. Mean response latencies (RT, in ms) and error rates (%E) for nonwords in Experiment 6.

To investigate the pattern of response latency change due to the correlation manipulation, response latencies were compared between the correlation and no-correlation conditions, separately for each type of prime. These comparisons were expected to show whether the correlation cue served to reduce response latency to repetition primed targets, increase latency in the unrelated prime condition, or both.

The correlation manipulation had a significant effect on response latency to word targets with an unrelated prime, $F(1, 67) = 11.94$, $MSE = 5{,}313$. Subjects made slower responses to targets with an unrelated prime when there was a correlation between type of prime and target color than when there was no correlation (661 ms vs. 648 ms). The correlation also showed a significant effect on response latencies to word targets with a repetition prime, $F(1, 67) = 5.73$, $MSE = 2{,}339$. Response latencies to word targets with a repetition prime were shorter in the correlation condition than in the no-correlation condition (604 ms vs. 612 ms). Thus, the correlation led to increased priming because of reduced latency with repetition primes and increased latency with unrelated primes.

To examine whether the correlation manipulation effect appeared immediately or accumulated more slowly across the experimental session, priming in the correlation and no-correlation condition was examined across the whole test session. The trials were divided into four blocks with 100 trials in each block and priming across the four blocks was computed. This analysis included the combined data of Experiments 2 and 6. A three-way ANOVA was conducted with the block as the third independent variable.

A reliable priming effect was observed, $F(1, 67) = 273.582$, $MSE = 588{,}690$. Block had a significant effect on response latency, $F(3, 67) = 5.653$, $MSE = 20{,}471$. Response latencies got longer in the late part of the test session compared with the early part. The correlation manipulation had no effect, $F < 1$. The priming by correlation manipulation interaction was also observed, $F(1, 67) = 4.74$, $MSE = 30{,}855$. The priming effect in the correlation condition was larger than that in the no-correlation condition. There was no significant three-way interaction, indicating that the amount of priming was almost equal across the four blocks and the influence of the correlation manipulation was equally strong across blocks.

To determine whether the correlation manipulation effect functions to increase priming in the correlation condition or decrease priming in the no-correlation condition, priming in the correlation or the no-correlation condition in the two experiments showing the correlation manipulation effect (Experiments 2 and 6) was compared to priming found in the control experiment (Experiment 3). The data were collapsed across target color (red, green, and black) in Experiment 3. Experiment number was added as an independent variable. Two two-way ANOVAs, one for each correlation condition were conducted with experiment number and type of prime as the independent variables and response latency as the dependent variable.

In the analysis that compared priming in the correlation condition of Experiments 2 and

6 to priming in the control experiment, a reliable priming effect was found, F(1, 93) = 257.792, MSE = 98,449. Experiment had no effect on response latency, F < 1. There was a significant interaction between priming and experiment, F(1, 93) = 4.716, MSE = 1,801. The amount of priming in the correlation condition in Experiments 2 and 6 was larger than in Experiment 3 (57 ms vs. 44 ms).

In the analysis that compared priming in the no-correlation condition of Experiments 2 and 6 to priming in the control experiment, a reliable priming effect was found, F(1, 93) = 143.782, MSE = 62,094. Experiment had no effect on response latency, F < 1. The priming by experiment interaction was not significant, F(1, 93) = 1.142, MSE = 492.9. The amount of priming in the no-correlation condition in Experiments 2 and 6 was slightly smaller than in Experiment 3, but the difference was not significant (37 ms vs. 44 ms).

Discussion

The results of Experiment 6 confirmed the expectation that there is a larger priming effect in the condition where the target color is dependent on what type of prime the target has compared with the condition where the target color is unrelated to type of prime. The difference between Experiment 6 and Experiment 2 is that correlation and RP were manipulated together. Moreover, there was no counterbalancing problem in Experiment 6. The finding was that when RP in the correlation condition and no-correlation condition was .5 versus .8, respectively, high RP did not increase the amount of priming to the same degree as correlation did, even though RP was only .5 in the correlation condition. From this result it can be concluded that the influence of correlation can override the RP effect, at least when both of these two contextual factors are manipulated within subjects.

The combination of Experiments 2 and 6 shows how response latencies are modulated by correlation cues. In the correlation condition, a decrease in response latency to targets with a repetition prime and an increase in response latency to targets with an unrelated prime were found. That pattern supports the assumption that target color is a useful cue for type of prime in the correlation condition. It makes subjects more likely to rely on the prime for target processing.

Another finding is that the correlation influences the amount of the priming effect from the earliest trials and lasts through the whole test session. When the trials were divided into four blocks, the larger priming in the correlation condition relative to the no-correlation condition was observed across the four blocks. Although the response latencies in the fourth block were longer than those in the previous three blocks, the amount of priming was not changing. The longer response latencies in the fourth block may have been due to fatigue. The primary conclusion from this analysis was that the influence of the correlation cues begins within the first block of critical trials.

However, the correlation effect was not consistently observed across the experiments. The color correlation caused influence on response latency in Experiments 2 and 6 but this effect was not observed in Experiments 4 and 5. Comparing the amount of priming between the correlation and no-correlation conditions across these experiments, priming in the correlation condition of the two experiments showing the correlation effect (57 ms.) was larger than that in the control experiment, Experiment 3 (44 ms). Priming in the no-correlation condition of the two experiments showing the correlation manipulation effect (37 ms.) did not differ much from that in the control experiment (44 ms). These results suggest that correlation cues increase subjects' reliance on primes, consistent with the episodic account.

Experiment 7

A larger masked repetition priming effect was observed when there was a correlation between the color of the target and type of prime and this effect was stronger than the RP effect. The purpose of Experiment 7 was to examine whether only the few preceding trials causes the correlation influence or all the trials across the whole test session attribute to the correlation effect. In this experiment, the trials were divided into different blocks, with the correlation cues present or absent in different blocks. The blocks of trials with correlation cues and blocks of trials without the correlation cues were presented to subjects alternately. Previous experiments have provided evidence that only when there is a contrast between trials with the correlation and trials without the correlation, will the correlation increase subjects' reliance on primes. When the trials with and without correlation were presented to subjects in separate blocks in this experiment, the contrast existed only when one type of block ended and the other type of block began. In late part of the block, subjects would have been given many trials of a certain type so there was no contrast to be experienced during those trials. It was expected that early in a block of correlation trials, priming might be larger, due to the contrast with the preceding block of no-correlation trials. Priming might be reduced in later trials in a correlation block because no contrasting no-correlation trials would have appeared. Alternatively, priming might be smaller early in a block of no-correlation trials because of the contrast with the preceding block of correlation trials. Over the course of the block, however, priming might recover to a larger size because contrasting correlation trials would not have occurred recently.

Method

Subjects. Forty-eight students from the same source as Experiment 1 were tested in Experiment 7.

Materials and design. The same 200 high frequency words and 200 nonwords from Experiment 5 were used as practice trials and critical trials. The 400 word pairs and nonword pairs were divided into ten blocks with twenty word pairs and twenty nonword pairs in each block randomly. For five blocks of trials, there was a correlation between the color of the target and type of prime. Whether the target was printed in red or in green was dependent on what type of prime it had. The assignment of color to prime condition was counterbalanced across subjects. For the other five blocks of trials, there was no correlation and all the targets were presented in black. The blocks with the correlation or without the correlation were presented to subjects one by one alternately. For half of the subjects, the first block presented to them was a block of trials with the correlation. For the other half of the subjects, the first block presented was a block of trials without the correlation. For all 40 trials within a block, half were in the repetition prime condition and the other half were in the unrelated prime condition. The assignment of each target to prime condition was randomly determined across subjects in the same way as in Experiment 3. There were eight practice trials with four trials in the correlation condition and four trials in the no-correlation condition.

Procedure. The procedure was the same as in Experiment 1. Eight practice trials were presented to subjects in a random order. Then ten blocks totaling400 critical trials were presented. The 40 trials within each block were presented in an independently determined random order. Subjects were asked to classify letter string as a word or a nonword as quickly and as accurately as possible. There was a break after each block. Subjects could press any button to stop the break and continue the experiment. The same three questions as in Experiment 1 were asked to examine the awareness of the prime after subjects completed the experiment.

Results

Prime awareness. Forty-three subjects reported they saw nothing between the mask and the target letter string. Five subjects reported they saw a flash between the presentation of the mask and the target but they could not recognize which word or nonword the flash was and nobody reported noticing any relationship between the flash and the target.

Word targets. Mean response latencies and error rates for word targets are shown in Figure 15. A two-way within-subject ANOVA was conducted with type of prime (repetition vs. unrelated) and the correlation (correlation vs. no-correlation) as the independent variables and response latency as the dependent variable. Another ANOVA was conducted with the same independent variables and error rate as the dependent variable.

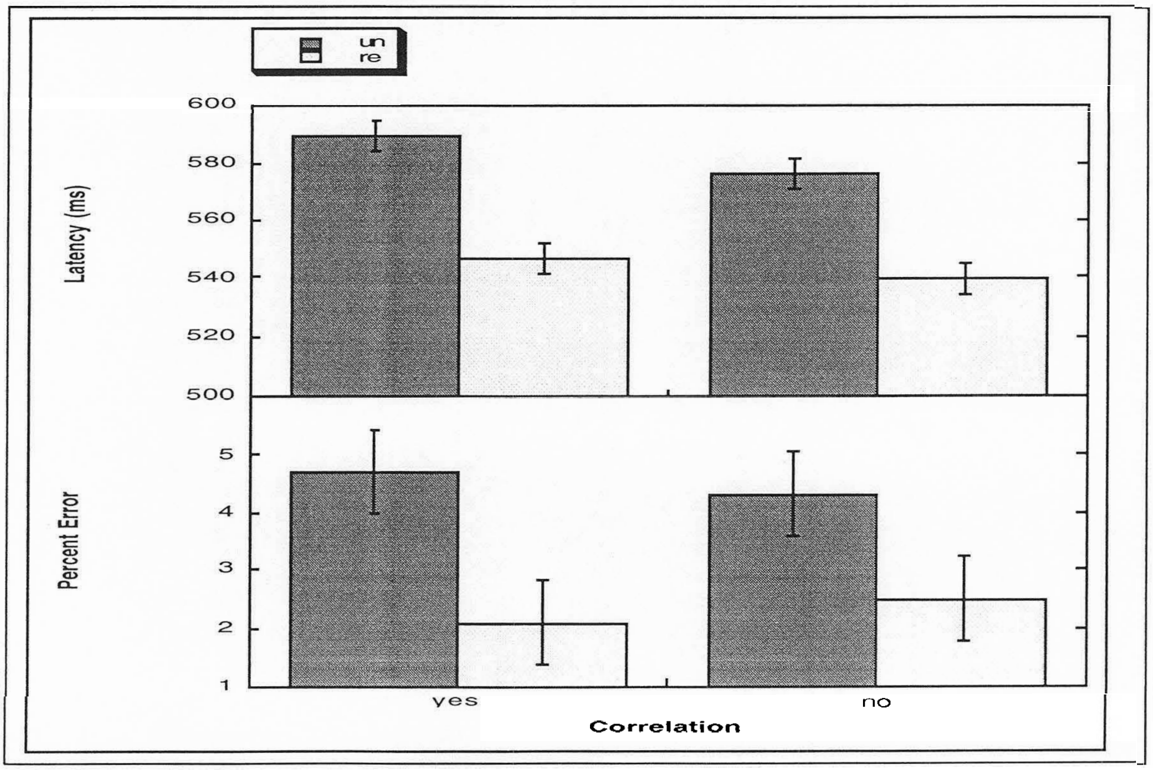


Figure 15. Mean response latencies (RT, in ms) and error rates (%E) for words in Experiment 7.

In the analysis of response latency for word targets, there was a significant priming effect, F(1, 47) = 263.34, MSE = 75,327. Subjects made faster responses to targets with a repetition prime than with an unrelated prime. There was also a significant effect of the correlation manipulation, $F(1, 47) = 9.415$, $MSE = 5{,}282$. In the correlation condition, the response latencies were longer than in the no-correlation condition. There was no significant interaction between priming and the correlation manipulation. Priming in the correlation condition was larger than in the no-correlation condition from the pattern, but the difference was not significant (43 ms vs. 36 ms).

Previous experiments provided evidence that only when the correlation was manipulated within subjects, creating a contrast between correlation and no-correlation trials, was the amount of priming modulated by correlation cues. Therefore, it was expected that priming in the early part of each block would be more susceptible to the correlation manipulation than trials in the later part. The first block was excluded from the analysis because no contrast could occur there. The difference in priming between the first two trials and the remaining eight trials in each block was examined to reveal how the correlation manipulation influences priming across a block of trials. This analysis was conducted separately for the correlation condition and the no-correlation condition. In the correlation condition, there was no interaction between priming and trial number, $F < 1$. The amount of priming for the early trials of each block was very similar to the amount of priming for the late trials of a block (38 ms vs. 45 ms). However, in the no-correlation condition, there was a significant interaction between priming and trial number, $F(1, 47) = 4.484$, $MSE = 2{,}851$. Priming for the early trials was smaller than priming for the later trials in each block (24 ms vs. 40 ms).

Besides this, the slope of response latencies across trials within a block was analyzed by examining the linear trend for the repetition and unrelated prime trials across a block. This analysis was conducted separately for the correlation and the no-correlation condition. For the no-correlation condition, the linear trend analysis indicated a significant interaction of trial by type of prime $F(1, 47) = 4.508$, $MSE = 8{,}807$. The slope for the two prime conditions diverged significantly across the ten trials. For the correlation condition, the slopes for repetition and unrelated primes did not diverge across trials. Figures 16 and 17 show the pattern of response latency change across the ten trials within a block in the correlation condition and the no-correlation condition.

The analysis of error rate also showed a reliable priming effect, $F(1, 47) = 32.505$.

Subjects made fewer errors to targets with a repetition prime than with an unrelated prime. The correlation manipulation had no effect and no interaction was observed in the analysis of error rate.

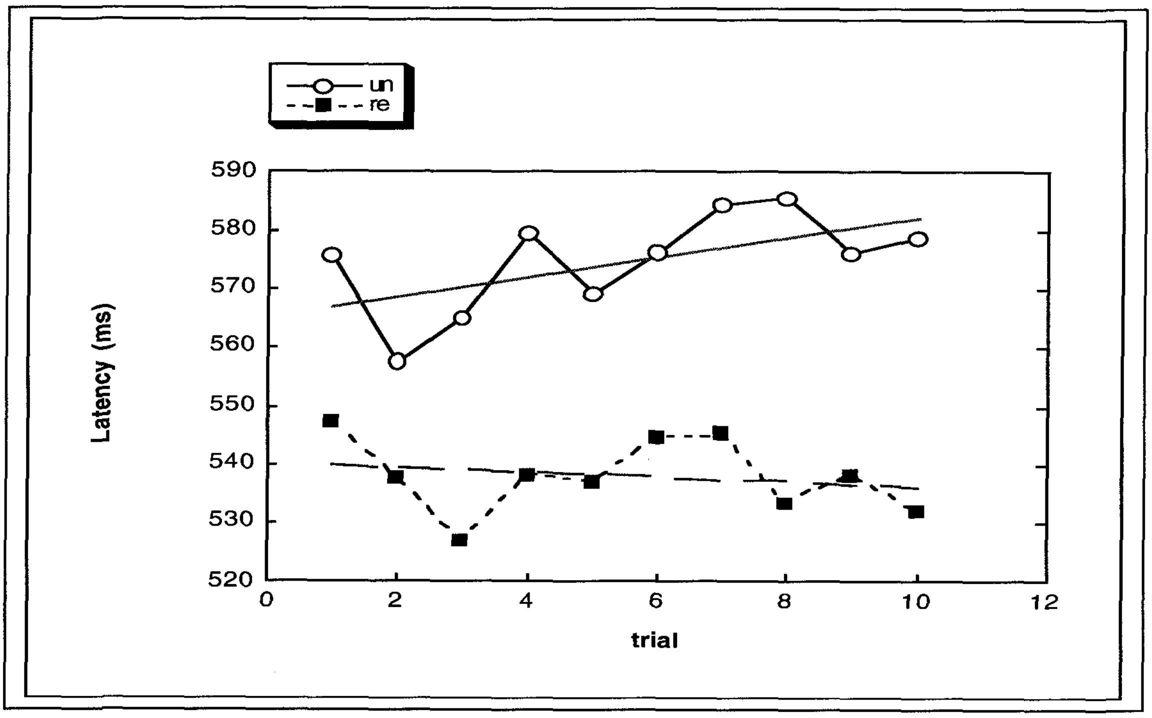


Figure 16. Response latency (RT, in ms) change across ten trials in one block in the no-correlation condition in Experiment 7.

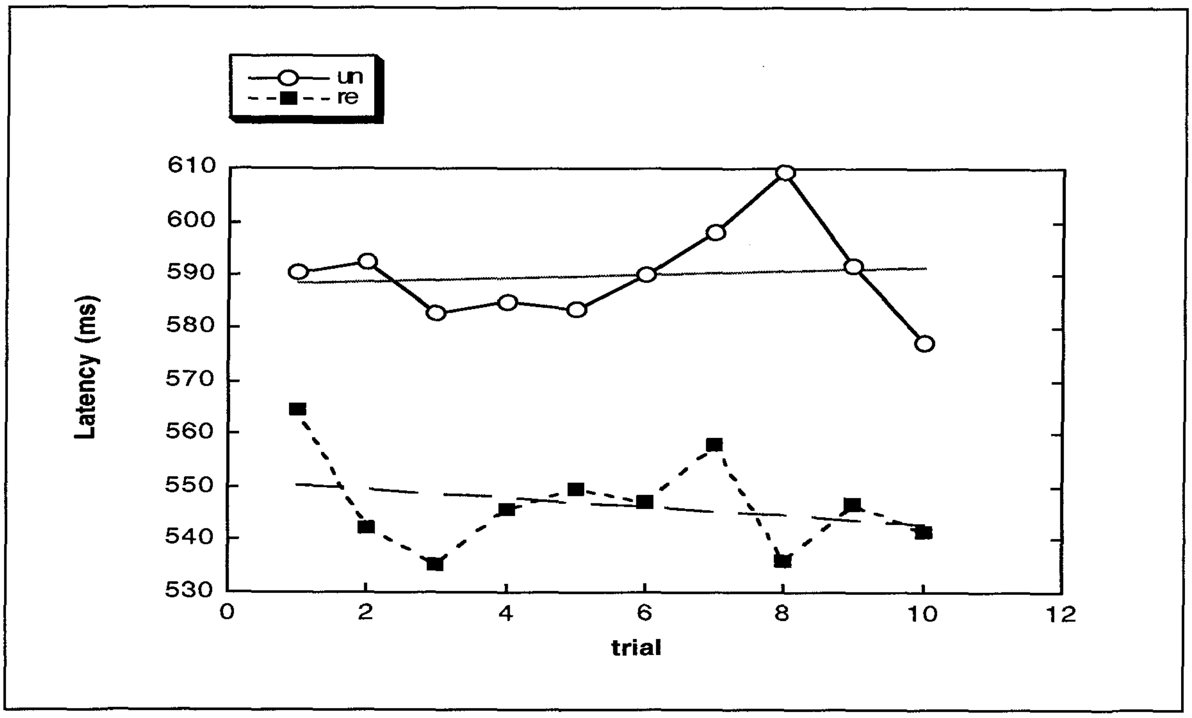


Figure 17. Response latency (RT, in ms) change across ten trials in one block in the no-correlation condition in Experiment 7.

Nonword targets. Mean response latencies and error rates for nonword targets are shown in Figure 18. A two-way within-subject ANOVA with type of prime (repetition vs. unrelated) and the correlation (correlation vs. no-correlation) as the independent variables and response latency as the dependent variable as conducted. Another ANOVA was conducted with the same independent variables and error rate as the dependent variable.

The analysis of response latency for nonwords showed no reliable priming effect. There was a significant effect of the correlation manipulation, F (1, 47) = 9.719, MSE = 6,064. Subjects made faster responses to nonword targets in the no-correlation condition than in the correlation condition. There was no significant priming by correlation manipulation interaction. The analysis of error rate showed a reliable priming effect, F (1, 47) = 32.505, MSE = 221.235. Subjects made fewer errors to nonword targets with an unrelated prime than with a repetition prime. The correlation manipulation had no effect on error rate and there was no priming by correlation interaction.

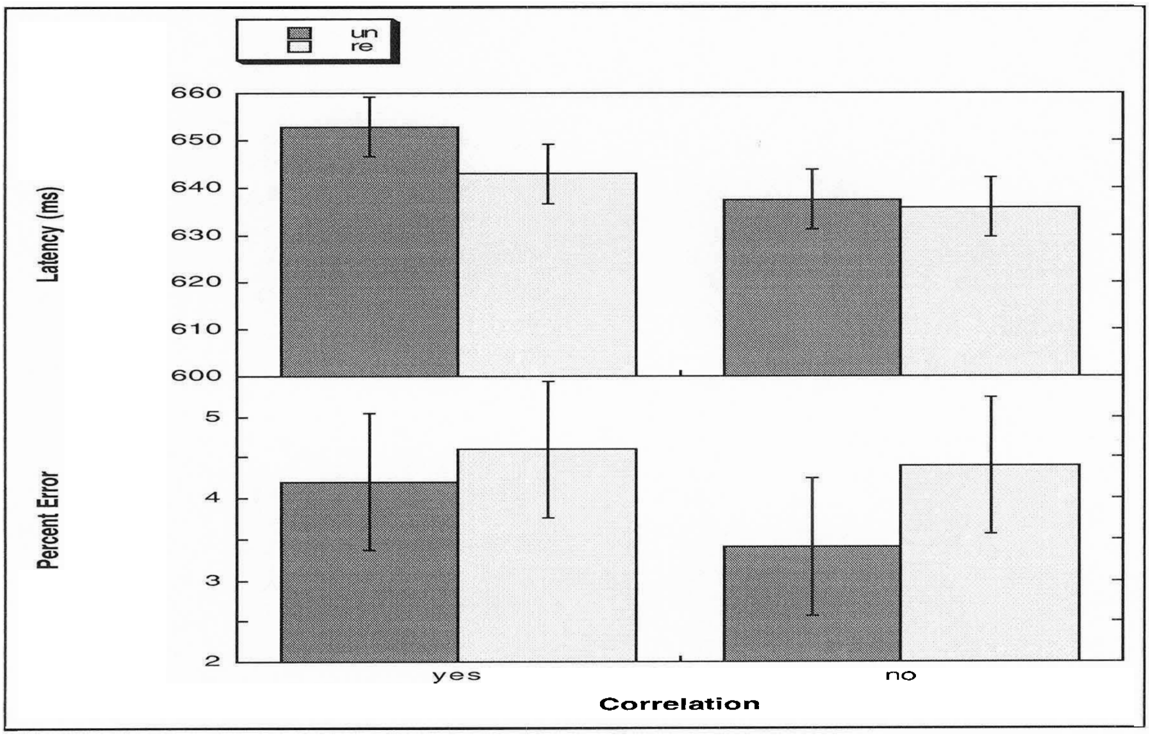


Figure 18. Mean Response Latencies (RT, in ms) and Error Rates (%E) for Nonwords in Experiment 7.

Discussion

The results of Experiment 7 did not show reliable correlation manipulation effect but did provide evidence that the color cue modulates the priming effect locally instead of globally. The lack of an overall correlation manipulation effect in Experiment 7 may be due to the fact that the blocks of trials with and without the correlation were presented to subjects separately and the contrast between the two kinds of trials is not as strong as mixing the two kinds of trials together. The contrast exists only where the block in the correlation condition changes into the no-correlation condition, or vice versa.

Across the sequence of ten trials within each block in the no-correlation condition, the priming effect of the first two trials was larger than that of the remaining eight trials and the slopes of response latencies for repetition and unrelated prime trials diverged. This finding supports our assumption that the correlation manipulation can be found only when there is contrast between different types of trials. For blocks in the correlation condition, the influence of correlation manipulation on the amount of priming was not as reliable.

The lower reliance on the prime for target processing in the blocks in the no-correlation condition is similar to the phenomenon of learned irrelevance. In previous research on animals, researchers have found that animals could learn about irrelevance when there was lack of correlation between two events (Mackintosh, 1973; Baker, 1976). When two initially uncorrelated stimuli (one is the conditioned stimulus and the other one is the unconditioned stimulus) are later consistently presented together, animals tend to not to set up an association between these two stimuli even though they are now perfectly related to each other (Baker, 1976; Baker & Mackintosh, 1977). During the learned irrelevance phase, animals can learn that one event is not associated to the other and consequently delay the subsequent acquisition of the association. If the conditioned and unconditioned stimuli are presented to animals in separate sessions, then the delay to form conditioning is less than the situation in which the two types of stimuli are presented uncorrelated within the same session. Animals can learn irrelevance between the conditioned stimulus and the unconditioned stimulus only when the stimuli are mixed together. This effect requires that these two irrelevant events be presented to animals together (Bennett, Maldonado, & Mackintosh, 1995). This is similar to the present experiments in that the correlation effect required a within-subject design and there was no correlation effect when trials with and without the correlation are presented to subjects in separate blocks or to separate groups of subjects. In the present experiments, subjects may have learned that black target color was unrelated to type of prime and therefore relied less on the prime for target processing in those cases.

General Discussion

The purpose of the seven experiments in this thesis is to investigate whether a correlation between the color of a target and type of prime, which is a post-prime cue, can modulate the amount of masked repetition priming. In the correlation condition, target color was the cue as to the type of prime. In Experiments 2 and 6, where correlation was manipulated within subjects, a larger amount of priming on response latency appeared in the correlation condition compared with the no-correlation condition. In Experiment 4, the priming effect on error rate in the correlation condition tended to be larger than that in the no-correlation condition. Comparing response latencies in the correlation and the no-correlation condition, we found an increase in response latency for targets with an unrelated prime and a decrease in response latency for targets with a repetition prime in the correlation condition. The larger priming in the correlation condition was not an artifact of the target color but was due to the correlation between target color and type of prime. These findings provide evidence that masked priming is susceptible to contextual information of the target presentation.

Correlation Manipulation Effect

The correlation manipulation effect functions immediately after the experiment session starts. In Experiments 2 and 6, when the whole test session was divided into four blocks according to the presentation order, the correlation manipulation effect was observed from the first block and lasted until the last one. In each block, a larger priming occurred in the correlation condition compared with the no-correlation condition. The contrast can be established quickly and then modulate the amount of priming.

The correlation manipulation appears to be a local effect. The results of Experiment 7 suggest that the presence of correlation trials influences a few subsequent no-correlation trials (reducing the priming effect), but this influence wears off as no-correlation trials continue. The correlation manipulation effect does not seem to have a global influence, but is confined to early trials in the no-correlation blocks, where the contrast with trials in the correlation condition exists.

When correlation and RP are manipulated within subjects at the same time and arranged in opposition, the effect of the correlation was stronger than the effect of RP. In

Experiment 6, masked repetition priming in the correlation condition (with a lower RP) was greater than in the no-correlation condition (with a higher RP). The higher RP in the no-correlation condition did not increase masked repetition priming when RP was in competition with the correlation effect. The within subjects manipulation is a necessary requirement of the correlation effect, whereas the within subjects manipulation of RP may not be salient enough to modulate subjects' reliance on the prime for target processing. If correlation and RP are both manipulated within subjects, the influence induced by RP manipulation seems to be overridden the correlation. Additional evidence is needed to support this proposal.

Episodic Account of Memory

The correlation manipulation effect is assumed to be due to modulation of prime recruitment by the context of target presentation. In the correlation condition, target color contains the information about whether there is a repetition prime or an unrelated prime. Subjects unconsciously have a tendency to use the information from the prime to facilitate the processing of the target. They increase their reliance on the prime driven by the contextual information, which is the target color in this series of experiments. When the target has an unrelated prime, more recruitment of the prime will impair the target processing because the episode of the prime is not useful for target processing. The enhanced facilitation of targets with a repetition prime and enhanced impairment of targets with an unrelated prime will result in a larger priming effect in the correlation condition.

In contrast, in the no-correlation condition, there is no cue to prime type. Subjects are less likely to recruit the memory event of the prime for target processing. As a result, the amount of priming in the no-correlation condition was not as large as the priming effect in the correlation condition.

Pattern of Response Latency Change

The amount of priming in the two experiments showing the correlation effect relative to the control experiment indicated that the correlation condition generated more priming than the control experiment whereas the no-correlation condition did not change the amount of priming relative to the control experiment. In contrast, the results of Experiment 7 suggest that it is priming in the no-correlation condition that changes under the influence of recently occurring correlation trials

This inconsistency suggests that we do not yet have enough evidence to be sure whether the correlation manipulation increases the amount of priming in the correlation condition or decreases the amount of priming in the no-correlation condition. One possible reason for the different patterns is that low-frequency words were used in Experiments 2 and 6 but high-frequency words were used in Experiment 7. Another possibility is that in Experiment 6 a high RP of .8 was used for the no-correlation condition. This may have influenced response latencies.

Attentional Shifts

The association of one stimulus with reinforcement does not depend only on the characteristics of that stimulus but also may depend on the nature of other stimuli present at the same time (Mackintosh, 1975). The tendency to use one cue depends on the usefulness and salience of other cues (Kruschke & Johansen, 1999). These effects can be found to occur in both animals and human subjects.

In Pavlov's (1927) research on classical conditioning, he observed an overshadowing effect in which the presence of an equally relevant, more salient stimulus might damage or prevent learning of an association between a less salient stimulus and reinforcement. A dog could set up an association between a weak (thermal) stimulus and the reinforcement (food) when the weak stimulus was presented by itself. However, if the weak stimulus was presented together with a strong (auditory) stimulus, the dog was less likely to associate the weak stimulus with the reinforcement. In masked repetition priming paradigms, subjects may have a general tendency to make use of the prime for target processing if either they can get indication from the context of the target as to whether the prime is useful or not. In the present experiments, when targets that contained information about the usefulness of the prime (the correlation condition) and targets that did not contain such information (the no-correlation condition) were presented together, subjects were more likely to rely on the prime to process targets in the correlation condition.

Research on attentional learning (Oades & Sartory, 1997), for example conditioned blocking and highlighting phenomena, shows that subjects can learn to ignore or attend to particular cues in some situations. The phenomenon of blocking involves learning to ignore a cue (Kruschke & Blair, 2000; Kruschke, 2004) whereas highlighting refers to a situation in which people learn to attend to a cue (Kruschke, 2001a, 2004). Whether a new cue will be blocked or highlighted depends on the presentation context and how this cue interacts with the context, potentially leading to an attention shift. This is similar to the flexible reliance on the prime in the correlation and the no-correlation situations.

In the present experiments, subjects' processing experience depends on the nature of the prime and target color in the correlation condition can predict one particular difference in processing fluency between targets with repetition primes and unrelated primes. Targets with repetition primes have relatively high processing fluency whereas targets with unrelated primes have lower processing fluency. In the correlation condition, the processing fluency is related to the target color but in the no-correlation condition targets with high processing fluency or low processing fluency are printed in the same color. The difference in processing fluency between targets with repetition primes and unrelated primes is correlated with a visible cue in the correlation condition. Therefore, subjects may learn to make more use of differences in processing fluency between repetition and unrelated prime condition when correlation cues are relevant (i.e., in the correlation condition). They will make less use of differences in processing fluency among targets in the no-correlation condition, hence, a reduced priming effect is produced.

The phenomenon of attentional contrast is another attentional shift mechanism. In this case, once a cue has been associated with an outcome, attention is shifted to other cues when another outcome needs to be predicted (Kersten, Goldstone, & Schaffert, 1998; Markman & Wachtel, 1988; Schyns & Rodet, 1997). In Kersten et al.'s experiments (1998) on associating verbs to corresponding pictures, they found that once subjects had learned the verbs by one cue value (one type of leg motion) they attended less to this cue value and were more likely to depend on another cue for later learning of other verbs. One can compare the attentional contrast phenomenon to the situation in which subjects learn to make more use of masked primes when target color is associated with prime type. To subjects, red and green targets are a single indication of a useful prime but black targets do not consistently indicate a useful prime. However, they were unable to discriminate the difference in usefulness of prime between red and green targets and had similar dependence on primes in both cases.

Future Replication

The amount of priming in the no-correlation condition in the two experiments showing the correlation effect was similar to the amount of priming seen in the control experiment (Experiment 3), but was smaller than the amount of priming in the no-correlation condition in Experiment 1 where correlation was manipulated between subjects. In Experiment 1, targets in the no-correlation condition were randomly assigned to be red or green but in other experiments all the targets in the no-correlation condition were printed in black. In a future experiment, one might present all the targets in the no-correlation condition in a color other than black with the within-subject manipulation of the correlation. In this way, one can determine whether subjects have a particular degree of reliance on primes when targets are black.

More evidence is needed regarding whether subjects increase their reliance on the prime for target processing in the correlation condition or decrease the reliance on the prime in the no-correlation condition. High-frequency words were used to investigate the trend of response latency change within a block of trials. A replication with low-frequency words is needed to compare against the pattern of response latency changes in Experiments 2 and 6, where low-frequency words were used.

Another interesting line of research would be to pursue the comparison between the correlation manipulation and RP. The present results show when correlation and RP are manipulated within subjects at the same time, the correlation effect is stronger than the RP effect. More evidence is needed to support this claim.

Conclusion

The results of the experiments in this thesis provide evidence to support the episodic memory account of masked repetition priming. The amount of priming is sensitive to contextual information, namely, a correlation between the target color and type of prime. The correlation causes a larger amount of priming compared with a no-correlation condition, but only when the correlation is manipulated within subjects. In particular, there is a decrease in response latency to targets with a repetition prime and an increase to targets with an unrelated prime in the correlation condition because subjects were more likely to recruit the prime for target processing. In the no-correlation condition, target processing was less dependent on retrieval of the prime. The correlation effect was stronger than the RP effect, at least when both were manipulated within subjects.

Response latencies for targets with unrelated versus repetition primes diverge across a sequence of ten trials, but only when there is no correlation. However, the correlation effects were not consistently observed in these experiments. Additional evidence is needed regarding the pattern of response latency changes across correlation and no-correlation conditions.

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