The masked repetition priming effect dissipates when increasing the inter-stimulus interval: Evidence from word naming

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Received 29 September 1994; revised 28 February 1995; accepted 16 March 1995

Abstract

We report a word naming experiment that investigated the life duration of the masked repetition priming effect for high- and low-frequency words across a range of five inter-stimulus intervals (0, 50, 150, 500 and 1000 ms). The results clearly demonstrate that the masked repetition priming effect is a very short-lived phenomenon since, while it remains robust for ISIs up to and including 150 ms, it dissipates with ISIs of 500 ms and 1000 ms. Moreover, we replicated the classical additive effect of target frequency and masked repetition priming. These results are discussed in relation to different explanations of masked repetition priming effects in visual word recognition.

PsycINFO classification: 2300, 2323, 2340

Keywords: Masked repetition priming; Word naming; Visual word recognition

1. Introduction

The processing of a target word is facilitated if that target word has been presented as a prime prior to target presentation. This effect known as the repetition priming effect is one of the most robust experimental effects reported in the field of reading (see for instance Besner and Swan, 1982; Caroll and Kirsner, 1982; Feustel et al., 1983; Forbach et al., 1974; Scarborough et al., 1977).
1.1. The masked repetition priming effect

Prior experimentation has demonstrated facilitatory effects of repetition (or identity) priming when a prime is masked and unavailable for conscious report in tasks such as speeded naming (Ferrand, 1995; Ferrand et al., 1994; Forster and Davis, 1991; Sereno, 1991), lexical decision (Forster, 1985; Forster and Davis, 1984, Forster and Davis, 1991; Grainger and Jacobs, 1993; Jacobs and Grainger, 1992; Jacobs et al., 1995; Rajaram and Neely, 1992; Segui and Grainger, 1990a, Segui and Grainger, 1990b, Segui and Grainger, 1993; Sereno, 1991), and perceptual identification (Evett and Humphreys, 1981; Forster, 1993; Humphreys et al., 1982, Humphreys et al., 1987, Humphreys et al., 1988, Humphreys et al., 1990).

In the masked priming paradigm (combined with tasks such as lexical decision and naming), primes are preceded by a forward pattern mask and briefly presented (typically for about 30–60 ms) before target presentation. This renders the prime extremely difficult to identify, and very little information about it is available for report. For example, Forster and Davis (1984) showed that subjects were completely unable to judge whether or not the masked prime was a word. Moreover, Ferrand et al. (1994; see also Ferrand, 1995 and Forster and Davis, 1984) found chance-level performance when subjects were asked in a forced-choice ‘same/different’ judgement task whether or not the prime was the same as the target. Finally, the overall percent-correct value was almost identical for high-frequency and low-frequency targets. This absence of a frequency effect provides further evidence that the subjects had very little information available from the prime stimuli. Even in such impoverished prime presentation conditions, there is evidence that pre-lexical and/or lexical representations are activated during prime word processing and can subsequently affect the processing of the target.

A ubiquitous problem with priming procedures is the choice of a suitable baseline (i.e. a neutral condition). In the perceptual identification task, Humphreys et al. (1988) pointed out that using an unrelated condition as a baseline can overestimate the masked repetition effect. The facilitatory nature of the masked repetition priming effect was further tested by Segui and Grainger (1990b) and Sereno (1991) in tasks such as lexical decision and naming, by comparing the repeated condition with both an unrelated word prime and a neutral prime (XXXX or ****) condition. Equivalent facilitatory repetition effects were obtained when measured against both baseline conditions (see also Perea and Algarabel, 1992, for similar results).

Also, previous data showed an absence of interactivity of masked repetition priming effects with target frequency in tasks such as naming (e.g. Ferrand et al., 1994; Sereno, 1991), lexical decision (e.g. Forster and Davis, 1984; Jacobs and Grainger, 1992; Rajaram and Neely, 1992; Segui and Grainger, 1990a, Segui and Grainger, 1990b, Segui and Grainger, 1993; Sereno, 1991) and perceptual identification (e.g. Humphreys et al., 1988, Humphreys et al., 1990). In other words, equal repetition priming effects were observed for both high- and low- frequency words.

1.2. Different explanations of the masked repetition effect

There are several ways of explaining the masked repetition effect. Within the framework of the lexical search model (Forster, 1976; Forster and Davis, 1984), a
lexical entry is made more accessible by its immediately prior presentation in that the lexical entry has been 'opened' and remains open for a short period of time. Thus, according to Forster and Davis (1984) the masked repetition effect is due to the repeated access of the same lexical entry. Lexical entries remain 'open' for some limited period of time. So, when the same word is presented twice, its entry may still be in the 'open' state on the second presentation. What is primed is the state of the entry (not the access path to it) when it is accessed. It follows that the priming effect for high-frequency and low-frequency words should be the same under this analysis.

According to activation-based models of visual word recognition (e.g. McClelland and Rumelhart, 1981; Paap et al., 1982), masked repetition priming can be explained by the preactivation of the target's lexical representation by the prime stimulus. The briefly presented masked prime produces a rise in the activation level of its lexical representation, so that when target processing is initiated the target's lexical representation already has a higher activation level than when a different word was presented as prime. Thus, the higher the starting activation level the faster the word will be recognised (see Jacobs and Grainger, 1992, for a simulation of the results obtained by Segui and Grainger, 1990a). According to the interactive-activation model (McClelland and Rumelhart, 1981), if the word corresponding to the activated unit is presented again while there is still residual activation, fewer sensory features will need to be extracted for the unit to reach threshold again. Under masking conditions, one has to postulate that the increase in activation is of the same magnitude regardless of frequency to account for the additive effects of repetition and frequency in the masked priming task. The activation-verification model (Paap et al., 1982) explains the masked repetition effect in the same way as the interactive-activation model, since the effects arise at the activation stage. In the activation-verification model, the activation stage is affected by repetition and the verification stage by frequency and so repetition and frequency effects should be additive.

1.3. The present experiment: Word naming

The masked repetition priming effect is observed when the prime and target are repeated immediately after one another. In particular, Forster and Davis (1984) observed that when the masked prime occurs immediately prior to the target, a masked repetition effect is obtained compared with the condition where as many as three words intervened. These results suggest that the masked repetition effect is short-lived. Forster and Davis (1984) have tested directly this possibility by using two lag values: in the first condition, 17 items were interpolated between the prime and the target, whereas in the second, only 1 item intervened. The results confirm the idea that the masked repetition effect dissipates rapidly since there was no effect at a lag of 17 items (a delay of 9 s), whereas at a lag of 1 item (a delay of less than 1 s) the effect was obtained. These results suggest that most of the decay takes place within the first second. However, as underlined by Forster and Davis themselves, this decay could be the result of an interference effect produced by the intervening items.

In a similar vein, Humphreys et al. (1988) have tested whether the repetition effect with masked primes remains when repetitions are separated by a number of intervening
items. Their tachistoscopic word identification data were very similar to those reported by Forster and Davis (1984) using a lexical decision task. The masked repetition effect was not significant when the target was repeated after three to six intervening trials. Recall that Forster and Davis (1984) reported masked repetition effects when there was only one intervening item between prime and target presentations. Thus, it seems that time, rather than the number of intervening items, is the critical factor here (as underlined by Humphreys et al., 1988). However, neither Forster and Davis (1984) nor Humphreys et al. (1988) directly tested empirically the hypothesis that the time between the prime and the target was the critical factor.

Thus it is an empirical question whether the masked repetition priming effect will dissipate, when the inter-stimulus interval (ISI) between the prime and the target increases (from 0 ms to 1000 ms). If the decay is time-dependent, then the masked repetition effect should vanished as the ISI increases. This experiment thus investigates masked repetition priming across a range of five ISIs (0, 50, 150, 500 and 1000 ms), to test whether there is a (continuous) decrease in any effects to a nonsignificant level. It also examined repetition effects for high- and low-frequency words. The subject’s task was to name the target words as quickly as possible. Naming latencies were the main dependent variable.

2. The experiment

2.1. Method

2.1.1. Subjects

Twenty psychology students at René Descartes University, Paris, served as subjects for course credit. All were native speakers of French, with normal or corrected-to-normal vision.

2.1.2. Stimuli and design

Forty words were taken from the stimuli used by Ferrand et al. (1994; see their Appendix A). In addition, there were 10 practice words. Half had high printed frequencies (with an average of 461 occurrences per million, ranging from a minimum of 58 to a maximum of 2,373; Trésor de la langue française, 1971), and the remaining half had low printed frequencies (with an average of 27 occurrences per million, ranging from a minimum of 58 to a maximum of 52). For each target word, two types of word prime were selected: (1) word primes that were identical to the target word (e.g. table-TABLE), and (2) word primes that were unrelated to the target word (e.g. tirer-TABLE), but shared the same first phoneme as the target. As reported by Forster and Davis (1991), it is important to have all primes begin with the same phoneme as the target when using the naming task, otherwise different onsets may produce an interference effect in target production. Word primes were always written in lowercase letters whereas word targets were written in uppercase letters. However, for word primes, each character covered approximately 0.38° of visual angle from a viewing distance of 60 cm, whereas for word targets, each character covered approximately 0.87° of visual angle.
This was done in order to minimize physical overlap in the identical-prime condition (e.g. table-TABLE) since, as reported by Davis and Forster (1994), much featural overlap remains between prime and target even when primes are printed in lowercase and targets in uppercase. Five different ISIs were used: 0, 50, 150 500, and 1000 ms. The prime-type factor was varied within blocks; the ISI factor was blocked, the order being counterbalanced within each subject in a Latin square design. Thus each target item was responded to ten times by each subject.

2.1.3. Procedure

Stimuli were presented in isolation on the center of the display screen of an AT386 personal computer with a 70 Hz refresh rate. The items appeared on the screen as white characters on dark background. The masked priming procedure with the naming task used in the experiments of Ferrand et al. (1994) was adopted here. Each trial consisted of the following sequence of four stimuli presented on the same screen location. First, a forward pattern mask (consisting of a row of hash-marks, #######) was presented for 500 ms, this was immediately followed by presentation of the prime for 29 ms, followed immediately by a backward pattern mask (#####) for 14 ms, which finally was immediately followed by presentation of the target word which remained on the screen until the subjects responded. The ISI was the interval between the offset of the backward pattern mask and the onset of the target word. Subjects were asked to fixate the middle of the forward mask. They were also instructed to name as rapidly and as accurately as possible the target word. The existence of a prime was not mentioned. The computer recorded the naming times, measured from target onset to the triggering of the voice key by the subject's response (via a Sennheiser MD211N microphone). The experimenter sat

![Graph](image-url)  
**Fig. 1.** Mean naming latencies (in ms) as a function of type of prime-target relation (repeated vs. unrelated), target frequency (low vs. high) and ISIs (0, 50, 150, 500 and 1000 ms).
in the same room as the subject in order to check and note the responses of the subject. The next sequence followed after a 2-second delay. Stimulus presentation was randomized, with a different order for each subject.

2.2. Results

Mean naming latencies are given in Fig. 1 for each ISI. An ANOVA on the reaction time data was performed with relatedness (repeated vs. unrelated prime), target frequency (low vs. high), and ISIs (0, 50, 150, 500, and 1000 ms) as factors. Because the error rates were consistently too low (less than 1%), no ANOVA was conducted on the error rates. *F* values are reported by subject (*F*1) and by item (*F*2).

There were significant main effects of repetition priming (*F*1(1,19) = 53.9, *p* < 0.001; *F*2(1,38) = 55.05, *p* < 0.001), target frequency (*F*1(1,19) = 29.04, *p* < 0.001; *F*2(1,38) = 77.93, *p* < 0.001), and ISI (*F*1(4,76) = 11.11, *p* < 0.001; *F*2(4,152) = 3.06, *p* < 0.02). Relatedness interacted significantly with ISI (*F*1(4,76) = 6.99, *p* < 0.001; *F*2(4,152) = 22.02, *p* < .001). None of the other interactions between these three factors was significant (all *F*s < 1). Furthermore, the masked repetition priming effect did not interact with target repetition (all *F*s < 1).

Planned comparisons between repeated primes and unrelated primes (i.e. repetition priming) showed a significant effect only for ISIs up to and including 150 ms (at 0 ms, *F*1(1,19) = 24.66, *p* < 0.01 and *F*2(1,38) = 25.03, *p* < 0.001; at 50 ms, *F*1(1,19) = 65.76, *p* < 0.001 and *F*2(1,38) = 31.6, *p* < 0.001; at 150 ms, *F*1(1,19) = 11.29, *p* < 0.005 and *F*2(1,38) = 43.72, *p* < 0.001; at 500 ms, *F*1(1,19) = 2.61 and *F*2 < 1; at 1000 ms, *F* < 1 and *F*2 < 1). Fig. 2 illustrates the net effects of repetition priming for each of the five ISIs tested in the present experiment with 95% confidence intervals (see Loftus and Masson, 1994). As can be seen from this figure, the effects of repetition priming are significant for ISIs up to and including 150 ms.

On the other hand, planned comparisons between high frequency targets and low frequency targets showed a significant effect for all the ISIs (at 0 ms, *F*1(1,19) = 18.24, *p* < 0.001 and *F*2(1,38) = 19.08, *p* < 0.001; at 50 ms, *F*1(1,19) = 11.77, *p* < 0.005

![Fig. 2. Net effects of repetition (in ms) as a function of target frequency and ISIs (0, 50, 150, 500 and 1000 ms). Vertical bars represent 95% confidence intervals.](image-url)
and \( F(1,38) = 19.84, \ p < 0.001; \) at 150 ms, \( F(1,19) = 35.97, \ p < 0.001 \) and \( F(1,38) = 16.94, \ p < 0.001; \) at 500 ms, \( F(1,19) = 9.22, \ p < 0.01 \) and \( F(1,38) = 8.85, \ p < 0.01; \) at 1000 ms, \( F(1,19) = 9.39, \ p < 0.01 \) and \( F(2,38) = 25.64, \ p < 0.001 \). In fact, the word frequency effects were quite comparable across both word frequencies across all ISIs, ranging from 16–22 ms.

3. General discussion

As in previous studies, we found practically equivalent repetition priming effects produced by an immediately preceding masked prime for high- and low-frequency words, confirming previous observations of the additive effects of stimulus frequency and masked repetition priming (e.g. Ferrand et al., 1994; Forster and Davis, 1984; Jacobs and Grainger, 1992; Humphreys et al., 1988, Humphreys et al., 1990; Rajaram and Neely, 1992; Segui and Grainger, 1990a, Segui and Grainger, 1990b, Segui and Grainger, 1993; Sereno, 1991). Furthermore, this masked repetition priming effect did not interact with repeated prime–target presentations (see Ferrand, 1995, for similar results). This masked repetition priming effect remained robust even after that subjects had become familiar with the stimuli, suggesting it is a highly automatized and mandatory effect.

More important, the present results clearly demonstrate that the masked repetition priming effect is a very short-lived phenomenon. When the masked prime occurs immediately prior to the target, a robust repetition effect is observed. But if sufficient time intervened between the offset of the prime and the onset of the target (estimated around 500 ms to 1000 ms), no repetition effect is observed. It suggests that most of the decay of the preactivation of the prime takes place within the first 500 milliseconds as illustrated by Fig. 2. A very close temporal proximity of the prime and the target seems required to observe the masked repetition effect, which is a highly transient effect that dissipates during the interval between the prime and the target. These results extend the previous work of Forster and Davis (1984) who demonstrated that identity priming was capable of exerting an effect across several intervening words, although the effect was considerably diminished if even one word intervenes between the prime and the target (see also Humphreys et al., 1988).

The lexical search model (Forster, 1976; Forster and Davis, 1984) explains the masked repetition effect as follows: the brief exposure of the prime is sufficient for the lexical entry corresponding to the prime to be accessed, and this induces a short-term modification of that entry, so that recognition of the subsequently presented target word is facilitated. Thus the masked prime alters the state of the lexical entry which remains ‘open’ for a short period of time. According to our results, this lexical entry seems to be maintained in an open state for a period as short as 150 ms to less than 500 ms. After this period of time, the lexical entry is in a ‘closed’ state and no repetition effect is observed. Since in this model, the masked repetition effect is independent of the frequency effect, we still observe a frequency effect while the repetition effect dissipates.

According to activation models (e.g. McClelland and Rumelhart, 1981; Paap et al.,
1982), after a unit has been sufficiently activated to attain threshold or to be selected for the verification stage, its activation level returns toward its resting level. The present results suggest that most of the decay takes place within the first 500 milliseconds. However, there still remains a frequency effect. According to the interactive-activation model, this frequency effect is explained in terms of variations in the resting level activation of high- and low-frequency detectors (corresponding to words), whereas according to the activation-verification model, this effect is explained in terms of a frequency ordered serial comparison occurring in the verification stage.

One important issue is whether this masked repetition priming effect with word stimuli occurs at a purely visual level (see for instance Davis and Forster, 1994), whether it is the result of priming at a graphemic level of representation (see for instance Humphreys et al., 1988; and Sereno, 1991), whether it stems from preactivation at the lexical level (see for instance Forster and Davis, 1984), or whether both pre-lexical and lexical levels of representation contribute to the overall priming effect (see Jacobs et al., 1995). The masked repetition priming effect could be simply due to purely low level visual processing. Since the prime is presented very briefly, it could be fused or integrated with the target thus enhancing target perceptibility (see Davis and Forster, 1994; and Forster, 1993). This integration could occur at the feature level, since much featural overlap remains between prime and target even when primes are printed in lower case and targets in uppercase (as is typical in masked priming experiments). However, this possibility is ruled out in the present experiment since the masked repetition effect occurs despite an intervening pattern mask between the prime and target, and despite the fact that the physical overlap between prime–target word pairs was reduced to a minimum by using different sized prime and target words. The fact that robust priming effects were obtained in these conditions is unequivocal evidence that masked identity priming effects are subtended by abstract codes above the feature level. Davis and Forster (1994) reached the same conclusion. They pointed out that there was no evidence of visual integration effects with the lexical decision task combined with masked priming, where the target is not briefly presented. According to Davis and Forster (1994), visual integration effects only occur when both the prime and the target are briefly presented (as is typical with the four-field masked priming technique used by Evett and Humphreys, 1981). However, the present results do not permit a choice between the other three alternatives, but other recent results are helpful concerning this issue.

Forster and Davis (1984) favour a lexical explanation of masked repetition priming. Although they observed repetition priming in high and low frequency words in a lexical decision task, they did not find graphemically similar priming. However, more recently, Forster et al. (1987) and Forster (1987) found that graphemically similar but nonidentical forms produced priming effects in longer words (on average, eight letters long) or words located in low density neighborhoods (e.g. miar–LIAR). But since neighbourhood density is defined at the word level, Forster et al. (1987) suggested that these priming effects can also be interpreted as lexically based effects. Moreover, Forster and Davis (1984), Forster et al. (1987), and Forster (1987) observed no reliable priming effects for nonword targets. These results have been taken as evidence that the priming effects in this task are not pre-lexical (see Forster, 1993).
Other results (see for instance Evett and Humphreys, 1981; Grainger and Jacobs, 1993; Humphreys et al., 1987; Humphreys et al., 1988; Jacobs et al., 1995; Sereno, 1991) lead to a different conclusion. In particular, Sereno (1991) observed in both the naming task and the lexical decision task a significant facilitation effect in a graphemic priming condition using orthographically legal nonword primes (e.g. beist–BEAST). Sereno (1991) argued that Forster (1987) and Forster et al. (1987) failed to find graphemic priming since orthographically illegal letter strings were used as primes. On the other hand, the use of orthographically regular primes seems to result in consistent and robust graphemic priming effects (Evett and Humphreys, 1981; Ferrand and Grainger, 1992, Ferrand and Grainger, 1993, Ferrand and Grainger, 1994; Ferrand et al., 1994; Humphreys et al., 1987, Humphreys et al., 1988; Sereno, 1991). These results suggest a graphemic, sublexical contribution to the masked repetition priming effect obtained with words. Moreover, in contrast to Forster and Davis (1984) and Forster et al. (1987), Grainger and Jacobs (1993) obtained significant repetition priming effects for nonword targets in three experiments (see also Jacobs et al., 1995; and Masson, 1991). In these experiments, however, subjects saw each target stimulus several times. Thus the relative familiarity of the (repeated) nonwords might explain the repetition priming effect, not obtained by Forster and Davis (1984). Similarly, Rajaram and Neely (1992) obtained masked repetition effect for nonword targets when these nonwords had been previously studied. However, Feustel et al. (1983), Grainger and Jacobs (1993), Masson and Isaak (1991), and Sereno (1991) obtained robust repetition priming effects for nonwords that were seen only once.

If the masked repetition priming effect was purely lexical in origin, then Grainger and Jacobs (1993), Jacobs et al. (1995), Masson and Isaak (1991), Rajaram and Neely (1992), and Sereno (1991) should not have obtained facilitation for identical nonwords. Since they did, a joint graphemic-lexical origin seems the best explanation of the masked repetition priming obtained with words.

Acknowledgements

I am indebted to Juan Segui and Jonathan Grainger for their help concerning this research. The research reported in this article was partially supported by a post-doc grant (COGNISCIENTES) from the Centre National de la Recherche Scientifique. I thank Gezinus Wolters and two anonymous reviewers for their comments on an earlier version.

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