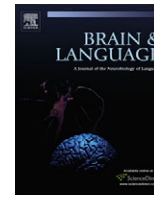
Brain and Language 106 (2008) 65–71

Contents lists available at ScienceDirect

Brain & Language

journal homepage: www.elsevier.com/locate/b&l



Masked repetition priming using magnetoencephalography

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ARTICLE INFO

Article history:
Accepted 26 February 2008
Available online 15 April 2008

Keywords:
Magnetoencephalography
MEG
Masked priming
Backward masking
Identity priming
Immediate repetition priming

ABSTRACT

Masked priming is used in psycholinguistic studies to assess questions about lexical access and representation. We present two masked priming experiments using MEG. If the MEG signal elicited by words reflects specific aspects of lexical retrieval, then one expects to identify specific neural correlates of retrieval that are sensitive to priming. To date, the electrophysiological evidence has been equivocal. We report findings from two experiments. Both employed identity priming, where the prime and target are the same lexical item but differ in case (*NEWS-news*). The first experiment used only forward masking, while the prime in the second experiment was both preceded and followed by a mask (backward masking). In both studies, we find a significant behavioral effect of priming. Using MEG, we identified a component peaking approximately 225 ms post-onset of the target, whose latency was sensitive to repetition. These findings support the notion that properties of the MEG response index specific lexical processes and demonstrate that masked priming can be effectively combined with MEG to investigate the nature of lexical processing.

1. Introduction

Masked priming has proven to be a powerful psycholinguistic tool in probing lexical activation. Priming allows for the comparison of psychophysical responses at the initial stages of lexical access, avoiding the types of strategic cognitive processes thought to be involved in straightforward lexical decision experiments (Forster & Davis, 1984; Forster, 1998, 1999; Forster, Mohan, & Hector, 2003 see Masson & Bodner, 2003 for a critical review). Moreover, it has been shown that priming is possible even at very brief prime durations (roughly 30–60 ms), considerably minimizing the amount of controlled or conscious processing, and ideally, allowing for mostly automatic processes to influence decision to the target (see Forster, 1998 for a recent assessment).

Behavioral masked priming studies have shown robust effects on reaction times to targets. For example, Forster and Davis (1984) found an identity priming effect. Primes were presented for 60 ms and followed by either the identical word (different case) or a different word. Both high and low frequency words showed this priming effect, and there was no interaction between frequency and priming. More recently, masked priming studies have investigated the morphological relation between primes and targets. For example, in French, Longtin, Segui, and Hallé (2003) found priming for morphologically transparent (*gaufrette-GAUFRE* 'wafer'-'waffle'), opaque (*fauvette-FAUVE* 'warbler'-'wildcat') and pseudo-derived (*baguette-BAGUE* 'little stick'-'ring') pairs when primes were presented for 46 ms. Rastle, Davis, Marslen-Wilson, and Tyler (2000), Rastle, Davis, and New (2004) found a similar pattern of results in English for masked primes at durations of 43 and 42 ms, respectively.

Despite the utility of priming tasks—and in particular masked priming—for studying automatic, unconscious lexical processing, it is important to note that even in these experiments, our only index of processing is manifested in a decision stage response. Electrophysiology, however, provides the potential for measuring pre-decision processes (see Pylkkänen & Marantz, 2003). Thus, combining a psycholinguistic methodology that purportedly probes automatic lexical activation with a recording technique that indexes pre-decision responses should prove insightful for our understanding of lexical representations and the (temporal sequence of) processing stages involved in lexical access.

Given that prior studies suggest that properties of averaged MEG responses do, indeed, reflect specific subroutines in lexical processing (Beretta, Fiorentino, & Poeppel, 2005; Embick, Hackl, Schaeffer, Kelepir, & Marantz, 2001; Fiorentino & Poeppel, 2007; Pylkkänen, Stringfellow, & Marantz, 2002), there is reason to think that, when using priming designs concurrently with MEG, we may be able to identify how and when a particular prime-target relation influences the time course of processing a given target. As a matter of fact, previous MEG studies using overt immediate priming (Stockall & Marantz, 2006) and medium distance repetition priming (Sekiguchi, Koyama, & Kakigi, 2000, 2001) have shown effects around 300–600 ms post-onset of the target. However, there has

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doi:10.1016/j.bandl.2008.02.002

been no evidence reported in the literature to date establishing the neural correlates of masked priming using MEG.

In the EEG literature, there have been several recent reports showing evoked responses sensitive to masked priming. In a recent ERP study, Holcomb and Grainger (2006) tested word-form relatedness under masked conditions. Participants were presented with 500 ms of mask ('########'), followed by 50 ms of prime, 20 ms of backward mask and subsequently the target. They tested three conditions: whole-word identity priming (*table*-TABLE), partial-identity priming (*teble*-TABLE) and unrelated prime-target pair (*mouth*-TABLE). They found a difference between the unrelated condition and the identity and partial-identity conditions at 150 ms post-onset of the target, and found three-way-differential patterns in the ERP evoked response from roughly 250 ms post-onset of the target through the N400. Morris, Frank, Grainger, and Holcomb (2007), also using ERP, compared morphologically transparent (*hunter-HUNT*), opaque (*corner-CORN*) and orthographic overlap (*scandal-SCAN*) conditions, using primes of 50 ms. They found a significant difference in the amplitude of a component whose peak latency was around 250 ms across all three conditions. Lavric, Clapp, and Rastle (2007) tested prime-target pairs that were either morphologically transparent (*hunter-HUNT*), morphologically opaque (*corner-CORN*) or had no morphological relationship (*brothel-BROTH*). Primes were presented for 42 ms between the forward mask (500 ms) and target. They found a reduction in N400 amplitude for the morphologically transparent and opaque conditions relative to the no morphological relationship condition, again providing further evidence that ERP evoked responses are sensitive to priming under masked conditions. Given that ERP studies seem to identify responses sensitive to priming, it reinforces the question whether or not an equivalent or related response is observable using MEG.

More generally, the use of MEG is motivated by the further fact that the added sensitivity of this methodology permits the investigation of within-subjects effects of the type at stake here. The ERP studies that have demonstrated sensitivity to masked priming (where it must be noted that the effects are sometimes in amplitude and sometimes latency) report grand average data. The experiments discussed here suggest that these effects can be observed at a single subject level, thereby extending the findings from the literature.

Assuming that MEG responses reflect aspects of lexical processing (in a practically useful manner), then the neuromagnetic signal should show sensitivity to masked priming. This link has not yet been unequivocally demonstrated, even with masked *identity* priming. Fujimaki, Hayakawa, Munetsuna, and Matani (2004) used MEG and tested cross-syllabary priming in Japanese under very brief prime durations. Primes and targets were presented vertically, just left of center. The prime was preceded by 1000 ms of mask and its duration was 70 ms. Primes were presented in the Hiragana syllabary, and the targets (same lexical item) were presented in the Katakana syllabary. Fujimaki et al. (2004) failed to find any difference when the MEG waveform for the repeated prime condition (prime and target are same lexical item, but from a different syllabary) was subtracted from the control condition (the prime is composed of pseudo-characters and the target is a real word in Katakana). There are two caveats that should be mentioned regarding this study, however. First, no robust behavioral effect was found across participants for the repeated condition. This makes interpreting the electrophysiological data more difficult. Second, it should be emphasized that the prime and target were not simply presented in a different case, as is commonly done. Instead, they were presented in different syllabaries. This is not equivalent to presenting prime-target pairs that only differ in case (stroke differences between Hiragana and Katakana are often significant), and consequently, could have led to the neutralization any priming effect that might have been found.[1]

Since behavioral data on identity priming are robust (Forster & Davis, 1984; Forster et al., 2003) and, by all accounts, should yield facilitatory effects for repeated words, identity priming constitutes an ideal test of the fundamental assumption that priming should be reflected in the MEG signal. Thus, in the current study, we chose identity priming.

Previous MEG studies have identified a series of response components following the onset of a visual word that appear to index stages in lexical processes. Activation around 100–200 ms stimulus post-onset, originating from occipotemporal regions, has been shown to be sensitive to visual word form properties, such as letter-string length and perceptibility (Pammer et al., 2004; the type I and II responses reported in Cornelissen, Tarkiainen, Helenius, & Salmelin (2003); Tarkiainen, Helenius, Hansen, Cornelissen, & Salmelin, 1999). Similarly, bilateral occipitotemporal components peaking around 130 ms (M130) and 170 ms (M170) have been observed in a number of MEG visual lexical decision studies, but typically do not systematically vary on properties thought to affect lexical access, such as word frequency, semantic properties, and priming (Stockall, Stringfellow, & Marantz, 2004; cf. Assadollahi & Pulvermüller, 2003). A subsequent component, the M250 has been argued to be sensitive to phonotactic probability (Stockall et al., 2004), and the M350 has been shown to be sensitive to lexical frequency (Embick et al., 2001), phonotactic probability (Pylkkänen et al., 2002), morphological family size (Pylkkänen, Feintuch, Hopkins, & Marantz, 2004) and the number of polysemes and homophones associated with a given lexical entry (Beretta et al., 2005). As a consequence, the time window of 100–350 ms provides the temporal boundary conditions within which we are looking for a systematic response modulation of the MEG temporal signal associated with stages of lexical access. Moreover, previous ERP experiments using masked priming with prime durations of roughly 50 ms have shown differences around 250 ms post-onset of the target (Holcomb & Grainger, 2006; Morris et al., 2007). Therefore, we too, might expect to find differences around this latency.

We present two masked identity-priming experiments and identify a component peaking approximately 225 ms post-onset of the target whose latency is sensitive to repetition. Our data are consistent with recent ERP findings using masked priming (Holcomb & Grainger, 2006; Morris et al., 2007) that show response modulation at approximately the same latency. This component is consistent across two experiments, which employ slightly different masking paradigms (forward mask only; forward and backward mask). There are two reasons why we tested two paradigms. First, both paradigms are used in the psycholinguistic literature to argue for claims about lexical access and structure (Dehaene et al., 2004; Forster, 1998, 1999; Forster & Davis, 1984; Forster et al., 2003; Holcomb & Grainger, 2006; Morris et al., 2007). Second, we hoped to determine that a neurophysiological result would be robust and replicable under two slightly different elicitation conditions.[2] Our findings lead to at least two conclusions. First, the evoked MEG response indexes and is demonstrably sensitive to specific processes involved in lexical access and representation. Ultimately, this provides a window into the neurocomputational mechanisms involved in word recognition and linguistic

[1] It should be noted, however, that some cases of cross-script priming have been found in Japanese. For example, Hino, Lupker, Ogawa, and Sears (2003) found priming between Kanji and Katakana.

[2] Researchers disagree on which design is most suitable for investigating lexical access (for discussion of methodological concerns, see Forster, 1999; Forster & Forster, 2003; Masson & Bodner, 2003; Masson & Isaak, 1999). This study is not designed to adjudicate between the differing options, but instead to show that both paradigms can be used productively in combination with the advantages that MEG offers.