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# CORRELATION BETWEEN PRIME DURATION AND SEMANTIC PRIMING EFFECT: EVIDENCE FROM N400 EFFECT

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**Abstract—When the prime word is masked and flashed very quickly, its presence cannot be perceived by the subjects, but it can still accelerate the processing of the subsequent relevant target stimulus. This is known as the masked priming effect. Adopting a similar experimental paradigm, in this study we take the gray scale pictures describing ordinary objects as prime stimuli and the environmental sounds as target stimuli. The subjects are then asked to classify the target sounds to investigate whether incongruent target sounds elicit the N400 semantic priming effect. At the same time, the prime-mask withdraw value is made at these time intervals: 16 ms, 33 ms, 50 ms, 66 ms and 83 ms, so as to reveal whether there exists a correlation between the prime duration and the priming effect. The result shows that, at each time interval, the processing of sounds that are congruent with prime pictures is sped up and sounds that are incongruent with prime pictures trigger the N400 effect. The amplitude of the N400 effect is enlarged proportionally with the time interval and gradually approaches the point of saturation. Given this, it is believed that the N400 effect reflects automatic semantic processing, that consciousness is not a prerequisite of semantic priming, and that early visual information has an accumulative priming effect on target sounds.** 

**Key words: masked priming effect, prime duration, N400, correlation.**

## INTRODUCTION

Semantic priming is a typical paradigm commonly used in cognitive scientific studies. When the prime and the target are from the same semantic category and share features, the prime can pre-activate the target (Tulving and Schacter, 1990). Moreover, the non-related targets will induce a greater N400 component (a negative-going deflection that peaks around 400 ms post-stimulus onset) than related targets, namely the N400 effect (Kutas and Hillyard, 1980). The N400 effect is closely related to semantic processing. It was first discovered in a semantic priming experiment with words as the stimulus and was believed to have reflected the contextual integration of words (Kutas and Hillyard, 1980; Liu et al., 2009a, 2010b,c, 2011a,c). Later, large numbers of studies proved that the N400 effect could be found not only in linguistic cases but also in semantic priming experiments using voices, pictures and videos as experimental materials (Gunter and Bach, 2004; Shibata et al., 2009). In particular, when the prime stimulus and the target stimulus were from different modalities, the N400 semantic priming effect still existed (Orgs et al., 2006; Senkowski et al., 2007; Schneider et al., 2008a,b; Liu et al., 2012c). Researchers like Schneider et al. (2008b) presented visual stimuli (pictures) before the appearance of target voice stimuli, modulated their semantic matching, and asked the subjects to classify the target voices. They found that when prime pictures were congruent with target voices semantically, the subjects needed less time to respond. The consequent event-related potential (ERP) result showed that, unlike semantic consistency, semantic inconsistency produced the N400 effect (Schneider et al., 2008a). These results suggested that the N400 reflected a common semantic mapping process (Kutas and Federmeier, 2011; Liu et al., 2011d,e,f,g,h).

As a matter of fact, the prime stimuli, without even entering a person's consciousness, can pre-activate the target (Greenwald et al.,1996; Kiefer et al., 1998; Dehaene et al., 1998). In other words, the prime word is masked and cannot be consciously perceived by the subjects, it can still accelerate the processing of target words. This paradigm was first introduced by Forster and Davis (1984), and is called the masked priming paradigm. In 2000, Deacon et al. (2000) found significant priming effects on the mean amplitude of the N400 when the words were masked. And the size of N400 semantic priming was relatively reduced at the shortest durations than at longer durations (Holcomb et al., 2005). After that, masked picture priming (including picture-picture priming and word-picture articulation priming) was studied (Eddy et al., 2006; Blackford et al., 2012). Eddy et al. (2006) revealed that target pictures that were unrelated to the prior masked prime picture could elicit a widely distributed N400. As well, pictures preceded by semantically related (versus unrelated) words would lead

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*Abbreviations:* ERP, event-related potential; ROI, region of interest; SOA, stimulus onset asynchrony.

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to attenuation of the N400 (Blackford et al., 2012). Kiyonaga et al. (2007) and Kouider and Dupoux (2001) further pointed out that masked cross-modal priming effects existed and were also larger at the longer prime duration than at the shorter prime duration. All in all, it suggests the existence of automatic spreading activation, which enables the prime to trigger semantic priming subconsciously. This result was supported by many behavioral studies (Kiefer, 2002; Vorberg et al., 2003; Kiefer and Brendel, 2006). While common consensus has been reached on the validity of the evidence given by behavioristics in this regard, evidence given by electrophysiology has been under dispute. Two major views on the cognitive process represented by the N400 emerged. One view maintained that N400 reflected the unconscious automatic process (Greenwald et al., 1996; Kiefer, 2002) and another argued that the N400 effect reflected strategic semantic matching based on the observation that N400 was modulated only by visible, not masked, primes (Brown and Hagoort, 1993; Hagoort et al., 1996). Most recent studies inclined to support the former view, posited that the unconscious automatic process was also modulated by the factor of attention. In the case that there was enough attention, consciousness of the prime was not required for the appearance of the N400 effect (Kiefer and Brendel, 2006; Martens and Kiefer, 2009).

Based on the above-mentioned arguments, it might be possible to get more information if the visibility of the prime was controlled in a more accurate way through control of the backward-masking effect. Therefore, we designed our experiment based on a masked cross-modal priming paradigm, adjusted the time interval of the prime-mask and observed whether the N400 semantic priming effect would be evoked and whether there existed correlation between the time intervals of the prime-mask and the N400 semantic priming effects. If the prerequisite for the appearance of the N400 effect was the consciousness of the prime, we would see a dramatic change of the N400 effect from nonexistent to existent as the time interval increased. If not, we could posit that the consciousness of the prime was not necessary for the appearance of the N400 effect. This would help us better understand the cognitive mechanism reflected by the N400 effect.

## EXPERIMENTAL PROCEDURES

### Subjects

The subjects of this experiment were 16 undergraduates (8 males and 8 females, averaging 22 years old (SD = 4.12)) from the Tsinghua University. All the subjects had normal or corrected vision and normal hearing without achromatopsia or hypochromatopsia. Before taking part in this experiment, they were asked to fill in a questionnaire on handedness (in Chinese) (Li, 1983) and were confirmed as right-handed. None of them had any major medical or neurological disease or mental disorder and did not take any neurological medicine in the recent week.

This experiment strictly observed Helsinki declarations (suggestions given by the supervising doctor on body and biomedical research). Prior to the experiment, the subjects understood the experimental procedures and the possible impacts to the human body. They all filled out the Consent on Experiment. They were paid in proportion to the time they spent in this experiment (35 Yuan RMB per hour).

### Materials

This experiment used 64 gray scale pictures describing a single object as the visual stimuli and corresponding 64 sound voices as the acoustic stimuli; for example, a picture depicting a dog corresponded to the bark of dog. The pictures and voices were collected from the multisensory stimulus set built by Schneider et al. (2008a,b). All the pictures were transformed into gray scale pictures to reduce the interference of color information with masked priming effects. Half of the 64 pictures described animals and the other half described artificial (inanimate) objects like a door, telephone, etc. Besides 64 stimulus pictures, a white noise image was used as mask. The sound intensity was balanced by Cool Edit Pro (Liu et al., 2009b, 2010d,e), and the length of time was reduced unanimously to 400 ms. Finally, it was formalized into a single channel of 16 bit with a frequency of 22 k Hz and broadcasted through the loudspeakers with 70db SPL at both sides of the display (Liu et al., 2011b, 2012a).

### Procedure

Before the experiment, 16 volunteers were asked to take part in our pretest to assess the prime visibility of each masked picture in the test phase. The results showed that each picture was sufficiently masked.

The masked priming paradigm was adopted in this experiment. Every trial began with a white cross (+) lasting for 200–300 ms in the center of a black screen, so that the subjects could focus their attention. Then, a prime picture was displayed and followed by a mask picture which was displayed for 200 ms. The prime duration alternated randomly between trials, with five possible values: 16 ms, 33 ms, 50 ms, 66 ms and 83 ms, each corresponding to a stimulus onset asynchrony (SOA) situation. A target sound would be played 400 ms after the mask and the subjects were asked to respond to the sound by pressing the corresponding button after they heard the sound. If they heard an animal sound, they pressed Y. If they heard an artificial sound, they pressed N. After making judgment, the screen turned black for 800–1000 ms and then the next trial started (see Fig. 1). Whether the sound and the object represented by the picture were congruent or not was decided randomly by the experimental program. The combination of 5 SOAs and the consistency and inconsistency could lead to 10 different conditions, in which each stimulus would appear only once. By doing so, there were 640 trials in total (10*64). The 640 trials were divided into 32 blocks and each block consisted of 20 trials. After each block was played, the subjects could decide themselves when to play the next block to make sure they had enough time to rest. Trials in each block were randomized, with the restriction that trials containing the same picture or sound would not be displayed two times or more consecutively.

The subjects finished this test sitting on comfortable chairs in a dark room. The room was sound-proof and had electromagnetic-shielding. The visual stimulus was shown on a 17-inch flat screen monitor with a 120 Hz refresh rate. The screen was placed at the same level as the subjects' eyes and 90–100 cm away from the subjects. The horizontal view angle and the vertical view angle of the subjects were 6.74 degrees and 4.5 degrees, respectively. The sound was played through the speakers on each side of the monitor. In order to ensure the reliability of the data, the subjects were told to refrain from blinking, swallowing, shaking their heads and hands except while making keystrokes.