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Research Report

Positive and negative congruency effects in masked priming: A neuro-computational model based on representation, attention, and conflict

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A B S T R A C T

Studies on masked and unmasked priming have long shown reliable positive effects of the congruent prime on target processing. Paradoxically, a negative effect has also been found, showing faster and more accurate responses in the incongruent compared to the congruent trials. Positive effects have been found with a short time between the prime and the target, while negative effects have been found with a long time between the prime and the target. This has been modeled by assuming that the prime initiates a motor self-inhibitory process that causes these effects (Bowman, H., Schlaghecken, F., Eimer, M., 2006. A neural network model of inhibitory processes and cognitive control. Vis. Cogn. 13, 401–480). We have developed an alternative explanation based on attentional neuro-modulation. In this paper we show that attentional neuro-modulation can be used to model a wide range of findings in this area.

1. Introduction

Masked priming method is based on the semantic priming paradigm, long known in the literature. In semantic priming (e.g., Meyer and Schvaneveldt, 1971), lexical decision (deciding if a string is a word or non-word) on a target word (e.g., NURSE) is faster when it is semantically related to a preceding prime word (e.g., DOCTOR prime) compared to a trial where the prime (e.g., CHAIR) is unrelated to the target (e.g., DOCTOR prime). Similarly, in masked priming tasks, a brief masked stimulus (the prime) can affect the decision on the stimulus that follows (the target). A prime, a mask, and a target are presented sequentially and the task is to make a decision on the target. The result is usually a Positive Congruency Effect (PCE), also known as the positive compatibility effect. In PCE, the prime improves the decision (in terms of the speed and accuracy) on the target if they are congruent and vice verse if they are incongruent (Marcel, 1983; Neumann and Klotz, 1994; Dehaene et al., 1998; Schlaghecken and Eimer, 2000). For example, participants were asked to press the left response button when a female face was presented and to press the right response button when a male face was presented (Enns and Oriet, 2007). When a female face was preceded by another female face, the task was performed faster than when a female face was preceded by a male face, although the task was just to respond to the second face.

Conversely, a negative priming effect has been found, called the Negative Congruency Effect (NCE). This effect is also known as the negative compatibility effect, where paradoxically the prime improves the decision on the target if they are

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incongruent and vice verse if they are congruent (e.g., Schlaghecken and Eimer, 2000, 2002, 2006; Eimer, 1999; Eimer and Schlaghecken, 1998, 2001, 2002; Lleras and Enns, 2004, 2006; Verleger et al., 2004; Jaśkowski and Ślósarek, 2007). For example, participants were asked to press the left response button when a happy face was presented and to press the right button when an angry face was presented. Under some conditions (see below), when a happy face was preceded by an angry face, the response was paradoxically faster than when a happy face was preceded by a happy face (Bennett et al., 2007). The PCE has been shown with a short mask-target Stimulus Onset Asynchrony (SOA), while the NCE has been shown with a longer mask-target SOA (e.g., 100 ms).

To explain these results, some researchers (Schlaghecken and Eimer, 2000; Eimer and Schlaghecken, 2003; Bowman et al., 2006), based on Event Related Potential (ERP) measurements and computational modeling, argue that when SOA is short, response selection can already take place during the initial response activation phase; this is reflected as an early increase of activation difference in Lateralized Readiness Potential (LRP) for the congruent compared to incongruent trials, and this should result in the congruency effects in the form of a PCE. When SOA is longer, responses have to be selected during the subsequent inhibitory phase. This inhibitory phase is reflected as a late decrease of activation difference in LRP for congruent compared to incongruent trials, and this should be demonstrated as a negative effect (i.e., NCE). In these studies, the reduction of activation difference in LRP has been attributed to a motor self-inhibition, causing the NCE effect. The mask causes this inhibition to be reversed, by removing the sensory evidence for the corresponding response and initiating its suppression.

Across all studies the interaction between PCE and NCE and the manipulations in the experiments is complex. Therefore, computer simulations of potential models are required to see if the model can account for all the changes. Demonstrating the effectiveness of this approach, Bowman et al. (2006) developed a neural network model of this process that accounts for many findings in this area. Their approach, although it has not been applied to all of the data seems, capable of explaining this phenomena (although minor modifications of the model might be required). However, with modeling it is important to establish if other processes can achieve the same effect (Sloman, 2008; Taatgen and Anderson, 2008) to establish the different possibilities for explaining the phenomena. Different models can also suggest different possibilities in terms of the neural processes involved. To this end, we created an alternative model using neuro-computational modeling. Unlike the Bowman et al. (2006) model, our model is not based on motor self-inhibition, instead it works through attentional modulation that can be affected by conflict. It shows the effect of other factors such as degradation (Schlaghecken and Eimer, 2002), mask density (Eimer and Schlaghecken, 2002), prime duration (Eimer and Schlaghecken, 2002), and the finding that NCE decreases and eventually disappears or turns into a very small PCE (e.g., Jaśkowski and Ślósarek, 2007; Sumner and Brandwood, 2008). Our goal with this was to show an alternative modeling approach involving different cognitive functions.

2. Results

2.1. Simulation 1: mask-target SOA

This simulation was intended to model the effect of SOA, i.e., a PCE and an NCE with short and long mask-target SOAs, respectively (e.g., Schlaghecken and Eimer, 2000; Jaśkowski and Ślósarek, 2007) with no changes in the parameters except the mask-target SOA. We used seven intervals of the mask-target SOA (from 65 to 245, with 30 cycles interval) to show the effect of SOA on priming pattern. The duration of the mask was 100 cycles (Dehaene et al., 1998), but different mask durations have similar effects (as used in other simulations, see Sohrabi, 2008).

In previous studies (e.g., Schlaghecken and Eimer, 2000; Eimer and Schlaghecken, 1998; Jaśkowski and Ślósarek, 2007), the NCE has been shown at long SOAs. As shown in Fig. 1a, here at the first SOA a PCE occurred (stronger PCE can be found with shorter SOAs), and at longer SOAs an NCE occurred. Then

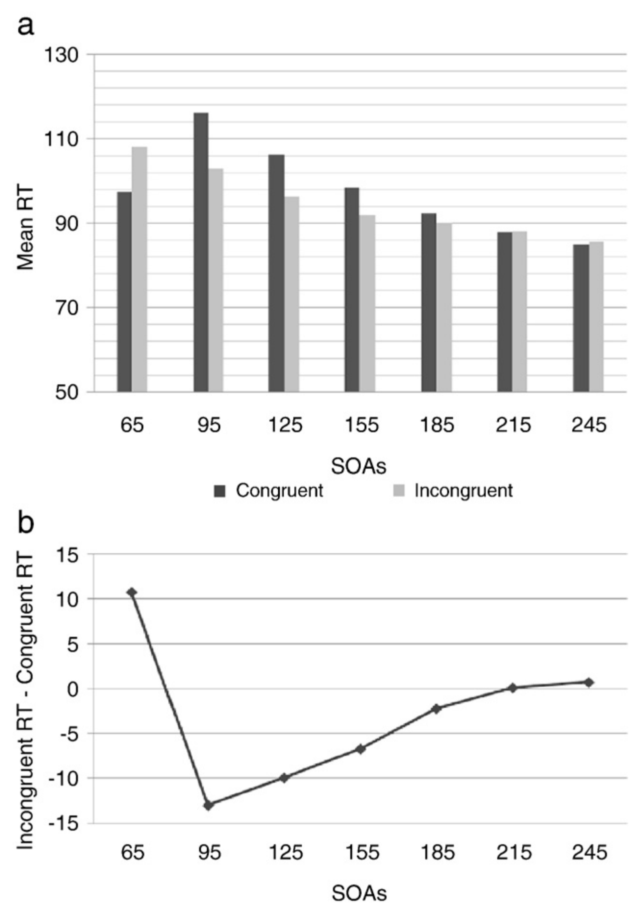

Fig. 1 – The results of Simulation 1, SOA effect. (a) Modeling results at seven levels of mask-target SOA, starting from 65 cycles. Each SOA follows 30 cycles after the previous one, with mask duration of 100 cycles. (b) The same result was shown by the congruency difference (Incongruent – Congruent) in the seven SOAs. This is similar to the different lags in attentional blink paradigm, showing a similar attentional basis for priming and attentional blink.