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Does response link updating contribute to the negative compatibility effect?

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ABSTRACT

Lleras and Enns (2004) argued that the negative compatibility effect (NCE) may partly originate from object updating (OU) between a prime and mask. This process could occur not only at the feature level, which facilitates target identification via feature updating (the updated feature is identical to the target in the feature), but also at the response level, which benefits target response via response link updating (an updated response link has an identical reaction to the target). This study aims to present experimental evidence for the latter hypothesis that response link updating is one process that triggers an NCE. The design used a 4 (stimuli) to 2 (responses) paradigm in which the left-hand response was assigned to "1" and "2" and the right-hand response was assigned to "3" and "4" (counterbalanced across the participants). Additionally, we manipulated the strength of OU (strong, "1" and "3" as primes versus weak OU condition, "2" and "4" as primes), response set of prime and target (e.g., same, "1" and "3" as both primes and targets versus different response set, "1" and "3" as primes or targets but "2" and "4" as targets or primes), and compatibility (compatible versus incompatible). The results showed a significant NCE in the strong OU (effective object updating) and different response set (separating response link updating from OU process) condition. Combined with the response time quartiles, which showed a special developmental course for this condition, the results suggest that response link updating is one process that triggers an NCE when the prime and target come from different response sets, and the processing of response link updating does not share identical developmental courses as the motor inhibition.

1. Introduction

The traditional view of selective attention suggests that perception and response are two separate stages and that the information may be processed in the response stage only after an analysis of perceptual processing (e.g. Broadbent, 1958; Treisman, 1964). However, research regarding the masked priming effect (invisible stimuli can have an unconscious influence on behaviour) challenges this view. In a typical experiment, a briefly presented visual stimulus (prime) being masked by a subsequent stimulus (the mask) so that it is rendered invisible can affect the reaction to the next stimulus (the target). Usually, responses to the targets are facilitated if prime and target are compatible (i.e., call for the same response) but delayed if they are incompatible (i.e., call for different responses) (Klotz & Neumann, 1999; Merikle & Joordens, 1997).

However, Eimer and Schlaghecken (1998) found a reversed effect called the *negative compatibility effect* (NCE). The classic NCE paradigm presents a series of stimuli in sequence, which contains a prime (16 ms), mask (100 ms) and target (100 ms). Left- or right-pointing double arrows are typically used as primes and targets, and the superimposition of two types of primes is used as a mask. The task requires participants to respond to the orientation of the target (a left-pointing arrow with a left-hand response and a right-pointing arrow with a right-hand response). A typical NCE finding is that viewer responses to the targets exhibit faster response times (RTs) and fewer errors when the targets are preceded by incompatible primes (i.e., cueing opposite responses to the targets). However, delayed responses and more errors are identified if targets are preceded by compatible primes (i.e., cueing the same responses as the targets) (Eimer & Schlaghecken, 1998). One critical determinant of this counterintuitive effect turned out to be the time interval between mask onset and target onset, which was 100 ms in Eimer and Schlaghecken (1998). When this time interval was reduced (e.g., reduced to 60 ms or less in Schlaghecken and Eimer (2000), Experiment 1), a *positive compatibility effect* (PCE, i.e., reactions to a target are faster when preceded by a compatible prime, whereas reactions are delayed when preceded by an

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incompatible prime) occurred (Lingnau & Vorberg, 2005; Schlaghecken & Eimer, 2002; Seiss & Praamstra, 2004).

To account for the NCE phenomenon, Eimer and Schlaghecken (1998) originally developed a self-inhibition hypothesis (Eimer, 1999; Eimer & Schlaghecken, 1998, 2002; Klapp, 2005; Klapp & Hinkley, 2002; Schlaghecken & Eimer, 2002, 2004, 2006). According to this hypothesis, the prime automatically causes a motor activation. However, the appearance of the mask shortly after the prime removes the prime-induced perceptual evidence, which in turn leads to automatic inhibition of the initial motor activation (Bowman, Schlaghecken, & Eimer, 2006). Thus, if a compatible target emerges, the required response remains inhibited, which results in performance costs and the NCE. There is increasing evidence that this automatic inhibition is more effective when the prime's perceptual evidence is removed by the mask (Eimer & Schlaghecken, 2002). Moreover, the occurrence of inhibition is broadly related to the prime's activation strength (Schlaghecken & Eimer, 2002); thus, the prime's activation strength must be sufficiently high to trigger inhibition during the given stimulus onset asynchrony (SOA) between the mask and target (Lingnau & Vorberg, 2005; Liu, Chen, Dai, Wang, & Wang, 2014).

However, Lleras and Enns (2004) claimed that a subliminally presented prime could also be processed at the perceptual level. These authors hypothesised that the NCE might be alternatively triggered by the perceptual interaction between a prime and relevant mask (Bennett, Lleras, Oriet, & Enns, 2007; Lleras & Enns, 2004, 2005, 2006). The relevant mask is defined as a stimulus that shares features with the prime (e.g., two overlaid opposite-pointing double arrows). According to this object updating (OU) hypothesis, the rapid serial visual presentation of a prime and mask is interpreted by the visual system as a changing object. An initial representation of the object is established when the prime emerges. However, once the mask appears, the object is updated with the new attributes of the representation (Lleras & Moore, 2003). If the mask comprises two overlaid double arrows, the updated elements require an alternative response to the response induced by the prime, which in turn benefits target identification (visual match) and leads to an NCE.

Although the OU process was initially interpreted as the result of perceptual facilitation to the target identification, Lleras and Enns (2004) argued that in addition to updating the visual attributes of an object representation, a similar process may also update the links that have been established between stimuli and their associated motor responses. This latter hypothesis can be better understood within the framework of the direct parameter specification model (Neumann, 1990a, 1990b; Scharlau & Ansorge, 2003; Scharlau & Neumann, 2003). According to this model, a stimulus and response link can be specified by establishing direct pathways from stimulus to response that do not require a conscious representation of the stimulus. Once a specific stimulus-response link has been established, based on the intention of the observer (Ansorge, Heumann, & Scharlau, 2002; Damian, 2001), new features relevant to this link are rapidly and continuously updated without conscious awareness, and the newly updated features automatically link to the specific response, which in turn benefits the target response if the target and the updated features link to the identical response. For example, when a left-pointing arrow is presented as a prime, not only the visual attributes but also the left response readiness (a left-pointing arrow automatically links to a left-hand response) might be activated. Once the relevant mask appears, the feature updating and the response link updating might be processed in parallel. Specifically, feature updating may produce a right-pointing arrow, which benefits the identification of the right-pointing arrow target because the features are visually matched between the updated features and the target. Moreover, response link updating may produce a right-hand response readiness, which benefits the reaction to the right-pointing arrow target in the response level.

The assumption of response link updating is useful in explaining previous lateralised readiness potential (LRP) results of the NCE (e.g. Eimer & Schlaghecken, 1998; Jaśkowski, Białuńska, Tomanek, & Verleger, 2008; Praamstra & Seiss, 2005; Seiss & Praamstra, 2004; Verleger, Jaśkowski, Aydemir, van der Lubbe, & Groen, 2004). Specifically, the LRP results demonstrated two phases of response preparation that comprised a same-as-prime tendency, which might be interpreted as the activation of a prime-triggered response link, and an opposite-to-prime tendency, which might be elicited by an updated response link. Response link updating is necessary to generalise the OU hypothesis in the explanation of most previous LRP results.[2] This situation occurs because if the NCE only derives from the perceptual origin, the prime-triggered response readiness phases could not be identified because the perceptual processing is less likely to elicit prime-related response readiness in the motor cortex.

However, the assumption (i.e., response link updating might independently trigger an NCE) remains arguable because some studies have demonstrated that the NCE is processed more via self-inhibition than response link updating (e.g., the third experiment of both Eimer and Schlaghecken (1998) and Klapp and Hinkley (2002)). These studies used arrow stimuli similar to the classical NCE paradigm and manipulated the prime/target compatibility. Furthermore, the authors varied the target response rule (i.e., two alternative responses versus one or three alternative responses). The aim was to investigate whether the NCE originates from motor inhibition or activation of alternative responses. For example, Klapp and Hinkley (2002) identified participants who responded to the last presented stimuli in each trial (e.g., an index-finger response to the left arrow, both middle- and ring-finger responses to the neutral arrow and a little-finger response to the right arrow). Presumably, if there are three rather than two potential responses, the activation of alternative links would not take effect because there would be no single opposite response to be activated. Thus, the NCE should be eliminated. In contrast, if the NCE occurs because of inhibition of the primed responses, the NCE should occur regardless of the number of alternative responses because inhibition of the directional prime activation would occur on the same directional targets. The results indicated the presence of a significant NCE in the three alternative responses condition, which favoured the explanation of motor inhibition rather than alternative response activation.

These previous results indicate that motor inhibition plays an important role in the occurrence of an NCE. However, the existence of response link updating in the traditional NCE, which always displays two alternative responses, could not be rejected because setting an odd number of responses may reduce the effectiveness of response link updating (i.e., two potential responses were updated in Klapp and Hinkley (2002), and no alternative response was updated in Eimer and Schlaghecken (1998)). Thus, to investigate whether response link updating exists in NCE processing, two alternative responses should first be guaranteed. Furthermore, the classic arrow primes and targets may be not suitable for the investigation of the present issue because it is difficult to separate feature updating and response link updating using left- or right-pointing arrow stimuli as prime and target.

Accordingly, the present study adopted a 4 (stimuli) to 2 (responses) paradigm to further investigate whether response link updating impacts the occurrence of an NCE. This paradigm is an altered version of the published work in our laboratory (Liu & Wang, 2014). The experimental stimuli in the paradigm can be divided into two groups: group 1 contains the numbers “1” and “3”, and OU between one of the stimuli and the mask “8” would produce a meaningful stimulus; group 2 contains the numbers “2” and “4”, and OU between one of the stimuli and the mask would produce a specific pattern that is difficult to

[2] However, response link updating could not explain the LRP results from Seiss et al. (2014), who used an altered NCE paradigm in which random lines were used as masks, left- or right-pointing arrows target appeared in two-thirds of the trials and no target stimulus was presented for the remaining trials. The results showed related LRP waveforms for the initial prime activation and the following reversal phase even in the nogo (no target) trials, although the impact of OU was strongly reduced in this experiment.