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Semantic priming revealed by mouse movement trajectories

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ABSTRACT

Congruency effects are taken as evidence that semantic information can be processed automatically. However, these effects are often weak, and the straightforward association between primes and targets can exaggerate congruency effects. To address these problems, a mouse movement method is applied to scrutinize congruency effects. In one experiment, participants judged whether two numbers were the same ("3\3") or different ("3\5"), preceded by briefly presented pictures with either positive or negative connotations. Participants indicated their responses by clicking a "Same" or "Different" button on the computer screen, while their cursor trajectories were recorded for each trial. The trajectory data revealed greater deviation to unselected buttons in incongruent trials (e.g., "3\5" preceded by a green traffic light picture). This effect was influenced by the type of responses but not by prime durations. We suggest that the mouse movement method can complement the reaction time to study masked semantic priming.

1. Introduction

Semantic priming has been studied for decades, and congruency effects are often taken as evidence that complex semantic processing occurs automatically. For example, in a semantic priming study, participants were instructed to judge whether two numbers were the same or different (e.g., "3 and 5" or "3 and 3"), preceded by two masked priming letters (e.g., "A and a" or "A and g"). Trials where the information of primes and targets conflicted were called incongruent trials (e.g., "A g" prime and "3 3" target); those trials that did not conflict were called congruent trials (e.g., "A a" prime and "3 3" target). It was found that the reaction time in incongruent trials was longer than that in congruent trials, indicating that a "same/different" relationship processed subliminally for priming letters could influence the "same/different" judgment for numbers (Opstal, Gevers, Osman, & Verguts, 2010).

However, semantic congruency effects found in many other studies are often weak and difficult to replicate, especially for masked priming (Van den Bussche, Van den Noortgate, & Reynvoet, 2009). In addition, a straight forward mapping between primes and targets undermines the reliability of claims that priming occurred at a semantic level, because participants could apply the same type of judgment to both the target number pairs and priming letter pairs. For example, in a picture priming study (Kiesel, Kunde, Pohl, Berner, & Hoffmann, 2009), participants judged whether a piece of chess was a configuration of check or non-check, preceded by a prime, which was also a configuration of check or non-check. In this case, a learned stimulus–response mapping could facilitate the processing of primes, therefore the congruency effects are *exaggerated* since the semantic relation between primes and targets was straightforward. It is found that congruency effects are modulated by the

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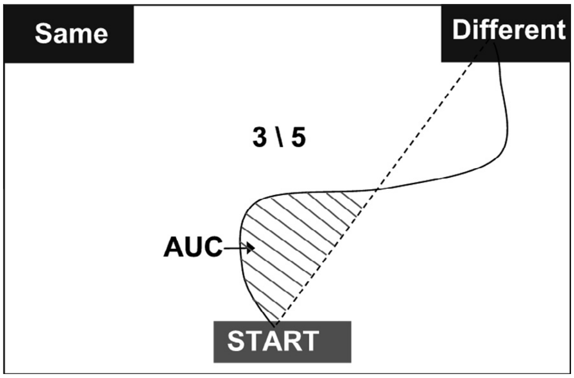

Fig. 1. Illustration of the area under the curve (AUC). In this example, a participant judges whether the numbers 3 and 5 are the same or different. The curve represents a hypothetical trajectory of a cursor from the onset position ("START" button) to the ending position (clicking the "Different" button). The straight line represents the "ideal path" between the onset and ending position. The AUC is defined by the area circumscribed by the ideal path and the actual trajectory curve that exceeds the ideal path toward the unselected option (shaded area), and is measured by pixels.

semantic relatedness between primes and targets, and are more robust when the prime-target relatedness is high (Ortells, Marí-Beffa, & Plaza-Ayllón, 2012). To mitigate these problems, the current study introduced two new procedures.

First, we applied a mouse movement method to reveal semantic processing. The merit of the mouse movement method is that it records dynamic temporal-spatial information about participants' responses, in addition to the response time data (Freeman & Ambady, 2010). Early works (Aglioti, DeSouza, & Goodale, 1995) show that hand movement can reflect one's visual perception without awareness: participants automatically adjusted their fingers when pointing to a vibrating object, but were unaware of adjusting their hand motion. Recent studies suggest that the temporal-spatial pattern of hand movement can reveal hidden cognitive states (Song & Nakayama, 2009). By analyzing the temporal-spatial features of mouse cursor trajectories, more details and further insights can be gained to understand congruency effects. However, only few studies have applied the mouse movement method to study priming. A notable exception is one by Friedman and Finkbeiner (2010), which found that the repetition priming and semantic priming could be distinguished by different cursor trajectory patterns. It is interesting to investigate whether the mouse movement method can complement reaction time techniques as an effective tool to measure semantic priming effects.

Recent studies shows that the trajectory of a cursor in trials with conflicting information was attracted to an unselected option; for example, participants were instructed to judge whether a face belonged to a white or black man, and the cursor trajectories were attracted to the option "white" when an atypical black face was presented, and vice versa (Freeman, Ambady, Rule, & Johnson, 2008). The magnitude of attraction is measured by the area under the curve (AUC), which is calculated as the geometric area circumscribed by the straight line from the onset position to the ending position and the actual trajectory that veers toward the unselected option. In the current experiment, participants judge whether two numbers are the same or different, by clicking one of the two buttons (i.e., "Same" or "Different") on the top of the computer screen (Fig. 1).

Second, to make the relation between primes and targets more abstract, we replace letter primes (e.g., "A a") with symbolic pictures with either positive (e.g., "go") or negative (e.g., "no go") connotations but still use the number pairs as targets (Fig. 2). Participants make same/different judgments for number pairs (e.g., "3\5"), whereas the priming pictures are not directly linked to semantic meanings as "same" or "different". By replacing the primes, we enhance the complexity of prime-target associations. It is expected that the congruent/incongruent relationships between primes and targets should influence the number judgment if the complex semantic relationship linking primes and targets is processed. That is, when responding to incongruent trials (e.g., positive primes followed by 3\5 or 5\3, or negative primes followed by 3\3 or 5\5), the cursor trajectories should show a greater attraction (AUC) towards the unselected option, as compared to congruent trials.

In psychophysics studies that investigated perceptual learning (Schoups, Vogels, & Orban, 1995), the same/different judgments of stimuli were shown to respectively correspond to "yes" or "no" responses. It is well known that positive ("yes") responses take shorter reaction time than negative ("no") responses (Sternberg, 1966). A similar trend is present in same/different judgment tasks: "same" responses result in shorter RT than "different" responses (Ratcliff, 1985). According to Proctor's Unified Theory (1981), such reaction time differences indicate that "same" and positive judgments employ an analogous processing mechanism, as distinct from the process underlying "different" or negative judgments. Following this reasoning, we assume that our priming pictures with positive connotations (e.g., a green traffic light) are congruent with "same" responses (e.g., "3\3") while primes with negative connotations (e.g., a red traffic light) correspond to "different" responses (e.g., "3\5"). Accordingly, we predict that positive primes facilitate "same" responses and negative primes facilitate "different" responses; in contrast, negative primes impede "same" responses and positive primes impede "different" responses.

Translating these prime-target relationships into mouse trajectories, we expect that larger AUCs arise in incongruent trials, compared to congruent ones. If such an indirect prime-target association still yields priming effects, it can be suggested that relatively complex relationships between primes and targets can be rapidly processed.