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The semantic origin of unconscious priming: Behavioral and event-related potential evidence during category congruency priming from strongly and weakly related masked words

Juan J. Ortells [a,*,1], Markus Kiefer [b,1], Alejandro Castillo [c], Montserrat Megías [a], Alejandro Morillas [a]

[a] University of Almería, Spain
[b] University of Ulm, Germany
[c] University of Murcia, Spain

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ABSTRACT

The mechanisms underlying masked congruency priming, semantic mechanisms such as semantic activation or non-semantic mechanisms, for example response activation, remain a matter of debate. In order to decide between these alternatives, reaction times (RTs) and event-related potentials (ERPs) were recorded in the present study, while participants performed a semantic categorization task on visible word targets that were preceded either 167 ms (Experiment 1) or 34 ms before (Experiment 2) by briefly presented (33 ms) novel (unpracticed) masked prime words. The primes and targets belonged to different categories (unrelated), or they were either strongly or weakly semantically related category co-exemplars. Behavioral (RT) and electrophysiological masked congruency priming effects were significantly greater for strongly related pairs than for weakly related pairs, indicating a semantic origin of effects. Priming in the latter condition was not statistically reliable. Furthermore, priming effects modulated the N400 event-related potential (ERP) component, an electrophysiological index of semantic processing, but not ERPs in the time range of the N200 component, associated with response conflict and visuo-motor response priming. The present results demonstrate that masked congruency priming from novel prime words also depends on semantic processing of the primes and is not exclusively driven by non-semantic mechanisms such as response activation.

1. Introduction

Masked congruency priming has become a well-established method to investigate the impact of unconsciously processed words on overt decisions and responses (e.g., Dehaene et al., 1998; Greenwald, Klinger, & Schuh, 1995; Kiefer, 2002; Klauer, Eder, Greenwald, & Abrams, 2007; for reviews, see Kouider & Dehaene, 2007; Van den Bussche, Van den Noortgate, & Reynvoet, 2009). In this paradigm, participants are asked to categorize visible targets words (for example, referring to an animal vs. a body part) that are preceded by briefly flashed, visually masked primes whose category (and/or response) is either congruent or incongruent with the target. The masks, typically visual patterns (e.g. random letter strings) presented before and/or after the prime word, prevent its conscious identification (e.g., Breitmeyer & Öğmen, 2006). A congruency priming effect occurs when target categorization on congruent trials (e.g., lion-dog) is faster and/or more accurate than on incongruent trials (hand-dog). Such priming has been described as unconscious in nature when subjects are phenomenally unaware of the masked primes and/or they cannot identify them in a separate test of prime visibility. Evidence for reproducible unconscious congruency priming has been accumulated across a variety of categorization tasks, such as positive vs. negative valence judgments (De Houwer, Hermans, Rothermund, & Wentura, 2002; Kiefer, Sim, & Wentura, 2015; Klauer et al., 2007; Naccache et al., 2005), number classification (Dehaene et al., 1998; Naccache & Dehaene, 2001a, 2001b), size discrimination (Kiesel, Kunde, Pohl, & Hoffmann, 2006), gender classification (Greenwald & Abrams, 2002; Klauer et al., 2007), and category classification (Forster, Mohan, & Hector, 2003; Ortells, Daza, & Fox, 2003; Ortells, Frings, & Plaza-Ayllón, 2012; Ortells, Vellido, Daza, & Noguera, 2006; Van den Bussche & Reynvoet, 2007).

Recently, however, the mechanisms underlying unconscious congruency priming from words have attracted considerable

* Corresponding author at: Departamento de Psicología, Universidad de Almería, 04120 Almería, Spain.
E-mail address: jortells@ual.es (J.J. Ortells).

[1] Both Juan J. Ortells and Markus Kiefer contributed equally to this work.

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interest and debate (Kang, Blake, & Woodman, 2011; Kouider & Dehaene, 2007; Van den Bussche et al., 2009). One of the most straightforward ways to explain masked priming effects is that they reflect unconscious access to the meaning of the prime and automatic preactivation of the semantic target representation (e.g., Kiefer, 2002; Kiefer & Martens, 2010; Masson, 1995; Naccache et al., 2005). In addition to semantic preactivation, congruency priming might be based on the implicit application of task-control representations ('task sets') (Ansorge, Kunde, & Kiefer, 2014; Kiefer et al., 2015; Klauer et al., 2007; Neumann, 1990) to the prime, whether consciously presented or subliminally, although it is not required by the task. According to this view, participants establish a task set on the grounds of the experimental instruction (e.g., "press left key in response to an animal, press right key in response to a body part"). If the prime matches this prepared task set, the task set is executed and the corresponding response is activated. Similar to the semantic activation account, the task set execution account of subliminal priming predicts priming also for unfamiliar, novel primes, which are not presented as targets. Unfamiliar primes can lead to task set execution, as long as they are sufficiently similar to the information specified in the task set. This includes at least a coarse semantic analysis of the prime stimulus, e.g. with regard to its category, in order to determine whether it is suited to execute the task set (Kiefer et al., 2015). Furthermore, the task set execution account of subliminal priming opens the room for attentional influences such as stimulus expectations or task sets, which determine whether an unfamiliar prime is able to elicit priming effects (Kiefer, Adams, & Zovko, 2012; Kiefer & Martens, 2010; Kiefer et al., 2015).

In contrast to these semantic accounts of priming, several findings have indicated that masked congruency priming effects could be caused rather by non-semantic processes such as direct stimulus–response associations (e.g., Klinger, Burton, & Pitts, 2000; see also De Houwer et al., 2002). Such non-semantic accounts, which have dominated research on category congruency priming for the last decade, are supported by several lines of evidence (for a discussion see Van den Bussche et al., 2009): On the one hand, many prior demonstrations of unconscious congruency priming have used a reduced stimulus-set with the undesirable consequence that the critical masked primes reappear as classified visible (conscious) targets in different trials (e.g., Dehaene et al., 1998; Draine & Greenwald, 1998; Greenwald, Draine, & Abrams, 1996). This repetition of items may allow the primes to be partially identified. Identification of isolated prime features (e.g., word fragments of one or more letters), could then aid the retrieval of its identity without accessing semantic information. Furthermore, the unconscious primes may activate the stimulus–response (S–R) links that were mapped and practiced with the conscious target stimuli (e.g., Damian, 2001; Neumann & Klotz, 1994), or even activate the practiced links between targets and a more abstract response-related representation, such as its response category (e.g., Abrams, Klinger, & Greenwald, 2002), curtailing the need for semantic processing of unconscious primes.

Another non-semantic account of unconscious congruency priming has been developed by Kunde, Kiesel, and Hoffmann (2003). These authors assume that following task instructions, participants intentionally prepare *action triggers* for the stimuli they expect to receive during the experiment. These action triggers create automatic associations between all expected stimuli and their appropriate responses. When a prime stimulus is included in the prepared action trigger set, it can automatically trigger the adequate response and evoke priming without the need of undergoing semantic processing. Note that action triggers would be more readily applied when a small stimulus set and/or category (e.g., months; farm animals) is used. However, albeit that such a mechanism is reliant on the sustained expectancy of a number of individual instances, it seems unlikely (as acknowledged by Kunde et al., 2003) that subjects are able to form action triggers for all possible members of *large* task categories that usually include many perceptually dissimilar members (e.g., positive vs. negative words; animals vs. non-animals).

To decide between semantic and non-semantic interpretations, it should be considered whether subliminal stimuli that are never presented as targets (i.e., novel or unpracticed primes) induce reliable congruency priming. If unpracticed primes remain ineffective despite their fit to the current task instructions, congruency priming would be restricted to acquired S–R mappings. By using *pictures* as prime stimuli, several prior studies (e.g., Dell'Acqua & Grainger, 1999; Van den Bussche et al., 2009; see also Pohl, Kiesel, Kunde, & Hoffmann, 2010) have reported reliable semantic congruity effects from subliminal primes that were part of a large stimulus set and never appeared as targets during the experiment. These findings provide a clear-cut demonstration of unconscious congruency priming at the semantic level, as they cannot be explained in terms of prime-target orthographic overlap, action triggers or stimulus–response mappings. But as suggested by Kouider and Dehaene (2007; see also Kang et al., 2011), it remains possible that picture stimuli could have a more direct access to meaning representations, thus leading to stronger semantic effects under subliminal conditions as opposed to word stimuli.

Nevertheless, when prime stimuli consist of symbolic carriers instead, such as words, the evidence of unconscious congruency priming with novel primes has been elusive thus far. An exception is the single category of number words, for which a convincing set of reports demonstrated unconscious semantic processing, including generalization to novel primes. For example, by using a number comparison task in which participants had to decide whether a visible target number (preceded by another invisible prime number) was larger or smaller than 5, Naccache and Dehaene (2001a) showed reliable response priming effects (i.e., faster responses when prime and target fell on the same side of 5 -congruent- than when they did not -incongruent trials-) even for *novel* prime stimuli that were never seen consciously, and for which no stimulus–response learning could conceivably occur. They also found an effect of semantic distance between prime and target, such that responses on congruent trials were gradually faster as the numerical distance between prime and target was smaller. In another study by Naccache and Dehaene (2001b), it was shown that subliminal number primes modulated fMRI activation in parietal areas known to be involved in semantic quantity processing, thus providing an even stronger empirical basis for unconscious semantic processing of numbers. It has been argued, however, that nonconscious access to quantity, the main semantic attribute of numbers, could be the single exception to a general principle stating that semantic representations are necessarily conscious (cf. Naccache et al., 2005, pp. 7713).

In clear contrast to the findings with number words, when unpracticed *nonnumeric words from large categories* are used as prime stimuli, unconscious congruency effects have often been weak and difficult to replicate (Abrams, 2008; Kiefer et al., 2015), with the observed priming effects being highly sensitive to minor procedural differences (e.g., target frequency, prime-target orthographic overlap, test power, type of masking or prime duration). Contradictory results have even been reported under very similar task demands and stimulus presentation conditions (see, for example, the opposite pattern of results reported by Forster et al., 2003, and Van den Bussche & Reynvoet, 2007, both using animal targets).

A difference between masked congruency priming and the more conventional semantic priming paradigm within lexical decision or naming tasks (e.g., Neely, 1991), which could be relevant here, concerns semantic similarity or association strength between prime and target words. *Semantic similarity* (e.g., McRae & Boisvert,