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Reexamining unconscious response priming: A liminal-prime paradigm

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ABSTRACT

Research on the limits of unconscious processing typically relies on the *subliminal-prime paradigm*. However, this paradigm is limited in the issues it can address. Here, we examined the implications of using the *liminal-prime paradigm,* which allows comparing unconscious and conscious priming with constant stimulation. We adapted an iconic demonstration of unconscious response priming to the liminal-prime paradigm. On the one hand, temporal attention allocated to the prime and its relevance to the task increased the magnitude of response priming. On the other hand, the longer RTs associated with the dual task inherent to the paradigm resulted in response priming being underestimated, because unconscious priming effects were shorter-lived than conscious-priming effects. Nevertheless, when the impact of long RTs was alleviated by considering the fastest trials or by imposing a response deadline, conscious response priming remained considerably larger than unconscious response priming. These findings suggest that conscious perception strongly modulates response priming.

1. Introduction

The notion that stimuli that are not consciously perceived can nevertheless undergo high-level processing is widely advocated (e.g., Dehaene & Changeux, 2011; Gibbons, 2009; Hassin, 2013; Jiménez-Ortega, Espuny, de Tejada, Vargas-Rivero, & Martín-Loeches, 2017; Kouider & Dehaene, 2007; Rohaut, Alario, Meadow, Cohen, & Naccache, 2016; Van Opstal, Gevers, Osman, & Verguts, 2010). Behavioral studies have shown that processes hitherto thought to fall in the exclusive realm of conscious abilities, such as semantic processing (e.g., Dehaene et al., 1998; Sklar et al., 2012), semantic integration (e.g., Mudrik, Breska, Lamy, & Deouell, 2011; Van Opstal, Calderon, Gevers, & Verguts, 2011; Van Opstal, de Lange, & Dehaene, 2011), high-level cognitive control (e.g., response inhibition: Hughes, Velmans, & DeFockert, 2009; Van Gaal, Ridderinkhof, Fahrenfort, Scholte, & Lamme, 2008), task-switching (e.g., Manly et al., 2014), conflict adaptation (e.g., Van Gaal, Lamme & Ridderinkhof, 2010), and context setting (e.g., Van Opstal et al., 2011) can occur in the absence of conscious perception. Likewise, growing evidence suggests that information that is not perceived consciously can be processed in a broad range of high-level brain regions including the prefrontal cortex (e.g., Lau & Passingham, 2006; Van Gaal & Lamme, 2012), which is traditionally associated with conscious control over behavior (e.g., Dehaene & Naccache, 2001). Although several methodological issues have been raised with regard to individual studies and failures to replicate have been reported (e.g., Desender & Van den Bussche, 2012; Hesselmann & Knops, 2014; Hesselmann & Moors, 2015; Moors, Boelens, van Overwalle, & Wagemans, 2016; Pratte & Rouder, 2009), these demonstrations raise the important question of what processes can unfold in the absence of conscious perception and conversely, for what processes consciousness is essential. More provocatively, they raise the possibility that unconscious processing may not have limits at all (e.g., Hassin, 2013).

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1.1. The subliminal-prime paradigm

The traditional way of establishing unconscious processing is to demonstrate that a stimulus affects behavior or brain activity even though conscious perception of this stimulus is absent (e.g., Marcel, 1983). Unconscious processing is most often probed in a paradigm, referred to here as the "subliminal-prime paradigm", that has become the gold standard for measuring unconscious priming (e.g., Almeida, Pajtas, Mahon, Nakayama, & Caramazza, 2013; Ansorge, Kiss, & Eimer, 2009; Dehaene et al., 1998; Frings & Wentura, 2008; Heinemann, Kunde, & Kiesel, 2009; Kiefer & Brendel, 2006; Kunde, Kiesel, & Hoffmann, 2003; Lau & Passingham, 2007; Manly et al., 2014; Naccache & Dehaene, 2001; Van Gaal, Lamme, & Ridderinkhof, 2010; Van Opstal et al., 2011; but see Rothkirch & Hesselmann, 2017 for an overview of alternative paradigms). This paradigm relies on the premise that conscious perception occurs whenever a stimulus can be classified with better accuracy than chance (e.g., Schmidt, 2015; see e.g., Peters, Ro, & Lau, 2016; Timmermans & Cleeremans, 2015 for a discussion of the relative advantages of objective and subjective measures of consciouness).

The subliminal-prime paradigm consists of two experimental phases: a priming phase and a prime-awareness phase. In the first (priming) phase, unconscious processing is assessed as the degree to which a subliminal prime influences the response to a visible target (in behavioral studies) or as the neural activity elicited by a subliminal prime (in brain studies). In the second (prime-awareness-test) phase, the observers' ability to discriminate some feature of the prime is assessed and chance performance on that task is held to attest to the subliminality of the prime. For example, Dehaene et al. (1998) required observers to classify a target digit as being smaller or larger than 5. Unbeknownst to the participants, a prime (also a number either smaller or larger than 5) was presented prior to the target. The prime was rendered subliminal by pre- and post-masks. Congruent trials (in which the prime and target were associated with the same response, e.g., > 5) were responded to faster than incongruent trials (in which they were associated with opposite responses). Yet, participants were at chance in post-experimental awareness tests, suggesting that they were objectively unaware of the prime. The authors concluded that a subliminal prime can be processed up to a semantic level (but see Abrams & Greenwald, 2000; Damian, 2001; Kunde et al., 2003 for alternative interpretations).

1.2. Caveats of the subliminal-prime paradigm

Despite its extensive use, the subliminal-prime paradigm can be criticized on several grounds. First, conscious perception of the prime during the post-experiment prime-awareness test may not provide an accurate estimate of conscious perception during the priming phase because it is not measured in the same context (e.g., Lamy, Carmel, & Peremen, 2017; Lin & Murray, 2014; Pratte & Rouder, 2009; see also Reingold & Merikle, 1988). For instance, Pratte and Rouder (2009) suggested that it is easier to maintain attention and motivation in the response-priming phase than in the prime-awareness phase, with the consequence that conscious processing during the prime-awareness phase is underestimated (but see Finkbeiner, 2011, for contradictory evidence). Second, the prime-awareness phase typically does not include enough trials to allow rejecting the hypothesis of null sensitivity to the prime (e.g., Amihai, 2012).

Finally, and most relevant for the present purposes, the prime is selected so as to be subliminal on all trials and therefore, the role of conscious perception cannot be assessed because unconscious processing cannot be compared to conscious processing under the same stimulus conditions (e.g., Lamy, Alon, Carmel, & Shalev, 2015; van den Bussche et al., 2013).[1] This limitation is particularly important, because high-level unconscious processing is often inferred from very small priming effects (e.g., Almeida, Mahon, & Caramazza, 2010; Kunde et al., 2003; Van den Bussche, Notebaert, & Reynvoet, 2009) that may result from just a few trials in which the prime is consciously perceived. Finding that priming effects are substantially larger when the prime is consciously perceived than when it is not (all stimulus parameters being kept equal) would strongly mitigate the conclusion that high-level processing can be independent of conscious perception.

1.3. The liminal-prime paradigm

Recently, several authors have advocated the use of the *liminal-prime paradigm* as an alternative to the subliminal-prime paradigm (e.g., Lamy et al., 2015, 2017; van den Bussche et al., 2013). In this paradigm, subjective perception of the prime is measured on every trial using some variant of the *Perceptual Awareness Scale* (PAS, Ramsøy & Overgaard, 2004), while the impact of this prime on responses to the target (i.e., priming) is concomitantly assessed. With PAS, observers report on the quality of their subjective experience, using a 4-point scale of visibility: (1) 'No experience', (2) 'Brief glimpse', (3) 'Almost clear image', and (4) 'Absolutely clear image'. The underlying rationale is that when subjects experience partial awareness of the stimulus, they will use the intermediate levels of the scale, thereby increasing the probability that the lowest visibility rating indeed reflects total absence of conscious awareness of the stimulus. Accordingly, several authors have found that when observers report the lowest level of stimulus visibility using PAS, their performance on a concomitant objective forced-choice discrimination task on that stimulus is at chance (e.g., Lamy et al., 2015, 2017; Liu et al., 2016; Lähteenmäki, Hyönä, Koivisto, & Nummenmaa, 2015; Peremen & Lamy, 2014; Ramsøy &

[1] Several authors assessed the role of conscious perception by comparing priming on weak-stimulation (subliminal-prime) trials and on strong-stimulation (supra-liminal) trials (e.g., Desender, Van Lierde, & Van den Bussche, 2013; Goller, Khalid, & Ansorge, 2017; Jiang, Bailey, Xiang, Zhang, & Zhang, 2016; Lin & Murray, 2015; Tapia, Breitmeyer, & Shooner, 2010; Van Gaal, Lamme, Fahrenfort, & Ridderinkhof, 2011; Van Gaal et al., 2014). In these studies, conscious information was found to have a much stronger impact on behavior and on brain activity than unconscious information but the effects of conscious perception were conflated with those of stimulation strength.