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Repeating a strongly masked stimulus increases priming and awareness

Anne Atas *, Astrid Vermeiren, Axel Cleeremans

Consciousness, Cognition and Computation Group, Université Libre de Bruxelles, Belgium
Centre de Recherche Cognition et Neurosciences, Université Libre de Bruxelles, Belgium

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ABSTRACT

Previous studies [Marcel, A. J. (1983). Conscious and unconscious perception: Experiments on visual masking and word recognition. *Cognitive Psychology*, *15*(2), 197–237; Wentura, D., & Frings, C. (2005). Repeated masked category primes interfere with related exemplars: New evidence for negative semantic priming. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 31*(1), 108–120] suggested that repeatedly presenting a masked stimulus improves priming without increasing perceptual awareness. However, neural theories of consciousness predict the opposite: Increasing bottom-up strength in such a paradigm should also result in increasing availability to awareness. Here, we tested this prediction by manipulating the number of repetitions of a strongly masked digit. Our results do not replicate the dissociation observed in previous studies and are instead suggestive that repeating an unconscious and attended masked stimulus enables the progressive emergence of perceptual awareness.

1. Introduction

Visual masking is a parsimonious and convenient method through which to contrast conscious and unconscious processing and now constitutes one of the most prominent paradigms to study consciousness (Breitmeyer & Ögmen, 2006). In a nutshell, awareness of a stimulus is prevented when it is surrounded temporally and spatially by another stimulus, called the mask. Effective masking is obtained when the duration of the informative stimulus is sufficiently short ($\leqslant$50 ms; Kouider & Dehaene, 2007) and when the mask shares features with the stimulus or fits its contours closely. The resulting signal is intrinsically weak and fleeting. However, under specific task instructions, the stimulus can be sufficiently processed to influence reaction times to a subsequent visible target (i.e. masked priming, see Kouider & Dehaene, 2007 for a review). A large number of studies have now confirmed that decision making in simple choice tasks can involve unconscious processes (e.g., Schmidt, 2002; Vorberg, Mattler, Heinecke, Schmidt, & Schwarzbach, 2003), which essentially correspond to the propagation of activation evoked by the stimulus from sensory cortex to motor cortex (Dehaene et al., 1998).

One of the most important methodological issues involved in the study of unconscious processing is to manage to achieve a balance between availability to consciousness and causal influence. Thus, one needs to identify conditions in which a stimulus is strong enough that its influence can be detected at the level of behavioral responses, yet weak enough that the participant fails to consciously perceive it. This is notoriously difficult to obtain using simple masking procedures. Recently however, methods such as continuous flash suppression (CFS, see Tsuchiya & Koch, 2005) or gaze-contingent crowding

* Corresponding author. Address: Consciousness, Cognition and Computation Group, Université libre de Bruxelles, Av. F. Roosevelt 50/122, 1050 Bruxelles, Belgium. Fax: +32 2 650 2209.
E-mail addresses: aatas@ulb.ac.be, aatas86@gmail.com (A. Atas).

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(GCC, see Kouider, Berthet, & Faivre, 2011) have made it possible to present stimuli for long durations (so achieving greater strength) while affording sustained invisibility (e.g. Almeida, Mahon, Nakayama, & Caramazza, 2008; Bahrami et al., 2010; Faivre & Kouider, 2011). Interestingly, Marcel (1983, see also Wentura & Frings, 2005) had already proposed a different manner to achieve both stimulus strength and stimulus invisibility: The repeated masking paradigm. In this paradigm, a strongly masked stimulus is repeated many times, thus resulting in a relatively long stream of identical masked stimuli. In such conditions, both Marcel (1983) and Wentura & Frings, 2005 found that stimulus processing, as reflecting through priming, improved with increasing repetitions while perceptual awareness did not, thus demonstrating reliable subliminal processing.

However, both studies suffer from methodological limitations that hinder their conclusions. Several aspects of the specific method used by Marcel (1983) are suggestive that his findings could have stemmed from partial awareness of the primes rather than from accumulation of unconscious evidence. Indeed, Marcel used a very long duration for the inter-prime interval (IPI, 1000 ms) and inserted a warning signal (a tone) between the final prime and the target, which were also separated by 1000 ms. With this procedure, it is likely that participants withheld their attention until the occurrence of the warning sound, hence dedicating little or no attention to the successive masked primes. Noteworthy, the priming effect found through this method contrasts with other studies on unconscious priming, which have systematically shown that prime influence completely vanishes (1) when the delay between the offset of the prime and the onset of the target exceeds a few hundred milliseconds or (2) when top-down attention is not directed to the masked prime (Dupoux, de Gardelle, & Kouider, 2008; Ferrand, 1996; Greenwald, Draine, & Abrams, 1996; Kiefer & Brendel, 2006; Naccache, Blandin, & Dehaene, 2002). Based on such studies, we might therefore expect, with the Marcel method, that the weak neural trace elicited by the current unattended prime completely disappears before the appearance of the next unattended prime or of the target, unless these masked primes were partially conscious. Importantly, prime awareness was assessed through a subjective measure in the Marcel study, whereas all the studies mentioned above assessed prime awareness through an objective measure, which is currently more prevalent in the literature (see Kouider & Dehaene, 2007 for a review). Thus, the priming effects observed by Marcel might be explained by an underestimation of prime visibility, at least based on an objective threshold of awareness. Therefore, an eclectic approach with objective and subjective awareness concurrently measured, is preferable (Pasquali, Timmermans, & Cleeremans, 2010; Vermeiren & Cleeremans, 2012).

Wentura and Frings (2005) compared a standard (i.e., single prime) and a repeated masked prime condition and found the same level of awareness in both cases, but a significant priming effect only in the repeated condition. Importantly however, the two conditions were not strictly comparable, and this is problematic insofar as interpretation is concerned. In the repeated masked prime condition, primes and masks both lasted 14 ms (IPI = mask duration) and each appeared 10 times in quick succession. In the standard masked prime condition, the single prime lasted 28 ms and was followed by a mask of 14 ms and then by of blank of 243 ms. The target was presented 14 ms after the last prime repetition in the repeated condition, while it was presented 257 ms after the single prime in the standard condition. Thus, the activation evoked by the single prime could have already decayed substantially when the target was presented (Greenwald et al., 1996), and the prime itself was probably presented outside the temporal window of attention allocated to the target (Naccache et al., 2002). Both factors can explain the absence of a priming effect in the standard condition (i.e., single prime). Moreover, Avons et al. (2009) failed to obtain a priming effect despite using exactly the same repeated masking procedure.

Whether the repetition of a masked stimulus can increase its potency without increasing its availability to awareness thus remains an open issue. In this respect, it is worth reflecting upon the predictions that contemporary models of consciousness would make in this particular case.

Let us first consider higher-order theories (HOT) of consciousness (see Dienes, 2004, 2008; Lau & Rosenthal, 2011; Rosenthal, 2005), which most naturally align with the use of subjective measures to assess awareness. According to HOT, a representation is a conscious representation when the agent entertains, in a non-inferential manner, a higher-order thought to the effect that the target first-order representation exists. Crucially, the higher-order thought (or representation) does not need itself to be conscious. Its existence, however, makes the agent conscious of the contents of the target first-order representation. An important prediction of HOT is that the strength, or quality of a first-order representation can be wholly dissociated from the extent to which it is available to consciousness. Such a dissociation is precisely what is observed in cases such as blindsight or change blindness, in which high-quality stimuli fail to be available to form the contents of conscious awareness in spite of their strength. HOT accounts for such phenomena by invoking the lack of relevant higher-order thoughts: The stimulus thus elicits appropriate first-order representations, which nevertheless remain unconscious because they fail to be accompanied by relevant higher-order representations. HOT thus predicts that a graded, repetition-dependent increase in priming is possible in the absence of awareness, just as observed in both the Marcel study and in the Wentura and Frings study.

However, and in contrast, the results of both studies appear to be at odds with the predictions of other contemporary models of consciousness (e.g., Cleeremans, 2008, 2011; Dehaene & Naccache, 2001; Lamme & Roelfsema, 2000), most of which would instead predict that repeated presentations of the same masked stimulus should increase availability to awareness. Indeed, according to Lamme and Roelfsema (2000), in the absence of a mask, the neural activation elicited by the stimulus propagates forward in the brain until it reaches higher areas, which then send feedback to the lower areas by means of recurrent interactions. Such re-entrant processing is assumed to maintain stimulus activation and ensure their stability, hence enabling awareness. However, when a mask is presented immediately after a brief stimulus, re-entrant processing—and hence awareness—is interrupted because the stimulus-driven activation in the lower areas is replaced by activation from the mask, so resulting in an absence of coherent feedback. Thus, on this account, if a single masked stimulus is