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Conscious awareness is required for the perceptual discrimination of threatening animal stimuli: A visual masking and continuous flash suppression study

Emma J. Cox[a], Irene Sperandio[b], Robin Laycock[c], Philippe A. Chouinard[a,*]

[a] Department of Psychology and Counselling, School of Psychology and Public Health, La Trobe University, Melbourne, Victoria, Australia
[b] School of Psychology, University of East Anglia, Norwich, United Kingdom
[c] School of Health and Biomedical Sciences, RMIT University, Melbourne, Victoria, Australia

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ABSTRACT

We investigated if the subliminal processing of threatening animal (snakes and spiders) and neutral object (cars and houses) stimuli can influence the discrimination of a subsequent visible stimulus. The prime and target pair were either identical, of the same category but with different physical features, or different in category and physical features. In two experiments, participants discriminated the basic level category (e.g. snake vs. spider) of a visible target stimulus that had been preceded by a visible or perceptually invisible prime stimulus. One experiment used visual masking to render prime stimuli perceptually invisible and the other used continuous flash suppression (CFS). Priming effects were demonstrated in both experiments when the prime was visible but not when the prime was rendered perceptually invisible. These findings demonstrate that conscious awareness could be required in the perceptual discrimination of threatening animal and neutral object images at their specific basic level category.

1. Introduction

From an evolutionary perspective, the rapid visual processing of threatening animals and other dangers serves a highly adaptive purpose for humans (Öhman, 2009). Studies demonstrate that this processing can occur outside of conscious awareness. For example, physiological responses, such as enhanced skin conductance (Öhman, 2009; Ruiz-Padial, Mata, Rodríguez, Fernández, & Vila, 2005; Tan, Li, Wang, & Yang, 2013) and neural activation (Carlsson et al., 2004; Fang, Li, Chen, & Yang, 2016), have been reported to occur in response to subliminally presented snakes and spiders. The subliminal presentation of a stimulus occurs when its bottom-up signals are either interrupted or insufficiently strong to cross the threshold necessary for conscious perception (Dehaene, Changeux, Naccache, Sackur, & Sergent, 2006). It is not fully understood if this change in skin conductance and neural activation reflects the subconscious detection of a potentially dangerous stimulus, or the recognition and identification of the presented animal. Thus, we aimed to determine whether or not sufficient processing of information can take place during the subliminal presentation of a threatening animal to facilitate its identification in a subsequent visible presentation.

Visual masking and continuous flash suppression (CFS) are two techniques for presenting stimuli subliminally (for review, see Kim & Blake, 2005; Breitmeyer, 2015). Visual masking involves briefly presenting an image consisting of high-contrast noise 30–200 ms before and/or after a target (Breitmeyer & Öğmen, 2006), while CFS is an interocular technique in which a series of flashing high-

* Corresponding author.
E-mail address: P.Chouinard@latrobe.edu.au (P.A. Chouinard).

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contrast images, such as Mondrians, are displayed to one eye and a low-contrast target is displayed to the other (Tsuchiya & Koch, 2005). In both cases, the masks are perceptually seen while the target appears invisible. However, discrepancies in the literature have raised the concern that the two suppression techniques might lead to different residual neural processing and behavioural responses (Almeida, Mahon, Nakayama, & Caramazza, 2008; Almeida, Pajtas, Mahon, Nakayama, & Caramazza, 2013; Fogelson, Kohler, Miller, Granger, & Tse, 2014).

Often, the two suppression techniques are used during a priming paradigm (Van den Bussche, Van den Noortgate, & Reynvoet, 2009). In this context, a visible target is preceded by a prime that has been rendered perceptually invisible by means of either visual masking or CFS (Kouider & Faivre, 2017). The subconscious processing of the prime is inferred when it is able to influence the response to the subsequent target (Kiefer et al., 2011). In behavioural studies, this is evidenced by a decrease in reaction time and response error when the prime shares a common feature with the target (congruent prime) or by an increase in reaction time and response error when the prime does not (incongruent prime). Manipulating similarities and differences between the prime and target in either a visual masking or CFS experiment can provide insight into what can and cannot be processed subliminally (Kiefer et al., 2011).

Much debated is the extent to which subliminal priming reflects the processing of physical features (perceptual processing) or conceptual meaning (semantic processing) (Kouider & Dehaene, 2007). Studies have suggested that semantic and evaluative information such as valence can be extracted from a subliminally presented prime (Dell'Acqua & Grainger, 1999; Dehaene et al., 2001; Draine & Greenwald, 1998; Greenwald, Draine, & Abrams, 1996; Pohl, Kiesel, Kunde, & Hoffman, 2010; Wentura & Degner, 2010). For example, Dehaene et al. (2001) demonstrated repetition priming effects for words along similar semantic categories, independent of whether the prime and target stimuli shared the same or different case (e.g. radio-RADIO). However, it is possible that Dehaene et al. (2001) did not fully suppress the perceptual visibility of their primes. Some authors have suggested that semantic processing can be present when participants are partially aware of the prime and that true subliminal priming is restricted to perceptual processing (e.g. Kouider & Dupoux, 2004). Others have argued that the subliminal priming of words reflects automatically triggered response tendencies rather than the spreading of activation in a semantic network (Abrams & Greenwald, 2000; Damian, 2001; Klinger, Burton, & Pitts, 2000). Manipulating the amount of overlapping perceptual and semantic information between a prime and a target using pictures could yield further insight into perceptual and semantic computations outside of conscious awareness – provided that the primes are properly rendered perceptually invisible.

Under visible conditions, Chouinard, Morrissey, Köhler, and Goodale (2008) presented prime-target image pairs that were either: (1) the same exemplar of an object (i.e. the same object twice) in which the physical and semantic features were identical between the two stimuli, (2) different exemplars of the same object (e.g. an open versus closed umbrella) in which the physical but not semantic features differed between the two stimuli, or (3) completely different objects in which both the physical and semantic features differed between the two stimuli. When participants named the target stimulus, priming was fastest for same exemplars, slower for different exemplars, and slowest for completely different objects – demonstrating both perceptual and semantic priming effects. The question arises as to whether or not similar results can be obtained when the prime is presented subliminally.

It is generally accepted that the amygdala plays a key role in processing emotional stimuli and is critically implicated in physiological arousal as measured by enhanced skin conductance (Tan et al., 2013) to stimuli associated with fear (Costafreda, Brammer, David, & Fu, 2008). Neuroimaging studies have demonstrated evidence for amygdala responsiveness to subliminal images of threatening animals (Carlsson et al., 2004; Fang et al., 2016). For example, a positron emission tomography (PET) study by Carlsson et al. (2004) found strong amygdala activation during the subliminal presentation of both phobic (e.g. snake image for snake phobic participants) and fear-relevant stimuli (e.g. snake image for spider phobic participants). In contrast, when stimuli were perceptually visible, strong amygdala activation was found for phobogenic stimuli, but not for fear-relevant, potentially due to inhibitory control by the prefrontal cortex. This suggests an initial subconscious response to potentially threatening stimuli, which can be modulated by top-down control in non-phobic individuals, when consciously perceived.

However, these findings are contentious. Subsequent functional magnetic resonance imaging (fMRI) studies failed to demonstrate an amygdala response to subliminal threat-related images in non-phobic individuals (Hoffmann, Lipka, Mothes-Lasch, Miltner, & Straube, 2012), including masked spider images (Lipka, Miltner, & Straube, 2011). Instead, the latter study could only demonstrate amygdala activation to masked spider images in people with arachnophobia (i.e. fear of spiders). This subliminal amygdala activation was positively correlated with an individual's level of vigilance for spider stimuli (e.g. excessive environmental threat monitoring), leading Lipka et al. (2011) to propose that a lack of stimulus-specific vigilance in non-phobic individuals may explain the absence of differential amygdala response during subliminal processing.

It has been suggested that the amygdala responds to biologically critical stimuli to permit their rapid visual processing (Aldophs, 2008; Sander, Grafman, & Zalla, 2003), which facilitates the necessary physiological/behavioural responses preconsciously and helps determine if a stimulus will reach conscious awareness (Diano, Celeghin, Bagnis, & Tamietto, 2017). LeDoux (1995) proposed that sensory information is able to access the amygdala via two pathways: a slow cortical pathway known as the 'high' road, which involves processing by the primary sensory cortices, and a fast subcortical route known as the 'low' road, which bypasses the primary sensory cortices. Accumulating evidence from human and animal studies suggests that the latter pathway to the amygdala involves connections through the superior colliculi and pulvinar nuclei (Diano et al., 2017; McFayden, Mermillod, Mattingley, Halász, & Garrido, 2017). Indeed, studies examining subliminal processing using functional neuroimaging often report activation in these three areas in response to invisible stimuli (Jiang & He, 2006; Morris, Öhman, & Dolan, 1999; Pasley, Mayes, & Schultz, 2004; Troiani & Schultz, 2013).

Few behavioural priming studies have examined the subconscious processing of threatening animal stimuli. Under visible conditions, Haberkamp, Schmidt, and Schmidt (2013) examined the visual processing of spiders, snakes, and neutral stimuli in people