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Top-down and bottom-up factors in threat-related perception and attention in anxiety

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ABSTRACT

Anxiety is characterized by the anticipation of aversive future events. The importance of prestimulus anticipatory factors, such as goals and expectations, is well-established in both visual perception and attention. Nevertheless, the prioritized perception of threatening stimuli in anxiety has been attributed to the automatic processing of these stimuli and the role of prestimulus factors has been neglected. The present review will focus on the role of top-down processes that occur before stimulus onset in the perceptual and attentional prioritization of threatening stimuli in anxiety. We will review both the cognitive and neuroscience literature, showing how top-down factors, and interactions between top-down and bottom-up factors may contribute to biased perception of threatening stimuli in normal function and anxiety. The shift in focus from stimulus-driven to endogenous factors and interactions between top-down and bottom-up factors in the prioritization of threat-related stimuli represents an important conceptual advance. In addition, it may yield important clues into the development and maintenance of anxiety, as well as inform novel treatments for anxiety.

1. Introduction

Emotional stimuli require rapid adaptive responses, such as avoidance of threat or approach towards a rewarding stimulus. To allow for these swift behavioural responses, our perceptual and attentional system prioritizes emotional stimuli over stimuli that are relatively unemotional in nature. Spiders, snakes and angry faces are hypothesized to belong to a special class of stimuli that are perceptually prioritized due to their importance for survival (Brosch, Pourtois, & Sander, 2010; New, Cosmides, & Tooby, 2007; Seligman, 1971). Empirical research supporting this view shows that spiders and snakes are detected more rapidly than mushrooms and flowers (Ohman, Flykt, & Esteves, 2001) and. angry faces are detected faster than neutral faces (Hansen & Hansen, 1988; Horstmann, 2007). Saccadic eye movements orient more quickly to images of threatening compared to neutral faces and body postures (Bannerman, Milders, de Gelder, & Sahraie, 2009). Threatening stimuli shown rapidly in a stream of images are identified more accurately than neutral stimuli (Anderson, 2005). While positive stimuli may also be associated with similar perceptual benefits, the effects tend to be smaller than those elicited by threatening stimuli (Carretie, Mercado, Tapia, & Hinojosa, 2001; Dijksterhuis & Aarts, 2003; Smith, Cacioppo, Larsen, & Chartrand, 2003; Stefanics, Csukly, Komlosi, Czobor, & Czigler, 2012; Sussman, Weinberg, Szekely, Hajcak, & Mohanty, 2016).

The facilitated perception of threatening stimuli has been attributed to bottom-up processing driven by the physical characteristics or evolutionary significance of these stimuli (Bannerman et al., 2009; Ohman et al., 2001). In line with this view, research in affective neuroscience has centered on examining the neural pathways that promote 'automatic' perception of emotional stimuli (Fox, 2002; Mendez-Bertolo et al., 2016; Vuilleumier & Pourtois, 2007). It is hypothesized that threatening stimuli are prioritized due to a processing bias (Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, & van, 2007; Cisler, Bacon, & Williams, 2009). This processing bias is not measured directly, and instead is inferred from accuracy and reaction time differences between the detection of threatening compared to neutral stimuli. Depending on the design of the task, the threat bias is hypothesized to facilitate detec-

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tion of threatening stimuli in visual search and dot-probe-like tasks or impede performance when threatening stimuli distract from the task at hand (Mathews & MacLeod, 1994; Ohman et al., 2001). Here, we explore the possibility that in addition to processing biases that occur coincident with stimulus presentation, prioritized perception of threatening stimuli in normal function and anxiety may be attributed to *pre*stimulus biases.

The idea that prestimulus biases impact threat-perception is consistent with research indicating that the process of perception starts prior to an encounter with a stimulus, and with research demonstrating that perception is guided by top-down factors such as goals and expectations (Bacon & Egeth, 1994; Itti & Koch, 2001). For example, both implicit and explicit prestimulus cues improve target perception (Chen & Zelinsky, 2006; Wolfe, Butcher, Lee, & Hyle, 2003). Similarly, in day-to-day life, we often use both implicit and explicit emotional information to guide our perception, for example, while scanning for spiders in an uninhabited room filled with cobwebs. These anticipatory search behaviors, aimed at rapidly detecting sources of potential reward or threat, are deployed in a wide range of situations from driving on a highway to navigating social gatherings. Prestimulus biases may be of particular importance in anxiety, as dispositional anxiety is associated with overestimation of the likelihood and cost of future negative events (Aue & Okon-Singer, 2015; Grupe & Nitschke, 2013). The importance of top-down processes in anxiety has also been demonstrated by studies showing that threat-related cues impact subsequent perception differently depending on type of anxiety (Sussman, Szekely et al., 2016).

In the present review we first discuss the current affective neuroscience literature on exogenous, 'bottom-up' factors in understanding perceptual and attentional biases towards threatening stimuli, both in normal function and in anxiety. While research has examined the role of top-down factors that are non-emotional in nature (for e.g., searching for matching Gabor patches) and their interaction with bottom-up processing of emotional stimuli (for e.g., task-irrelevant emotional faces in the background), very few studies have examined top-down factors that are themselves emotional in nature (e.g., cues indicating an upcoming threatening face) and their effect on perception. Hence, we discuss conceptual and methodological issues in the research literature that arise from an exclusive focus on bottom-up factors in understanding prioritized perception of threatening stimuli. We then discuss the importance of endogenous, emotion-related 'top-down' factors, such as expectations and prior knowledge regarding threat, in guiding basic human perception. We also discuss emerging evidence that underscores the importance of endogenous processing in the perceptual prioritization of threatening stimuli both in normal function and in anxiety. Finally, we highlight the importance of shifting the emphasis from stimulus-driven to top-down mechanisms as well as their interaction with bottom-up mechanisms in the study of the perceptual prioritization of threatening stimuli both in normal function and in anxiety (Mohanty & Sussman, 2013).

2. Bottom-up processes influencing the perception of emotional stimuli

The human visual system is constantly bombarded with information. The limited capacity of this system makes it impossible to process all incoming information (Tsotsos, 1990). As a result, stimuli entering the visual field compete for neural representation (Desimone & Duncan, 1995; Tsotsos, 1997). To deal with this overwhelming excess of information, the visual system biases the competition between stimuli towards preferential representation of the most relevant stimuli (Desimone & Duncan, 1995). This biasing process is a function of two mechanisms: a bottom-up, sensory driven mechanism that selects stimuli based on their physical salience, and a top-down mechanism with variable selection criteria, which selects stimuli based on expectations, knowledge and goals. Unlike top-down mechanisms, bottom-up mechanisms are thought to operate by automatically shifting resources to salient visual stimuli. For example, stimuli that create a local discontinuity in the visual environment, such as abrupt occurrence of a new object (Jonides & Yantis, 1998), sudden motion and looming (Abrams & Christ, 2003; Franconeri & Simons, 2003), and luminance contrast changes (Enns, Austen, Di Lollo, Rauschenberger, & Yantis, 2001) are given more priority.

Similarly, emotional stimuli are considered another class of stimuli that are hypothesized to be processed in a bottom-up manner. For example, in visual search arrays, snakes and spiders are detected faster than flowers and mushrooms (Ohman et al., 2001); and angry faces are detected faster and more efficiently than neutral and happy faces (Eastwood, Smilek, & Merikle, 2001; Tipples, Atkinson, & Young, 2002). Threatening faces are also processed earlier and receive more perceptual elaboration compared to other facial expressions (Schupp et al., 2004). Furthermore, saccadic reaction times are faster towards an emotional compared to neutral faces and body postures (Bannerman et al., 2009), as well as towards emotional compared to neutral scenes (Nummenmaa, Hyona, & Calvo, 2009). Similarly, negative words are detected more accurately (Dijksterhuis & Aarts, 2003; Nasrallah, Carmel, & Lavie, 2009) and more quickly (Dijksterhuis & Aarts, 2003) than positive words. Attentional probes appearing in the same location as threatening faces are detected faster than probes appearing in the opposite location (Armony & Dolan, 2002; Mogg & Bradley, 1999; Pourtois, Grandjean, Sander, & Vuilleumier, 2004).

It is hypothesized that emotional stimuli are prioritized due to their salience, as proposed by appraisal, constructivist and, dimensional theories of emotion (Barrett, 2006; Brosch et al., 2010; Ellsworth & Scherer, 2003; Russell, 2003), or their physical characteristics, as demonstrated by perceptual prioritization of shapes associated with threats (Larson, Aronoff, Sarinopoulos, & Zhu, 2009; Larson, Aronoff, & Stearns, 2007). For example, in one study, participants were asked to detect and rate the valence of a discrepant threatening, happy or neutral schematic face in arrays of otherwise identical faces (Lundqvist & Ohman, 2005). The schematic faces were manipulated such that three, two or one feature(s) of the schematic face conveyed emotion. Results showed better visual search performance for more negatively rated faces, even if only one feature conveyed emotion, indicating that the threatening meaning of the face drives improved detection (Lundqvist & Ohman, 2005). On the other hand, researchers have hypothesized that the search advantage of threatening compared to neutral faces may be due to features such as upturned lip corners, open eyes, or frowning that can be discriminated from neutral features (Calvo & Nummenmaa, 2008; Larson et al., 2007). This could be because of the salience of the threat-related features, resulting from their association with the holistic facial expression they come from (e.g., Cave & Batty, 2006), or because of physical differences between features of threatening vs neutral faces regardless of emotional meaning. Finally, some researchers have hypothesized that it is the configuration of threatening facial features, such as shape and positioning of the mouth relative to nose and eyes that aids visual search (Calder, Young, Keane, & Dean, 2000; Carey & Diamond, 1977), others have concluded that specific features are responsible for improved detection (Calvo & Nummenmaa, 2008), and some studies have presented results supporting both positions (Lundqvist, Esteves, & Ohman, 2004).