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Directed attention reduces processing of emotional distracters irrespective of valence and arousal level☆

Stefan Wiens*, Elmeri Syrjänen

Department of Psychology, Stockholm University, Stockholm, Sweden

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ABSTRACT

Emotional stimuli tend to capture attention, and this so-called motivated attention is commonly measured using the early posterior negativity (EPN) and the late positive potential (LPP). We hypothesized that voluntary, directed attention reduces motivated attention more strongly for highly than moderately arousing pleasant or unpleasant pictures. Participants were instructed to direct their attention to either a picture at fixation or the letters flanking the picture. Pictures varied substantially in arousal and valence. When the pictures were attended to, EPN and LPP increased linearly with arousal. When the letters were attended to, these linear effects decreased in the EPN for pleasant and unpleasant pictures and in the LPP for pleasant pictures. Thus, directed attention decreases processing of emotional distracters more strongly for highly than moderately arousing pleasant and unpleasant pictures. These results are consistent with the view that directed attention decreases emotion effects on sensory gain.

1. Introduction

Interacting with the environment requires human beings to process an abundance of input from multiple stimuli in different sensory modalities. Although the human brain has limited processing resources (Marois & Ivanoff, 2005), selective attention can be directed at particular stimuli to facilitate their processing. Selective attention can be influenced by voluntary mechanisms (i.e., top down) or by stimulus-driven features (i.e., bottom up) (Yantis, 2008). In everyday life, voluntary, directed attention and stimulus-driven attention need to be kept in balance. For example, if you go to the supermarket with your two-year-old son, your attention cannot be directed exclusively to finding the items you want to buy, as you also need to keep track of your son.

Because stimuli in the environment differ in how important they are, they also differ in their ability to capture attention. Emotional stimuli are intrinsically important because they contain information that is relevant for survival. Clearly, an approaching predator or aggressive conspecific has strong and direct implications for survival (Öhman & Mineka, 2001; Öhman & Wiens, 2003). However, even food, erotic scenes, and babies are relevant for survival (e.g., ingestion, copulation, nurturing of progeny) and thus are highly salient stimuli (Brosch, Sander, Pourtois, & Scherer, 2008).

According to the *motivational model* of emotion (Bradley, 2009; Bradley, Keil, & Lang, 2012; Lang, Bradley, & Cuthbert, 1997; Lang & Bradley, 2010), perceptual processing is facilitated and action is prepared in response to emotional stimuli. These two processes are initiated by either the *defense* system or the *appetitive* system. The type and degree of activation is reflected in self-report ratings of the stimuli in terms of *valence* and *arousal*. Traditionally, valence is measured on a 9-point bipolar scale (<5 as unpleasant, 5 = neutral, >5 as pleasant), and arousal is measured on a 9-point scale (1 = low, 9 = high) (Bradley & Lang, 1994). An unpleasant valence rating implies that the defense system is activated, and a pleasant valence rating implies that the appetitive system is activated. Further, the arousal rating captures (roughly) the level of activation of either system (Lang & Bradley, 2010).

In the motivational model of emotion, the notion that emotional stimuli facilitate perceptual processing is commonly referred to as *motivated attention* (Lang et al., 1997), and alternative terms are *natural selective attention* (Bradley, 2009) and *emotional attention* (Pourtois, Schettino, & Vuilleumier, 2013). Motivated attention differs from directed (i.e., voluntary, top-down) attention in that it refers to selective attention that is driven bottom up by the emotional stimulus features (Lang et al., 1997).

One of the main consequences of directed (voluntary) attention is that it facilitates sensory processing through increases in gain control (Hillyard, Vogel, & Luck, 1998). Accordingly, directed

* Corresponding author at: Department of Psychology, Frescati Hagväg 14, room 130, Stockholm University, 106 91 Stockholm, Sweden. Tel.: +46 8 163933.
E-mail addresses: sws@psychology.su.se, stefanwiens@gmail.com (S. Wiens).

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attention amplifies sensory processing of attended stimulus features, and stimulus competition is biased, favoring attended features over unattended features (Desimone & Duncan, 1995). Whereas a frontal-parietal network mediates this gain control in directed attention (Corbetta & Shulman, 2002), there is strong evidence that the amygdala mediates a similar increase in gain control to emotional stimuli through its backward projections to sensory areas (Pourtois et al., 2013).

Although research has consistently demonstrated that attention is captured more strongly by emotional than neutral stimuli (Öhman, Flykt, & Esteves, 2001; Schimmack, 2005; Vuilleumier & Huang, 2009), it has been debated whether or not motivated attention to emotional distracters is a mandatory process or whether or not it can be reduced and even eliminated (Pessoa, 2005; Vuilleumier, 2005). In a classic fMRI study (Vuilleumier, Armony, Driver, & Dolan, 2001), two faces (either fearful or neutral) were shown left and right of fixation while two houses were shown above and below fixation (or vice versa). Participants performed a same-different judgment task on either the horizontal pictures or the vertical pictures. Activation in the fusiform face area decreased when faces were unattended. In contrast, amygdala activation was greater to fearful than neutral faces, and this emotional modulation was similar regardless of whether or not the faces were attended to. These findings suggested that the amygdala may extract the emotion signal in the fearful faces independent of directed attention (Vuilleumier, 2005). However, this interpretation was challenged by findings of another fMRI study (Pessoa, McKenna, Gutierrez, & Ungerleider, 2002). When faces were shown at fixation but participants performed a difficult line discrimination task, activation in the amygdala as well as the fusiform face area was eliminated. Therefore, this finding suggests that motivated attention to irrelevant distracters can be reduced, if not eliminated, by directing attention away from the emotional pictures (Pessoa, 2005).

The issue of whether motivated attention to emotion pictures is influenced (reduced or eliminated) by directed attention has been studied extensively using electroencephalography (EEG). Participants were typically instructed to keep their gaze on emotional pictures while attending to task-relevant, non-emotional aspects of the visual input. Stimulus material was mostly negative and neutral pictures from the International Affective Picture System (IAPS; Lang, Bradley, & Cuthbert, 2008). This picture set contains more than 1000 pictures that represent various motifs and that vary substantially across normative ratings of valence (positive and negative) and arousal. Studies have consistently found that electrocortical measures of motivated attention to task-irrelevant, emotional pictures are reduced if attention is directed away from the pictures, irrespective of whether the pictures are shown in the periphery (De Cesarei, Codispoti, & Schupp, 2009; Eimer, Holmes, & McGlone, 2003; Holmes, Vuilleumier, & Eimer, 2003; Keil, Moratti, Sabatinelli, Bradley, & Lang, 2005; MacNamara & Hajcak, 2009) or in the center of the screen (at fixation) (De Cesarei et al., 2009; Dunning & Hajcak, 2009; Hajcak, Dunning, & Foti, 2009; Holmes, Kiss, & Eimer, 2006; Nordström & Wiens, 2012; Sand & Wiens, 2011; Schupp et al., 2007; Wangelin, Löw, McTeague, Bradley, & Lang, 2011; Wiens, Sand, Norberg, & Andersson, 2011).

Most of this research recorded event-related potentials (ERPs) and measured the early posterior negativity (EPN) and the late positive potential (LPP) as indexes of motivated attention. The EPN is the negative amplitude difference between emotional pictures (either positive or negative) and neutral pictures about 200 and 300 ms after picture onset recorded by the occipitotemporal electrodes. The EPN appears to reflect a call for attentional resources (Schupp, Flaisch, Stockburger, & Junghöfer, 2006). This process apparently requires minimal stimulus input, as the EPN can be recorded for even briefly presented emotional pictures that are shown at a rapid rate (i.e., for 83 ms at 12 Hz) (Peyk, Schupp, Keil, Elbert, & Junghofer, 2009). Source localization of the EPN shows contributions from the occipital and parietal cortexes (Junghöfer, Bradley, Elbert, & Lang, 2001). Additionally, EPN amplitudes for emotional and neutral IAPS pictures correlate significantly with fMRI activations in the anterior cingulate and the amygdala but not with cortical regions (Sabatinelli, Keil, Frank, & Lang, 2013). These nonsignificant correlations with cortical regions may be explained by confounding influences of physical features on cortical responses. Specifically, the EPN can be difficult to measure because other stimulus features such as picture complexity (figure vs. scene composition) affect the ERP at roughly the same interval and electrodes (i.e., P2) (Bradley, Hamby, Löw, & Lang, 2007; Wiens, Sand, & Olofsson, 2011). These features may effectively mask the EPN. For example, if emotional pictures mainly depict scenes and neutral pictures mainly depict figures, a larger P2 to the (emotional) scenes than (neutral) figures may fully mask the EPN (Strien, Franken, & Huijding, 2009). However, if a representative subset of IAPS pictures is used, the EPN appears weakened but not eliminated (Wiens, Sand, & Olofsson, 2011). Although one study matched pictures on rated complexity and did not observe an EPN (Bradley et al., 2007), another study with a similar rating procedure obtained a clear EPN for both figures and scenes (Nordström & Wiens, 2012), which is consistent with other studies of the EPN that controlled picture complexity statistically (Junghöfer et al., 2001; Wiens, Sand, & Olofsson, 2011). Furthermore, because EPN amplitudes increase with arousal ratings for either pleasant or unpleasant pictures (Junghöfer et al., 2001; Schupp, Junghöfer, Weike, & Hamm, 2003), these findings support the motivational model of emotion—that is, greater activation of either the defense system or the appetitive system increases motivated attention (Bradley, 2009; Lang et al., 1997; Lang & Bradley, 2010).

The LPP is a positive amplitude difference between emotional pictures (either positive or negative) and neutral pictures starting about 300 ms after picture onset over the central-parietal electrodes (Cuthbert, Schupp, Bradley, Birbaumer, & Lang, 2000). Although the LPP can be observed even for neutral pictures, we use the term LPP (and EPN) to refer to amplitude differences between emotional pictures (positive or negative) and neutral pictures. Confounding effects of low-level features on LPP seem relatively minor (Wiens, Sand, & Olofsson, 2011). For both pleasant and unpleasant pictures, LPP amplitudes increase with arousal rating (Cuthbert et al., 2000; Schupp et al., 2003), supporting the theory that greater activation of either the defense system or the appetitive system increases motivated attention (Bradley, 2009; Lang et al., 1997; Lang & Bradley, 2010). LPP amplitudes to IAPS pictures correlate with fMRI activations in the lateral occipital, inferotemporal, and parietal visual areas (Sabatinelli, Lang, Keil, & Bradley, 2007). A subsequent study confirmed that LPP amplitudes correlate not only with fMRI activations in multiple dorsal and ventral visual areas but also with fMRI activations in the insula, anterior cingulate, ventral striatum/nucleus accumbens, and amygdala (Sabatinelli et al., 2013). Furthermore, a combined EEG/fMRI study suggests that the contribution of different areas varies with valence (Liu, Huang, McGinnis-Deweese, Keil, & Ding, 2012).

The LPP appears to reflect an allocation of attention resources (Junghöfer et al., 2001; Olofsson, Nordin, Sequeira, & Polich, 2008; Schupp et al., 2003). Consistent with this idea, when emotional and neutral pictures were interjected with target symbols that required a fast button press, larger LPP amplitudes to the emotional pictures correlated with longer reaction time to the targets (Weinberg & Hajcak, 2011) (see also Brown, van Steenbergen, Band, de Rover, & Nieuwenhuis, 2012). However, in another study (Ferrari, Bradley, Codispoti, & Lang, 2011), startle probes (i.e., 50-ms noise bursts) were presented during picture viewing to measure P3 amplitudes as an index of resource allocation to the irrelevant startle probes.