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Neural correlates of attentional deployment within unpleasant pictures

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ABSTRACT

Attentional deployment is an emotion regulation strategy that involves shifting attentional focus towards or away from particular aspects of emotional stimuli. Previous studies have highlighted the prevalence of attentional deployment and demonstrated that it can have a significant impact on brain activity and behavior. However, little is known about the neural correlates of this strategy. The goal of the present studies was to examine the effect of attentional deployment on neural activity by directing attention to more or less arousing portions of unpleasant images. In Studies 1 and 2, participants passively viewed counterbalanced blocks of unpleasant images without a focus, unpleasant images with an arousing focus, unpleasant images with a non-arousing focus, neutral images without a focus, and neutral images with a non-arousing focus for 4000 ms each. In Study 2, eye-tracking data were collected on all participants during image acquisition. In both studies, affect ratings following each block indicated that participants felt significantly less negative affect after viewing unpleasant images with a non-arousing focus compared to unpleasant images with an arousing focus. In both studies, the unpleasant non-arousing focus condition compared to the unpleasant arousing focus condition was associated with increased activity in frontal and parietal regions implicated in inhibitory control and visual attention. In Study 2, the unpleasant non-arousing focus condition compared to the unpleasant arousing focus condition was associated with reduced activity in the amygdala and visual cortex. Collectively these data suggest that attending to a non-arousing portion of an unpleasant image successfully reduces subjective negative affect and recruits fronto-parietal networks implicated in inhibitory control. Moreover, when ensuring task compliance by monitoring eye movements, attentional deployment modulates amygdala activity.

Introduction

Compared to neutral stimuli, emotional stimuli are detected faster (Öhman et al., 2001; Vuilleumier and Schwartz, 2001) and hold attention more efficiently (Lang et al., 1997). However, it is not always adaptive to attend to emotional information; involuntary attention to task-irrelevant emotional stimuli can slow reaction times and decrease accuracy (MacNamara and Hajcak, 2009; Vuilleumier et al., 2001). Indeed, being too attentive to negative information represents a cognitive vulnerability for psychopathologies such as anxiety and depression (Bar-Haim et al., 2007; Joormann, 2009).

People are capable of exerting control over reflexive responses to emotional stimuli by using a number of emotion regulation techniques. Attentional deployment, for example, is a strategy that involves shifting attention towards or away from affective stimuli in the interest of an emotional goal (Gross, 1998; Gross and Thompson, 2007). Attentional deployment is one of the earliest emotion regulation strategies to emerge in development: very young children use distraction to delay gratification (Mischel and Ayduk, 2011), and even grade school children are aware that changes in attention can change the way they feel (Harris and Lipian, 1989). The use of attentional deployment continues beyond childhood; adults shift attention away from negative parts of images to reduce negative affect even without instruction to do so (van Reekum et al., 2007; Xing, 2006). Older adults in particular seem to divert gaze away from negative information and towards positive information in the interest of regulating mood (Isaacowitz et al., 2006, 2009; Mather and Carstensen, 2005). Individuals who are able to successfully deploy attention away from negative, or towards positive, information appear to experience both improved mood and decreased frustration with difficult tasks (Johnson, 2009; Urry, 2010). These data suggest that attentional deployment is an effective strategy to regulate emotional response that emerges early and persists throughout the lifespan.

Previous studies have also shown that attentional deployment can have a dramatic impact on brain activity. A number of studies have examined the late positive potential (LPP), a centro-parietal event-related potential that is larger for emotional compared to neutral stimuli (Cuthbert et al., 2000; Schupp et al., 2000). To examine the impact of attentional deployment on the LPP, Dunning and Hajcak (2009) asked participants to passively view unpleasant and neutral images for 3 seconds, after which a circle was presented to direct

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participants to either an arousing or a non-arousing portion of an unpleasant image, or to a non-arousing portion of a neutral image. The LPP was larger in response to emotional images both during the passive viewing period and when attention was directed towards the arousing portion of the image, but not when attention was directed to a non-arousing portion of the same unpleasant image. In another study, Hajcak et al. (2009) found that using a tone, rather than a visual cue, to direct participants to an arousing or non-arousing portion of an unpleasant image produced an analogous effect—the LPP was reliably reduced when participants were instructed to attend to a non-arousing portion of unpleasant images. These findings are in concert with those reporting reduced LPP magnitude during cognitive reappraisal—a strategy that involves changing the meaning of emotional situations or stimuli in order to change emotional significance (Foti and Hajcak, 2008; Hajcak and Nieuwenhuis, 2006; MacNamara et al., 2009). This suggests that attentional deployment, even in the absence of a goal to intentionally modify emotional experience, can function to reduce neural indices of attention to emotion.

Nevertheless, relatively little is known about the specific brain structures and networks involved in attentional deployment. It is estimated that the LPP reflects activity in fronto-parietal attention networks (Moratti et al., 2004) and some have suggested it may also reflect indirect activity from the amygdala (Lang and Bradley, 2010), however the exact neural sources of the LPP are unknown. While it is clear that the LPP is reduced following attentional deployment, it is not clear what changes in brain activity support this reduction. Although fMRI would be an ideal avenue to explore the neural correlates of attentional deployment, thus far, the majority of fMRI studies of emotion regulation have focused on cognitive reappraisal. The neural systems associated with this strategy have been extensively studied and have culminated in a model suggesting that successful emotion regulation relies on interactions between prefrontal regions associated with cognitive control, and limbic regions such as the amygdala which have been associated with response to emotion (Ochsner and Gross, 2008).

In addition to prefrontal and limbic regions, many emotion regulation studies also report increased activations in regions related to visual attention and inhibitory control, such as the superior parietal lobule and the precuneus (Hopfinger et al., 2000; Pessoa et al., 2003). As fronto-parietal regions are critical for visuospatial attention and visual control, van Reekum et al. (2007) reasoned that activation in these regions might reflect shifts in gaze to achieve emotion regulatory goals even though participants were instructed to use cognitive strategies such as reappraisal. Changes in subject emotional experience due to cognitive reappraisal should occur as a result of changes in appraisal, rather than changes in attention. Using eye-tracking, van Reekum and colleagues found that when participants were instructed to use cognitive reappraisal to increase or decrease their emotional response to unpleasant pictures, they spent more or less time, respectively, looking at the most arousing portions of these images. Further, when participants were instructed to decrease negative emotion using cognitive reappraisal, the amount of time spent looking at arousing portions of the images predicted a significant amount of variation in neural activity, including up to 35% in the amygdala, and as much as 75% in other regions often reported in emotion regulation studies such as the middle frontal gyrus, the precentral gyrus, and the cuneus (van Reekum et al., 2007). Thus, attentional deployment may account for some, but not all, of the variance in neural activity associated with cognitive reappraisal. Indeed, subsequent studies have shown that cognitive reappraisal results in reduced autonomic arousal and subjective affect even when gaze is held constant (Urry, 2010). However, these findings highlight the importance of attentional deployment as an emotion regulation strategy and inspire questions regarding the underlying neural mechanisms.

The goal of the present study was to examine the effect of attentional deployment on neural activation and subjective affect while participants viewed unpleasant and neutral images in the absence of a regulatory goal. In Study 1, we collected eye-tracking data from a subset of participants (5 of 41) during scanning to assess task compliance. In Study 2, we collected eye-tracking data from all participants of a second independent cohort ($n = 47$). We avoided any explicit instruction to modify emotional state in an effort to understand the impact of visual attention alone on neural activation and affect. While previous studies have independently demonstrated that attentional deployment can have a significant impact on brain activity and behavior, the neural correlates of attentional deployment are not well understood, and it remains unknown whether successful attentional deployment relies on the same well-defined circuits as cognitive reappraisal. As previous studies have reported that attentional deployment during cognitive reappraisal accounts for at least some of the variance in activity in limbic as well as fronto-parietal regions (van Reekum et al., 2007), we hypothesized that these regions would also be involved in attentional deployment in the absence of other explicit regulatory goals (i.e. cognitive reappraisal). Specifically, we hypothesized that directing gaze to a non-arousing, compared to an arousing, portion of a unpleasant image would result in reduced activation in areas of the brain implicated in emotional processing, including the amygdala, and corresponding increases in fronto-parietal regions associated with top-down attentional control. We also collected subjective ratings of negative affect during the course of the experiment in both studies. We predicted that participants would report reduced negative affect during unpleasant non-arousing compared to unpleasant arousing focus trials, and that unpleasant arousing focus trials would not differ from unpleasant trials without a focus.

Study 1

Materials and methods

Participants

Forty-one healthy adults (22 females) with a mean age of 22.29 and no history of neurological or psychological illness were recruited to participate in the study. Participants self-identified as 53.7% Caucasian, 31.7% Asian, 9.8% African American, and 4.8% "Other." The study was approved by The Committees on Research Involving Human Subjects at Stony Brook University. All participants provided informed consent and received payment for their participation. Participants were native English speakers who had normal or corrected-to-normal vision and no history of neurological or psychiatric diagnoses.

Stimuli

Sixty unpleasant and forty neutral images from the International Affective Picture System (Lang et al., 2008) were selected for this study. Normative ratings (Lang et al., 2005) indicated that unpleasant images were less pleasant ($M = 2.28$, $SD = 1.47$) than neutral images ($M = 5.14$, $SD = 1.28$), and that unpleasant images were more arousing ($M = 6.05$, $SD = 2.25$) than neutral images ($M = 2.91$, $SD = 1.92$); higher numbers indicate higher self-reported pleasantness and arousal.

Stimuli were presented in a counterbalanced block design. Twenty unpleasant and twenty neutral pictures were presented without modification. For the remaining images, attention was directed to a smaller portion of the image by placing a blue circle over that portion. These images were taken from a set of stimuli created by Dunning and Hajcak (2009), along with 20 additional neutral images. For the neutral pictures, the blue circle was always placed over a non-arousing, but visually complex portion of the picture. For the unpleasant pictures, the blue circle was either placed over an arousing or non-arousing portion of the image. The procedure for selecting areas of focus is outlined by Dunning and Hajcak (2009). Therefore we had 5 conditions: neutral images with no focus, neutral images with a non-arousing focus, unpleasant images with no focus, unpleasant images with an arousing focus, and unpleasant images with a non-arousing focus.