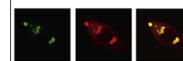


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Research Report

Human thalamic and amygdala modulation in emotional scene perception

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ABSTRACT

Emotional scene perception is associated with enhanced activity in ventral occipitotemporal cortex and amygdala. While a growing body of research supports the perspective that emotional perception is organized via amygdala feedback to rostral ventral visual cortex, the contributions of high-order thalamic structures strongly associated with visual attention, specifically the mediodorsal nucleus and pulvinar, have not been well investigated. Here we sample the activity of amygdala, MDN, pulvinar, and extrastriate ventral visual regions with fMRI as a group of participants view a mixed series of pleasant, neutral, and unpleasant natural scenes, balanced for basic perceptual characteristics. The results demonstrate that all regions showed enhanced activity during emotionally arousing relative to neutral scene perception. Consistent with recent research, the latency of emotional discrimination across subcortical and visual cortical regions suggests a role for the amygdala in the early evaluation of scene emotion. These data support the perspective that higher order visual thalamic structures are sensitive to the emotional value of complex scene stimuli, and may serve in concert with amygdala and fusiform gyrus to modulate visual attention toward motivationally relevant cues.

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1. Introduction

Meta-analyses of human functional magnetic resonance imaging (fMRI) studies demonstrate that emotional relative to neutral scene perception activates widespread ventral occipitotemporal and posterior parietal visual cortex, as well as anterior corticolimbic and subcortical structures (Kober et al., 2008; Sabatinelli et al., 2011). Models describing this “motivated attention” effect posit reentrant loops through which emotional stimuli are registered by rostral ventral

visual cortex and amygdala, prompting perceptual orienting, engaging associative networks, and mobilizing peripheral systems in preparation for action (Adolphs, 2002; Amaral and Price, 1984; Lang and Bradley, 2010; Davis and Whalen, 2001; Lang et al., 2008; Pessoa and Adolphs, 2010; Vuilleumier and Driver, 2007). Multiple lines of research support a reentrant perspective, including structural connectivity in the nonhuman primate (Amaral and Price, 1984; Freese and Amaral, 2005), intracranial recordings of human amygdala activity (Oya et al., 2002; Krolak-Salmon et al., 2004; Pourtois

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et al., 2010), fMRI analyses of patients with amygdala lesions (Vuilleumier et al., 2004; Bechara et al., 2000), as well as electroencephalographic (Keil et al., 2009; Pourtois et al., 2005) magnetoencephalographic (Rudrauf et al., 2008; Cornwell et al., 2008) and time-resolved fMRI measures (Sabatinelli et al., 2009) of emotional stimulus processing in healthy participants. However, higher-order thalamic structures (Guillery and Sherman, 2002) such as the mediodorsal nucleus (MDN) and pulvinar are densely interconnected with widespread regions of corticolimbic and primate visual cortex, as well as amygdala (Gaffan et al., 1993; Ray and Price, 1993; Shipp, 2003). In fact, a “multiple waves” model has been posited describing the pulvinar’s role in coordinating and refining affective processing in dorsal and ventral visual cortices involved in visual processing (Pessoa and Adolphs, 2010). In this model, the pulvinar both directly and indirectly innervates amygdala, which in turn innervates early ventral visual regions in accordance with a reentrant perspective of visual attention. In addition, recent fMRI work has linked higher-order thalamus to human visual selective attention (Saalmann et al., 2012), and aversive classical conditioning (Padmala et al., 2010).

However, while there is some evidence that MDN and pulvinar are associated with the processing of fearful faces (Morris et al., 1998; Ward et al., 2005; Vuilleumier et al., 2003) the role of these structures in human “motivated attention” to emotional scenes has not been explicitly tested.

In the current study we examine the contribution of thalamic nuclei to affective scene processing, along with more established emotional processing areas. Since previous studies have only associated thalamic nuclei in processing fearful faces, if thalamic nuclei are involved in emotional scene discrimination, we also aim to determine if they are modulated by emotional valence. Here we measured BOLD signal in a group of 27 participants as they viewed a series of pleasant, neutral, and unpleasant pictures, matched for simple perceptual characteristics. If higher-order thalamus contributes to the evaluation of emotional scenes, we could expect to see evidence of enhanced activity during the perception of pleasant or unpleasant, or both, relative to neutral scene perception. If the MDN and pulvinar do not demonstrate enhanced activity during emotional relative to neutral scene perception, these thalamic structures may not be modulated by the emotional quality of visual scenes, or their contribution may be beyond the sensitivity of standard fMRI methodology. Recent work has demonstrated early discrimination of emotional scene content in amygdala compared to other emotionally selective regions such as intraparietal sulcus and frontal eye fields (Sabatinelli et al., in press-a). Similarly, we might also expect to see earlier discrimination in amygdala than MDN pulvinar, should these regions demonstrate sufficient sensitivity to the emotional value of natural scene stimuli.

2. Results

2.1. Stimulus ratings

Valence and arousal ratings for the picture stimuli used here include normative ratings for the 20 picture stimuli selected

from the International Affective Picture System (IAPS; 1–9 scale, drawn from American undergraduate sample) as published in the IAPS technical manual (Lang et al., 1998), and differed reliably across valence (pleasant: 7.14, neutral, 5.88, unpleasant, 2.89; $F(2, 17)=69.00$, $p<.001$) with pleasant stimuli yielding higher valence ratings relative to neutral stimuli ($F(1, 10)=10.89$, $p<.01$), which yielded higher valence ratings relative to unpleasant stimuli ($F(1, 10)=30.80$, $p<.001$). Ratings of emotional arousal were also reliably different across pleasant (5.65), neutral (3.71), and unpleasant (6.34) stimuli ($F(2, 17)=14.70$, $p<.001$) with neutral stimuli yielding lesser ratings of emotional arousal relative to pleasant ($F(1, 10)=14.92$, $p<.01$) and unpleasant stimuli ($F(1, 10)=37.18$, $p<.001$), while pleasant and unpleasant stimuli did not reliably differ ($F(1, 14)=2.69$, $p>.1$). The remaining 20 pictures (assembled by our lab to be consistent with the IAPS stimuli) were rated equivalently by the subset of 8 participants viewing these pictures, and differed reliably across valence (pleasant: 6.67, neutral, 5.91, unpleasant, 2.40; $F(2, 14)=64.99$, $p<.001$) with pleasant stimuli yielding higher pleasantness ratings relative to neutral stimuli ($t(1, 14)=1.92$, $p<.05$), which in turn yielded higher pleasantness ratings relative to unpleasant stimuli ($t(1, 14)=8.78$, $p<.001$). Ratings of emotional arousal were also reliably different across pleasant (5.70), neutral (3.95), and unpleasant (6.72) stimuli ($F(2, 14)=21.02$, $p<.001$) with neutral stimuli yielding lesser ratings of emotional arousal relative to pleasant ($t(1, 14)=4.04$, $p<.001$) and unpleasant stimuli ($t(1, 14)=6.41$, $p<.001$), with unpleasant stimuli prompting greater arousal ratings relative to pleasant stimuli ($t(1, 14)=2.37$, $p<.05$).

2.2. Picture-driven activation in regions of interest

Fig. 1 depicts the results of random-effects ANOVA of picture-driven activity across the sample, at a FDR corrected threshold of $p<.05$. Significant activity was evident across the ventral visual system, the medial and posterior thalamus, and right amygdala. Table 1 lists the Talairach coordinates of the 6 ROIs sampled, the means and standard errors of peak BOLD signal change, and results of the repeated measures ANOVA assessing the effects of picture content on activity in each of the 6 ROIs. No effects of hemisphere in the 6 bilateral ROIs approached significance. All ROIs were significantly modulated by picture valence, and, as depicted in Fig. 2, shows significant quadratic trends demonstrating greater activity during emotionally arousing (pleasant and unpleasant) relative to neutral picture presentations (Table 2).

2.3. Timing of BOLD signal change across picture contents

The image volume at which BOLD signal discrimination of picture content was evident, as determined by non-parametric permutation tests (Maris, 2004; Maris and Oostenveld, 2007), is indicated by the arrow along the x-axis of time in Fig. 2, and demonstrates reliable modulation at 2s after picture onset in amygdala, and 4s after onset in all other ROIs.

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