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Effects of self-directed and other-directed introspection and emotional valence on activation of the rostral prefrontal cortex during aesthetic experience

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ABSTRACT

The medial area of the rostral prefrontal cortex (rPFC) has been implicated in self-relevant processing, autobiographical memory and emotional processing, including the processing of pleasure during aesthetic experiences. The goal of this study was to investigate changes in rPFC activity using functional near-infrared spectroscopy (fNIRS) in response to affective stimuli viewed in a self-relevant or other-relevant context. Positive and negative images were displayed to 20 participants under two viewing conditions where participants were asked to think of their own emotions (*self*) or think about the emotions of the artist who created the work (*other*). The results revealed an increase of HbO when participants viewed images during the other-condition compared to the self-condition. It was concluded that viewing stimuli from the perspective of another was associated with an increase of cognitive demand. The analysis of deoxygenated haemoglobin (HHb) at right hemispheric areas revealed that activation of the rPFC during the other-condition was specific to the negative images. When images were viewed from the perspective of the self, activation of the rPFC significantly increased at the right-medial area of the rPFC for positive images. Our findings indicate that the influence of valence on rPFC activation during aesthetic experience is contingent on the context of the viewing experience and there is a bias towards positive emotion when images are viewed from the context of the self.

1. Introduction

Q2 Understanding visual art involves processing aspects of the image in relation to the feeling and past experiences of the viewer. A painting of a harbour may be experienced as positive due to a general liking of boats and the sea or because the image evokes memories of a pleasant holiday. It is likely that naive viewers who are unfamiliar with artistic styles or the background of an artist draw from personal experience in order to impose meaning upon a work of art. Art experts, on the other hand, can draw upon their professional knowledge (e.g. style, technique, knowledge of the period or painter) in order to derive a level of meaning that is distinct from emotion or autobiographical memory (Leder et al., 2004; Leder, 2013). There is evidence from neuroscientific studies to support this distinction. Kirk et al. (2009) demonstrated that activation in memory-related areas, such as the hippocampus and precuneus, occurred only in art experts. Alternatively, Vessel et al. (2012) reported increased activation in the medial rostral prefrontal cortex (rPFC, BA10), an area related to emotional and self-relevant processing (Ochsner and Gross, 2005), during an evaluation of artworks that were experienced as intense by art naïve viewers.

The interaction between emotion and cognition during the processing of aesthetic experience has a long history. The level of interest in an object has been characterised as an interaction between affective stimulation and cognitive engagement (Engle, 1904). The biological process underpinning this interaction between cognition and emotion during aesthetic experience was explored by Berlyne (1960). More recently, cognitive and emotional aspects of the aesthetic experience have been investigated separately and in conjunction (e.g. Pelowski & Akiba, 2011; Silvia, 2012). It has been argued that the capacity to relate intellectually and emotionally to a work of art is rooted in an interpretation of meaning that is derived from experience (Freedberg and Gallese, 2007). Q3

This potential for a work of art to resonate with the person requires a capacity for reflection or empathy on the part of the viewer. The ability to understand those internal psychological

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states that motivate the behaviour of others is encapsulated by the Theory of Mind (ToM) perspective wherein empathy and perspective-switching is fundamental to one's ability to navigate the social world (Blakemore and Decety, 2001; Carruthers and Smith, 1996; Mahy et al., 2014; Spreng et al., 2013). One cornerstone of ToM is an assumption that the thoughts and feelings of others are estimated via an act of second-order processing designed to simulate the experience of another (i.e. putting oneself into another person's shoes) (Krienen et al., 2010; Völlm et al., 2006). In this instance, the perception of self is utilised in order to project a series of cognitive and emotional outcomes onto others.

Two neural systems have been implicated in ToM (see Mahy et al. (2014) for a review). The first is the Default Mode Network (DMN) which includes medial BA8/9, dorsal BA32/24, the temporoparietal junction, the lateral temporal cortex, the temporal pole, BA11, ventral BA32/24, the posterior inferior parietal lobule, the retrosplenial cortex, the parahippocampal cortex and the hippocampal formation as well as the posterior cingulate cortex and the rPFC (BA10). The DMN is traditionally associated with unstructured thought during rest phases (Buckner et al., 2008); however, recent work has linked DMN activity to ToM via self-referential information processing as well as autobiographical memory (Andrews-Hanna et al., 2010). Andrews-Hanna (2012) argued that the medial rPFC represents a 'hub' of interaction for processes related to self-related processing and autobiographical memory. In relation to the experience of art, Vessel, et al. (2013) argued that the DMN is implicated during aesthetic experiences because highly moving artworks 'strike a chord' with the viewer and this resonance activates the medial rPFC area.

The second system related to the ToM is the mirror neuron system (MNS), which co-activates actions, intention and emotions of both the self and others (Mahy et al., 2014; Molnar-Szakacs and Uddin, 2013; Spreng et al., 2013) and includes: inferior frontal gyrus, premotor cortex, anterior insula, primary sensory and primary motor cortices, superior temporal sulcus and rostral part of the inferior parietal lobule. This network may simulate the mental states of others by enabling a direct mapping of the actions, goals and intentions of others to the self. Understanding observed actions has been described as embodiment which is, in relation to the MNS, the simulation of another's physical action (see Gibbs (2006) for a discussion on embodiment and cognitive science). Molnar-Szakacs and Uddin (2013) have suggested that the DMN and MNS work together to provide a coherent representation of the self and of others by extension. The DMN may be activated during cognitive empathy or simulation of the mental state of another whereas activation of the MNS is related to embodiment (i.e. simulation of another's physical actions).

The rPFC appears to play a crucial role with respect to the integration of cognitive and emotional processes that are self-relevant (Lee and Siegle, 2012). Activation in medial PFC (including medial BA10) have been linked to the awareness of emotional valence (Amting, 2010), particularly of positive emotions and the awareness of appetitive behaviours during a picture rating task (Dolcos et al., 2004). Medial areas of the rPFC have also been associated with the processing of positive emotions within art. Vessel et al. (2012) found that only artworks that were seen as highly pleasing activated medial rPFC. Similarly, Kreplin and Fairclough (2013) identified increased activation of the medial rPFC using functional near-infrared spectroscopy (fNIRS) during viewing of visual art associated with positive affect.

Gilbert et al. (2006) suggested that the medial rPFC is involved in perspective taking whereas lateral areas of the rPFC are implicated in working memory or episodic memory. A recent meta-analysis revealed a ventral-dorsal gradient for activation in the PFC (Denny et al., 2012) where self-relevant processing was associated with activity in the medial, ventral and rostral PFC (ventral BA10 and BA11), whereas other-relevant processing activated the dorsal/medial area (dorsal BA10 and BA8/9) of the PFC. It is important to note that other studies found large overlaps of activation, particularly in BA10 located centrally between the ventral and dorsal areas, for self- and other-relevant processing (Araujo et al., 2013; Lee and Siegle, 2012; Spreng et al., 2013). Activation of the rPFC has also been associated with the processing of information that relates to close others such as family members or close friends (Benoit et al., 2010) as opposed to strangers (Krienen et al., 2010). On this basis, Krienen et al. (2010) suggested that the rPFC is part of an area related to the evaluation of social relations, such as identifying which persons are friendly/known, thus connecting activation of the rPFC with ToM.

It is hypothesised that the rPFC plays an important role in the processing of self-relevant information and understanding of mental states of others. A successful assessment and interpretation of emotional states includes a significant component of processes related to self and other (Amting, 2010). Afferent connections between medial rPFC and the amygdala support the sensitivity of the former emotional processing (Mitchell, 2011). For example, activation in the medial rPFC has been reported during modulation of positive and negative emotions (Mitchell, 2011), regulation of negative emotions (Kompus et al., 2009) and the experience of positive emotions (Dolcos et al., 2004; Viviani et al., 2010).

The purpose of the current study is to explore activation of the rPFC in response to positive/negative valence and self/other processing during the viewing of visual works of art. Activation of the rPFC has been demonstrated during the processing of visual art (Vessel et al., 2012) but it was unclear whether sensitivity of the region was due to sensitivity to emotional regulation or self-relevant processing related to ToM. The current study measured activation of the rPFC using function near-infrared spectroscopy (fNIRS). Participants were required to view artworks pre-rated as positive or negative with respect to emotional valence whilst reflecting upon emotional responses to the work either: (1) in relation to the self, or (2) in relation to another (the artist). It was predicted that medial rPFC would show greater activation (i.e. an increase of oxygenated haemoglobin and/or decrease of deoxygenated haemoglobin) when artwork was processed in relation to the self (Vessel et al., 2012, 2013). Furthermore, it was predicted that artwork associated with positive valence would result in greater activation of rPFC than images that elicited a negative emotional response (Kreplin and Fairclough, 2013).

2. Method

2.1. Participants

Twenty right-handed participants (10 female) with a mean age of 25.05 yr (s.d. 7 yr) were recruited from the student population at our university. All participants had no formal training in an art-related subject and no history of neurological disorder. Participants were informed about the procedure and operating mode of the fNIRS prior to providing written consent and received a £15 voucher for their time. All procedures were approved by the institutional Research Ethics Committee prior to data collection.

2.2. General procedure

Upon arrival, participants were informed about the nature of the study and provided written consent before the fNIRS device was fitted. Instructions were presented visually and participants had the opportunity to ask questions before and during four practice trials (two images per *self*/other condition). The experimental protocol began after the experimenter was satisfied that

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