The role of the rostral prefrontal cortex in the context of the aesthetic experience

By

Ute Kreplin

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Abstract

Background

The evaluation of visual art involves sensory, emotional and cognitive processes that lead to an aesthetic judgement or an aesthetic emotion (e.g. beauty). Aesthetic experiences are multisensory processes that undergo a variety of stages. Early processes occur in the visual and sensory cortices, and are central to object identification that may be no different from visual experiences of everyday objects. Later processing stages are related to complex human thought consisting of emotion and cognition that involve areas such as the orbitofrontal cortex, hippocampus and prefrontal cortex (PFC). The later stages are concerned with the comprehension and meaningful analysis of the artwork that contribute to the formation of an aesthetic judgement or emotion.

This thesis aims to investigate affective evaluations and their interactions with cognitive processes during the later processing stages of the aesthetic experience in the rostral prefrontal cortex (rPFC). The role of the rPFC will be explored using functional near-infrared spectroscopy (fNIRS) with reference to existing frameworks. Specifically: hemispheric asymmetry in the processing of emotional stimuli, the Gateway Hypothesis and the Default Mode Network will be explored.

Experimental Work

A database of sixty images was created in an online survey (chapter 3) at the beginning of the experimental programme. Images were rated online (N = 1028) for complexity, comprehension, novelty, activation, attraction and valence providing stimuli that could be systematically manipulated according to their psychological properties in the experimental studies.

The first hypothesis (is the rPFC involved in early perceptual processes such as complexity during aesthetic experience?) was addressed in a pilot study (chapter 4) and repeated in the first experimental study (chapter 5). Both cognitive (high/low complexity) and emotional (positive/negative valence) aspects of the images were manipulated. Images

were shown for sixty second and analysed in three time periods (early, middle and late) each consisting of twenty seconds. The results showed an interaction between valence and time with positive images yielding greater activation in the early period and negative images in the late period. This highlighted the importance of long exposure times to capture the aesthetic experience.

The second hypothesis (is the rPFC involved in implicit memory formation such as the comprehension of an image during aesthetic experience) was investigated in chapter 6 where the levels of comprehension (high/low) and postive/negative valence associated with the viewed image were manipulated. An interaction between comprehension and valence was found with respect to rPFC activity. Positive easy to comprehend images and negative difficult to comprehend images yielded greater rPFC oxygenation. These findings indicated that the experience of pleasure in positive artworks and increased cognitive effort during the resolution of uncertainty or threat in negative artworks is related to rPFC activation.

The third hypothesis (is the rPFC involved in prospective memory during aesthetic experience?) was investigated in chapter 7 where positive and negative artworks were shown under two conditions. Condition one asked participants to introspect about their emotions and condition two to direct their attention to features in the image through a spot-the-difference task. A main effect of emotion was found, but no interaction or effect for condition. Greater rPFC activation was found during the contemplation of positive images. This may be attributed to pleasantness experienced in relation to these images.

The last question (is the rPFC involved in self-referential processing and is this important to aesthetic experience?) was investigated in chapter 8 where participants viewed negative and positive images under two viewing conditions. Condition one asked participants to introspect about their own emotions (*Self*) and condition two about the artist's emotions at the time of painting (*Other*). The o*ther*-condition resulted in overall greater rPFC activation indicating that participants found it more challenging to think of another's emotions. An interaction showed greater rPFC activation for positive images in the *self* -condition and greater activation for negative images in the *other*-condition. This may have been the result of a positive bias and the detection of self-relevance in positive images and the analysis of threat or uncertainty in negative images.

Conclusions

This thesis used a cognitive model of the aesthetic experience as a framework to understand the interaction between emotional and cognitive processes in the formation of an aesthetic judgement or emotion. No evidence for asymmetrical processing of emotional stimuli, or the Gateway Hypothesis was found. The research reported here indicates that the rPFC has an important role during the later processing stages of the aesthetic experience. Viewing negative visual art activated rPFC when the images were difficult to comprehend and when participants thought about the artist's feelings. Positive emotions, on the other hand, activated rPFC when the images were easy to comprehend and when participants thought about their own feelings. The contemplation of visual art was continuously associated with medial rPFC activation, indicating that the rPFC has a key role in self-relevant processing of visual art. The rPFC may aid personal value judgements of visual art (e.g. this artwork means xyz to me) because this area of the brain mediates the interaction between self-relevance, autobiographical memories and continuously changing emotional states.

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Glossary

AM	Autobiographical Memory
ANOVA	Analysis of Variance
BA	Brodmann Area
BV	Blood Volume (HbO + HHb)
CW	Continuous Wave
dlPFC	dorsolateral Prefrontal Cortex
DMN	default mode network
dmPFC	dorsomedial Prefrontal Cortex
EEG	Electroencephalography
fEMG	facial Electromyography
fMRI	functional Magnetic Resonance Imaging
fNIRS	functional Near-Infrared Spectroscopy
HbO	Oxygenated haemoglobin
HHb	Deoxygenated Haemoglobin
IAPS	International Affective Picture System
I-SKE	Intensions - Sensations, Knowledge, Emotions
LRP	Laterised Readiness Potential
ANOVA	Multiple Analysis of Variance
MBLL	Modified Beer-Lambert Law
MEG	Magnetoencephalography
MNS	Mirror Neuron System

PET	Positron Emission Tomography
OFC	Orbitofrontal Cortex
Oxy	Oxygenation (HbO – HHb)
PFC	Prefrontal Cortex
pix	Pixel
ROI	Region of Interest
rPFC	rostral Prefrontal Cortex
s.d.	Standard Deviation
ToM	Theory of Mind
vlPFC	ventrolateral Prefrontal Cortex
vmPFC	ventromedial Prefrontal Cortex
VT	Viewing Time

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1. Introduction

This introduction will cover relevant background research for the thesis and is organised into four sections. The first section, 1.1 The Aesthetic Experience, will cover definitions and general frameworks of the aesthetic experience. The second section, 1.2 The Psychology of Aesthetics, will elaborate on specific hypothesis such as processing fluency, and cognitive models of the aesthetic experience. The third section, 1.3 Neuroaesthetics, will provide a review of neuroaesthetics. Although some aspects, such as aesthetic emotions have received considerable attention in the literature cognitive and emotional process that underlie aesthetic experiences and lead to the formation of an aesthetic judgement or emotion are less well understood. Lastly, the fourth section, 1.4 The Anatomy and Functions of the rostral Prefrontal Cortex, will elaborate on the role of the prefrontal cortex and functions that have been associated with the rostral prefrontal cortex (rPFC) specifically.

1.1 The Aesthetic Experience

The term 'aesthetics' has been discussed extensively over the past two decades by artists, art critics and historians, philosophers, psychologists and recently neuroscientists. Definitions of this term vary according to subject and historical content (Shimamura, 2012). Philosophical approaches to the perception of art have considered four aspects of an aesthetic experience:

1. how successfully the artwork mimics the sensory experience of looking at the real world as if through a window (i.e. realism)
2. the extent to which the image or object expresses feelings and a sense of beauty (i.e. capacity of an artwork to create an emotional experience)
3. how well they create significant form (i.e. how well does an artwork enhance sensations purely through the aesthetic interplay of colours, lines, texture and shapes?)
4. capacity of artwork to convey conceptual statements (i.e. how well does an artwork communicate meaningful information?)

These four aspects can be combined to provide a framework for the aesthetic experience that offers a multi-sensory framework for aesthetic experiences (Shimamura, 2012).

The study of a multi-sensory aesthetic experience can be approached from three different positions; the artist, the artwork and the perceiver. Shimamura (2012) developed a framework termed I-SKE that refers to the artist's intention to offer an artwork for aesthetic evaluation and the viewer's three mental components, sensation, knowledge and emotion (i.e. Intentions – Sensations, Knowledge, Emotions). This framework describes the artist's intention to offer an artwork for aesthetic evaluation and the viewer's perceptual processes of sensation, knowledge (cognition) and emotion (Figure 1.1). This thesis will focus exclusively on the experience of the viewer of the artwork as opposed to the intentions of the artist or what art is. The main concern is how art is experienced, which may be understood by considering the ways in which an artwork influences emotion, sensation and cognition.

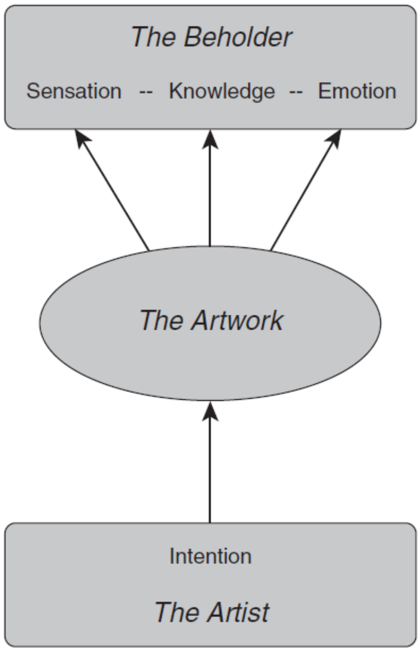

Figure 1.1 The I-SKE framework acts as a schema for experiencing art. The artist intends to create the artwork, which is experienced by the viewer, who uses sensations, knowledge, and emotion to generate an aesthetic experience. These three components of the viewer's psyche drive the art experience. (Taken from Shimamura, 2012:24).

The study of the viewer's subjective experience and the aesthetic object is called neuroaesthetics (Zeki, 1999a) which strives to understand the neural underpinnings of the aesthetic experience. The viewers' perception of artworks contains two assumptions that ought to be considered in neuroaesthetics; 1) aesthetic experience has multiple components, and 2) an aesthetic experience is not a response to a single component but rather it is derived from responses to different components of a visual object (Chatterjee, 2004). Chatterjee (2004) suggests that the neuroscience of vision can provide a framework under which neuroaesthetics can be studied (Figure 1.2). He highlights that the nervous system processes visual information both hierarchically and in parallel. Stages of visual information processing can be classified as early, intermediate and late vision. Early vision extracts simple components; intermediate vision groups these simple components together to form coherent concepts in what would otherwise be a chaotic and overwhelming sensory array and late vision directs attention and integrates old and new information to form meaning. Early and intermediate visions proceed automatically, seemingly without effort, and can be regarded as universal. Late vision on the other hand is inherently linked to selective attention and the regulation of attentional processes. This late stage evokes memories from which objects are recognised and meanings attached. In the aftermath of object recognition, emotions may be evoked and decision about the objects (e.g. will I eat it/grasp it etc.) can be made. Late vision always follows early and intermediate vision, but is a process that is shaped by culture and personal experience. Therefore, early and intermediate vision processes form whereas late vision processes content.

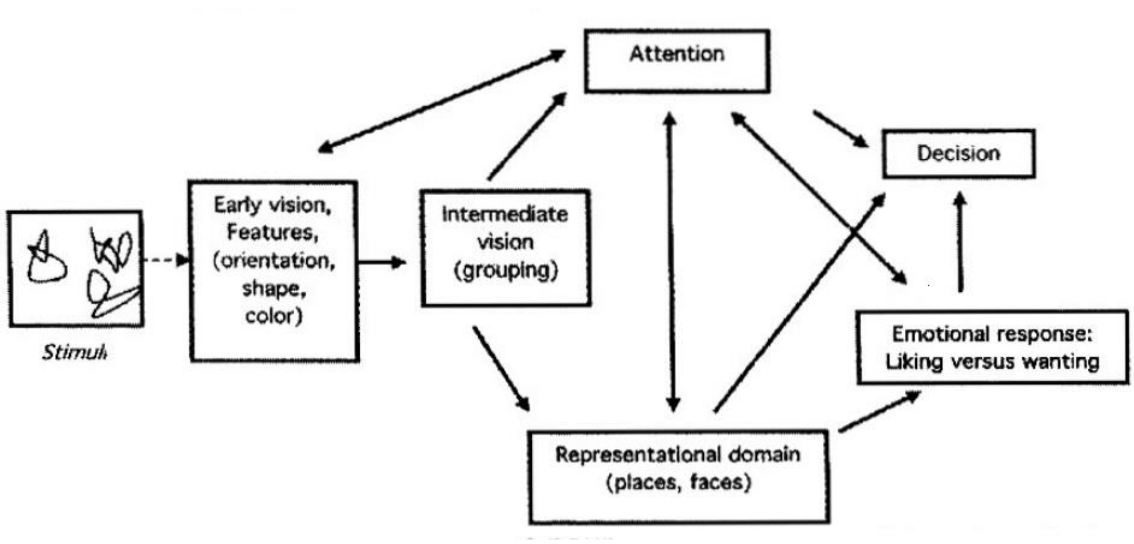

Figure 1.2 A general framework for the neural underpinnings of visual aesthetics guided by visual neuroscience. (Taken from Chatterjee, 2004).

This thesis will use a broad definition of the aesthetic experience similar to that used by Di Dio and Gallese (2009) who state that: "an aesthetic experience is one that allows the beholder to 'perceive-feel-sense' an artwork (from the Greek aisth-ese-aisthanomai), which in turn implies the activation of sensorimotor, emotional and cognitive mechanism" (2009: 682; italics in original). The focused will be on late visual processes and the processing of art on a conceptual level including cognitive, emotional and memory processes as opposed to early and intermediate visual elements (Figure 1.2).

Furthermore, this thesis will limit itself to the discussion of static visual art and therefore exclude aspects of film, music, dance or other mediums that may be classified as art.

1.2 Psychology of Aesthetics

Early theorists of the aesthetic experience, such as Plato, Kant and Fechner were concerned with the study of beauty which is still an essential part of the psychology of aesthetics and neuroaesthetics (Jacobsen, 2006). The search for a neural base of beauty has centred on the idea that beauty and the aesthetic value are in the perceiver rather than in the object (e.g. Zeki, 1999). The notion of beauty as an experience that originates in the perceiver rather than the object was first proposed by Kant in his publication Critique of the Esthetic Judgement (Kawabata & Zeki, 2004). Kant's publication marked an important change in the approach to the study of beauty because it was no longer object dependent, but a part of the individual; this change allowed the formulation of testable hypothesis about neural pathways that are relevant to the experience of beauty in the human brain (Kawabata & Zeki, 2004).

The study of aesthetics in psychology can be traced back to Fechner's Vorschule der Aesthetic in 1876 in which he argued for an 'aesthetics from below' in which objective knowledge about an artwork or the experience of beauty was derived from sensory processes (Fechner, 1876; Jacobsen, 2006). Fechner's influential work paved the way for modern aesthetic research and some of his ideas, for instance the notion that an aesthetic experience can be understood through the study of basic perceptual processes such as symmetry or colour preference, remain prominent today. However, Fechner's work addressed processes that are relevant to early and intermediate visual processing to the exclusion of the late processing stage described by Chatterjee (2004). Recent theories within the psychology of aesthetics (e.g. the information-processing model described by Leder, Belke, Oeberst, and Augustin, (2004) discussed below) have developed to incorporate different types of processing that include cognitive as well as sensory processes.

Leder et al. (2004) proposed an information-processing model that endeavoured to account for the cognitive as well as sensory processes within the aesthetic experience. This model intends to account for cognitive as well as emotional factors beyond the perception of beauty, by proposing that “the aesthetic experience is a cognitive process accompanied by continuously upgrading affective states” (Leder et al., 2004:493). Therefore, the emotional and cognitive understanding of artworks represents the main components of the aesthetic experience.

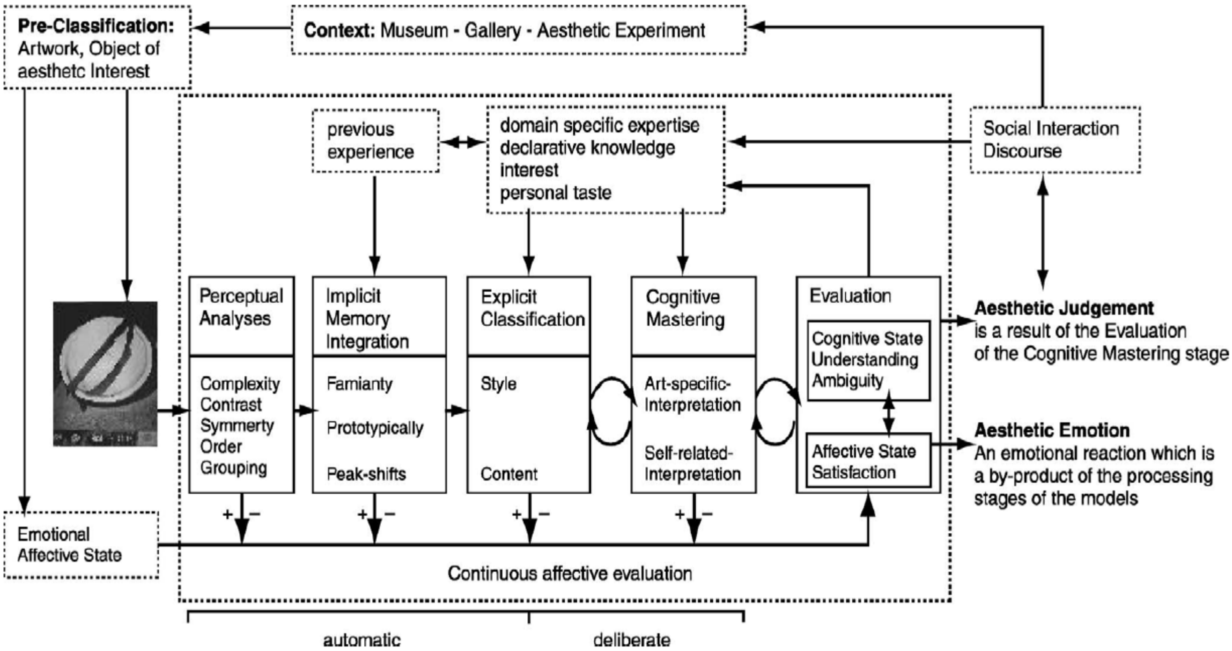

Figure 1.3 A model of aesthetic experience. (Taken from Leder et al., 2004:492).

This information-processing model proposes five distinct stages that are concerned with different cognitive analysis (Leder et al., 2004; Figure 1.3). Outside influences such as contextual information or social interaction may influence the processing order of the five stages, often creating interactions between them. The five stages are:

1. perceptual analysis
2. implicit memory integration

3. explicit classification
4. cognitive mastering
5. Evaluation

Perceptual analysis refers to earlier visual processing of the complexity, symmetry or order of the image. This analysis leads to implicit memory integration which deals with aspects of familiarity and both stages are performed unconsciously. Conscious awareness of evaluative processes associated with the artwork only becomes apparent during the third stage of explicit classification process when viewers will start to assign aspects of style and content to the image. This classification leads to cognitive mastering where the image is interpreted in the context of art-specific knowledge (i.e. what does the image mean in relation to other art from this painter/stylistic category) or self-related knowledge (what does this image mean to me). The final stage, evaluation, is concerned with the cognitive and emotional evaluation of the artwork which leads to an aesthetic judgement and emotion associated with an aesthetic experience.

Leder et al. (2004) suggested that the nature of emotional and aesthetic judgment is determined by the expertise of the viewer. Emotional and aesthetic judgment may be separate processes in the expert (e.g. judging a work as dissatisfactory but gaining pleasure from the experience of deriving this judgment) but these judgements are combined in the naïve viewer (e.g. finding an emotional connection to an artwork because the image displays a beautiful landscape that is liked). Leder et al. (2004) also made a distinction between two types of emotional experiences, the continuous affective evaluation and the aesthetic emotion. The affective evaluation refers to a continuously changing feedback loop that accompanies the cognitive processing stage and can be negative or positive or an interaction of both. Aesthetic emotion on the other hand is the satisfaction with the overall evaluation of the artwork and is usually a feeling of pleasure or beauty. Although this model incorporated emotional experiences of artwork into the aesthetic experience, it was mainly focused on cognitive processing and few details were provided on the function of the continuous affective states experienced during evaluation of the artwork.

The first two stages of Leder et al.'s (2004) model were concerned with aspects related to early and intermediate processes that were described by Chatterjee (2004; Leder, 2013). The first stage describes early visual processing that takes in sensory information such as colour recognition, symmetry or line style (i.e. curves, straight lines etc.), but it also overlaps with intermediate vision through ordering and grouping of the visual information which is continued in stage two through implicit memory associations. Aesthetic pleasure derived within the first two stages of Leder et al.'s (2004) model has been described in relation to processing fluency which is defined as the ease with which information flows through the cognitive system (Reber, 2012; Reber, Schwarz, & Winkielman, 2004).

The concept of processing fluency assumes that scenes that are easily processed create mild positive affect which is interpreted as aesthetic pleasure. Reber et al. (2004) described two aspects of processing fluency: perceptual fluency and conceptual fluency. Perceptual fluency is related to early visual process and aims to account for preferences towards symmetrical patterns, high contrasts and round edges. Symmetrical patterns are easier to detect than asymmetrical patterns, high contrasts are perceived more easily than low contrasts; and round edges are perceived more easily than jagged edges. Fluency on a perceptual level is therefore facilitated by the architecture of the human brain that detects some aspect of the environment easier than others (for a review see Reber, 2012).

Conceptual fluency relates to implicit memory associations (stage two in Leder et al.'s (2004) model), particular to familiarity or the ease of which objects/concepts within scenes are recognised. Prior exposure to objects or events within an image facilitates recognition and increases the ease with which an image is processed compared to those objects or events that are novel. Reber et al. (2004) argued that it is not necessary to see an exact repetition of the object or event in order to facilitate subsequent processing. It suffices to see examples of a particular object (e.g. a Chinese vase) or rules that follow a particular artistic style (e.g. expressionism) to identify new objects that are similar to that seen before to facilitate processing. When new images follow the same artistic rules as known representations, both can be classified as belonging to the same category and therefore induces a sense of familiarity. However, there are a number of challenges and limitations to this concept of processing fluency. Artistic styles may deliberately break fluent processing on a perceptual level. Modern styles in particular (such as cubism), aimed to break processing fluency to bring aesthetic experiences to their audience (Palmer, Schloss, & Sammartino, 2012), but does this breaking of convention fails to diminish the aesthetic pleasure derived from cubist paintings? Reber (2012) argued that fluent processing signals to the viewer that things are familiar and that ongoing cognitive processes are fluent, whereas difficult processing indicates that things are not fluent and additional attention is needed in order to resolve an interpretation. Reber (2012) provided convincing evidence that the speed of information processing is impeded and arguably information processing becomes more deliberate if information is more difficult to process but he does not describe whether the resulting aesthetic judgement is less aesthetically pleasing than one obtained from images that are processed fluently. A second limitation relates to the familiarity of the object, and conceptual fluency. What happens if an image, object or style becomes too familiar in the eyes of the viewer? Reber (2012) argued that familiarity only creates positive affect if that familiarity is not consciously perceived as such by the viewer and is consequently unexpected. A positive feeling towards an artwork, for example, may be experienced because it feels familiar provided the viewer is not aware of this familiarity. Positive affect is saturated and replaced by boredom if the familiarity of an object is consciously known to the viewer. The theory therefore does not account for a loss of interest in images that are too well known nor for interest in images that are liked because they are well known. Lastly, processing fluency struggles to account for images that are negative in affect. Thus, negative images may be easy to process, but they are not necessarily associated with positive affect or pleasant aesthetic experiences. Reber (2012; Belke, Leder, Strobach, & Carbon, 2010; Leder, 2013) acknowledged this discrepancy but only suggested that negative affect associated with content may override the mild pleasant emotion experienced as a result of processing fluency.

Emotional dimensions of the aesthetic experience were first investigated by Berlyne in the 1960s and 1970s. He studied the influence of image complexity, novelty, uncertainty and arousal on the aesthetic experience (e.g. Berlyne, 1960). Berlyne was also the first researcher to measure physiological changes during aesthetic experiences. He maintained that physiological arousal was directly linked to motivational drives that were influenced by cognitive factors such as the complexity or novelty of the stimulus. Berlyne suggested that increased complexity resulted in higher activation of a primary reward system, generating positive affect and increasing exploratory behaviour. However, a primary aversion system is activated if the stimulus under consideration becomes too complex resulting in negative affect and an inhibition of exploratory behaviours. This dynamic results in an inverted U-shaped relationship between preference and exploration (i.e. curiosity) towards the object (Berlyne, 1960). However, Berlyne's research did not always find a U-shaped effect of pleasantness and complexity (or aspects such as novelty or familiarity) and sometimes the relationship was linear or asymptotically increasing (Silvia, 2008).

Aesthetic emotions have been discussed in relation to appraisal theories of emotions (Silvia, 2001; 2007; 2008; 2010). These theories postulate that emotions are experienced because they are either congruent or incongruent with a person's goal or intrinsic values (Scherer, 2001). Emotions are the result of cognitive appraisal of situations in relation to one's inner goals and values. Silvia (2001; 2008; 2010) argued that knowledge emotions such as surprise, curiosity or interest are particularly important during the aesthetic experience. Interest, for example, is appraised in two stages. First an artwork is appraised as new, unexpected, conflicted and unfamiliar; secondly the ability to understand the new and complex thing is assessed. Appraisal theories refer to this process as coping potential (Silvia, 2010). Interest is therefore experienced if something is seen as new and as comprehensible. Similarly, positive emotions are experienced if the object (or artwork in this instance) depicts an event or stimulus that is coherent with one's own goals or values, and negative emotions are experienced if the content of the artwork contrasts with personal goals and values. The key point of Silvia's appraisal of emotions within an aesthetic context is that it does not rely on the object to create the feeling towards the artwork. Rather, this model relies on the personal experiences, values and goals of the individual that determine how the artwork is appraised. Appraisal theory is also positioned between step 5 (explicit classification) and 6 (cognitive mastering) of Leder et al.'s (2004; Figure 1.3) model.

Great emphasis has been placed on research of cognitive processes of the aesthetic experience and on aesthetic emotions such as beauty, which are often a result of these processes. Relatively little however is known about continuous affective evaluations and how these interact with the different cognitive processing stages described in Leder et al.'s (2004) model.

1.3 Neuroaesthetics

Neuroaesthetics strives to identify neural processes within the brain that are underlying the aesthetic experience. Areas of activation that have been related to aesthetic experience span a wide network distributed over both hemispheres and include the visual cortex, premotor cortex, temporal cortex, prefrontal areas and subcortical regions such as the hippocampus, amygdala, thalamus, caudate and substantia nigra (Nadal and Pearce (2011) for a review). Activation has also been identified during the experience of aesthetic emotion (e.g. beauty) in emotion-related areas such as the insula (Cupchik, Vartanian, Crawley, & Mikulis, 2009; Di Dio, Macaluso, & Rizzolatti, 2007), areas related to reward processing such as the orbitofrontal cortex (OFC) (Kawabata & Zeki, 2004; Lacey et al., 2011; Vartanian & Goel, 2004a), and pleasure processing subcortical regions such as the parahippocampal cortex (Yue, Vessel, & Biederman, 2007).

Processing stage models, as described by Chatterjee (2004) or Leder et al. (2004), can be used to understand neural processes underpinning the aesthetic experience. Early processing stages occur automatically and are not unique to aesthetic experiences, whereas late processing stages are necessary to define an aesthetic experience (Cupchik et al., 2009; Höfel & Jacobsen, 2007). Cupchik et al. (2009) proposed that the perception of art is concerned with stylistic and structural properties compared to everyday perception which is concerned with object identification. They argued that aesthetic experience requires the suppression of object identification in order to focus attention on the stylistic features of the artwork. The refocusing of attention suppresses automatic cuing of semantic categories (e.g. identifying individual objects such as an apple) to reinvest attention in sensory experiences elicited by the stylistic and affective properties of art. Deliberate cognitive control, a process associated with the PFC, is primed toward the attenuation of object identification and may be necessary to engage with art. Research by Augustin, Defranceschi, Fuchs, Carbon, and Hutzler (2011; see also Höfel & Jacobsen, 2007) supports this hypothesis. Augustin et al. (2011) investigated two aspects defined as central to the evaluation of representational art: object identification and extraction of stylistic features in an Electroencephalography (EEG) study. The authors investigated the lateralised readiness potential (LRP), an increase in electrical activity of the brains surface in preparation for response selection, between the availability of stylistic compared to object related information. The LRP response to stylistic information occurred approximately 40 – 94ms later than the equivalent response for object related information. The change in attention from everyday object recognition to stylistic features of the artwork suggests that the PFC is a critical structure for orienting cognitive and perceptual processing during aesthetic appreciations. Increased activation of the rostral PFC (rPFC) has been related to the judgments of beauty with respect to symmetrical patterns in comparison to ratings about their symmetry (Jacobsen, Schubotz, Hofel, Höfel, & Cramon, 2006), as well as emotional introspection (Cupchik et al., 2009) and the experience of highly pleasing images (Vessel, Starr, & Rubin, 2013). Furthermore, Cela-Conde et al. (2004) identified increased activity in the left dorsolateral PFC (dlPFC) using magnetoencephalography (MEG) when participants judged art images as beautiful during the 400 – 1000ms period following stimulus onset. No activation was observed in the dlPFC before 400ms suggesting that later processing stages are important to the formation of aesthetic judgements such as beauty. Similarly, when participants were asked to judged images that they either believed had been created by a computer or taken from a distinguished art gallery, Kirk (2008) found activation in the rPFC and OFC only during aesthetic judgements of images viewed under the aesthetic (art gallery) condition but not the computer-created condition.

Empathy has been implicated during the experience of art by Freedberg and Gallese (2007) who proposed that artworks are evaluated through direct bodily empathy that involves the mirror neuron system (MNS). They suggested that mirror neurons in the frontal cortex and posterior parietal cortices are activated through felt bodily empathy, therefore the viewer empathises with the movements that the artist depicted through vigorous lines in the painting or with the content of paintings itself. Freedberg and Gallese (2007) summarised this by suggesting two components of aesthetic experience that are involved in contemplating art: (1) the relationship between embodied empathetic feelings in the observer and the representational content of the artworks in terms of the actions, intention, objects, emotions and sensations depicted in the sculpture or painting, and (2) the relationship between embodied empathetic feelings in the observer and quality of the work in terms of the visible traces of the artists creative gestures such as vigorous movement in clay or brushwork. This is an interesting proposition that indicates a sensorimotor connection to the viewing of artworks that contributes to the aesthetic experience.

The study of aesthetic emotions such as beauty or preference has been a primary focus of neuroaesthetics. The OFC and rPFC are the primary areas of the brain that have been implemented in the experience of beauty during the contemplation of visual art. Ishizu and Zeki (2011) found that the OFC is particularly activated during the experience of beauty in visual art as well as in music. Ishizu and Zeki (2011, see also Ishizu & Zeki, 2013; Zeki, 1999) strongly argued that the OFC represents the brain's 'beauty centre'. Others found activation in rPFC and dlPFC in addition to activation in the OFC during the experience of beauty (Cela-Conde et al., 2004). Jacobsen et al. (2006) found activation in the rPFC, but not the OFC when participants judged the beauty of geometrical shapes compared to their symmetry. These authors suggested that aesthetic judgements of beauty rely on a network partially overlapping with the underlying evaluative judgements on social and moral cues. However, these studies have been limited to the understanding of aesthetic emotion with respect to perceptions of beauty or liking and little is known about the continuous generation of affective states during aesthetic experience described in Leder et al.'s (2004) model (Figure 1.3). One approach that aimed to be more inclusive in the study of emotions was taken by Di Dio et al. (2007) who proposed two types of beauty: type one - objective beauty and type two – subjective beauty. Objective beauty is the result of specific stimulus properties, for example symmetry, and results from stimulation from outside the individual. Subjective beauty is governed by the individual's own emotional experiences and results from personal experiences of the stimuli and involves emotional evaluation and memory processes. Processes involved in the evaluation of art may therefore not recruit specific 'beauty centres' but involve processing areas and pathways that include those related to affective evaluations, attention and memory (Brown, Gao, Tisdelle, Eickhoff, & Liotti, 2011; Munar et al., 2011; Zaidel, Nadal, Flexas, & Munar, 2013). Objective and subjective beauty arise in different processing stages in the models described by Chatterjee (2004) as well as Leder et al. (2004). Objective beauty occurs during early processing stages such as Leder et al.'s (2004) perceptual analysis or implicit memory integration (Figure 1.3). Subjective beauty on the other hand is a transactional process by which the art object interacts with the emotions and memories of the viewer and resonates at an idiosyncratic and individual level. The functional differentiation between objective and subjective beauty leads to the conclusion that separate brain areas are engaged by these processes.

Neuroaesthetics has identified the involvement of the OFC and rPFC in the perception of beauty and pleasure towards art. Whereas the OFC has been consistently associated with reward processing of beautiful stimuli, the role of the rPFC is less clear. The rPFC has been implemented in higher order brain processes such as the control of attention, emotion and memory which are also cognitive processes important to the aesthetic experience. Furthermore, little is known about these cognitive processes and how they interact with affective evaluations that result in aesthetic emotions.

1.4 Anatomy and Functions of the Prefrontal Cortex (PFC)

The PFC is a large area of the brain that has been implicated in a wide variety of functions such as visual attention (Squire & Noudoost, 2013 for a review), autobiographical memory (Cabeza & St Jacques, 2007; Svoboda, McKinnon, & Levine, 2006), working memory (Nee et al., 2013 for a review) and emotion regulation (Ochsner et al., 2004 for a review). The PFC is an area that is relatively larger in humans than other primates and evidence suggests that it evolved later than deeper brain structures such as the amygdala (Fuster, 2008). The PFC can be broadly divided into dlPFC (Brodmann Area (BA)8, BA9 and BA46; Figure 1.4), ventrolateral PFC (vlPFC; BA44, BA45 and lateral BA47), OFC (BA11 and medial BA47) and rPFC (BA10) (Faw, 2003; Fuster, 2008). The dorsolateral and ventrolateral areas have been implemented in the processing of positive and negative emotions (Mak, Hu, Zhang, Xiao, & Lee, 2009), the OFC in the experience of reward (the positive value an individual ascribes to a behaviour, a physical state or an object) (Damasio, Everitt, & Bishop, 1996) and beauty (Ishizu & Zeki, 2011; 2013; Zeki, 1999a; 1999b). The rPFC has been related to the processing of emotions (Goldin, McRae, Ramel, & Gross, 2008; Ochsner & Gross, 2004; 2005), self-related cognitions (Lee & Siegle, 2012; Maier et al., 2012; Ochsner & Gross, 2004) and memory (Buckner, Andrews-Hanna, & Schacter, 2008). The rPFC has recently received considerable attention, however, a variety of labels have been applied (e.g. medial PFC, ventral medial PFC, dorsal medial PFC, rostral PFC, frontal pole etc.) to indicate activation in the same area. We will therefore refer to this area as rPFC or BA10 in the remainder of this text.

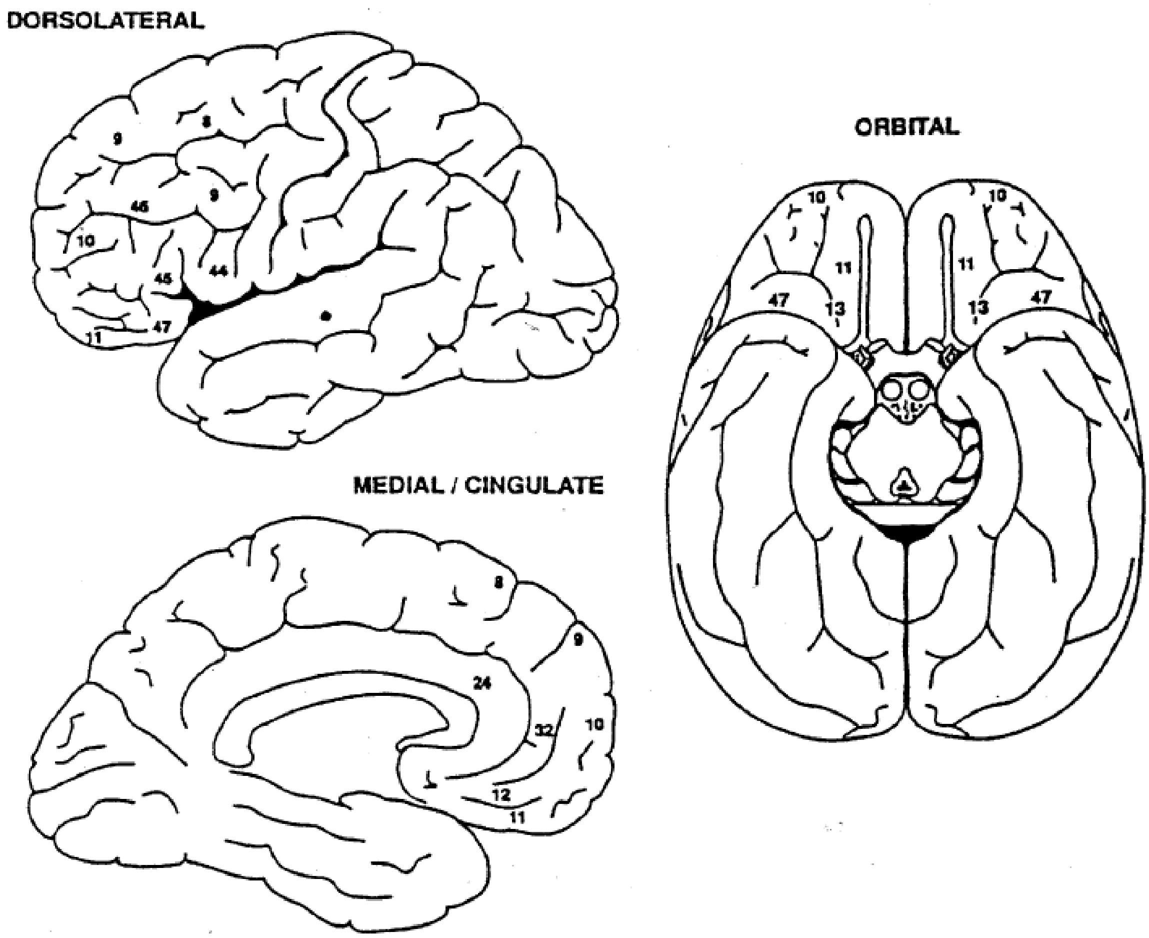

Figure 1.4 Three schematic views of the human brain with frontal cytoarchitectonic areas indicated according to Brodmann's map (1909). (Taken from Faw, 2003).

1.5 Emotions and the Rostral Prefrontal Cortex

The experience of emotion is a complex and dynamic process to determine whether a stimulus is hostile, hospitable or has features of both. Survival is dependent on the successful processing and regulation of incoming information from objects, individuals and the social world. Norris, Gollan, Berntson, and Cacioppo (2010) proposed that the primary function of the affect system is to discriminate bad from good or harmful from helpful as defined by operating characteristics that differ for positivity and negativity and across levels of the nervous system. The affect system does not depend on a bipolar configuration of positive and negative, rather it depends on the nuanced and independent operation of a positive and a negative structure underlying the whole system. Viewing positive and negative emotions as two components of one system can aid the understanding of the involvement of emotions in the navigation of the environment. Advances in neuropsychology have shed light on brain structures that are implicated during emotional processes. Activity within the amygdala has been linked to the experience of negative emotions, such as fear, anger or sadness (Klumpers, 2012; McNaughton & Corr, 2004; Kateri McRae et al., 2010; Rueda, Posner, & Rothbart, 2011). The PFC, on the other hand has been associated with cognitive control of emotions (Lindquist & Barrett, 2012; Mitchell, 2011).

The PFC has received increasing attention in its role in emotion regulation, but no main consensus to its function or cytoarchitechture has been reached. Ramnani and Owen (2004) suggested that the PFC is activated when the outcomes of two or more separate cognitive operations need to be integrated in the pursuit of a higher behavioural goal. Furthermore, PFC asymmetry has been linked to processing of positive (approach) and negative (avoidance) emotions (Davidson, 2004; Denkova, Dolcos, & Dolcos, 2013; Ernst, Weidner, Ehlis, & Fallgatter, 2012). The rPFC has been implemented in the processing of self-related information (Araujo, Kaplan, & Damasio, 2013; Denny, Kober, Wager, & Ochsner, 2012; Seitz, Franz, & Azari, 2009) and social cognition (Olsson & Ochsner, 2008; Vul, Harris, Winkielman, & Pashler, 2009). The rPFC has also been linked to the experience of aesthetic emotions during the contemplation of visual art (e.g. personal liking of artworks) (Vessel, Starr, & Rubin, 2012). However, the relationship between positive and negative emotions, self-related thought, and social cognitions in relation to art has not been explored.

Several brain regions in the frontal cortex have been linked to the cognitive control of emotions (i.e. emotion regulation), which aims to deliberately change the emotional intensity of a stimulus. Among the most prominent forms of emotion regulation are distraction and reappraisal. In the case of distraction, attention is drawn away from the emotional component of the stimuli (Goldin et al., 2008; Rueda et al., 2011). During reappraisal the meaning of a situation is cognitively reassessed as a means of modulating the intensity of the emotion. The intensity of negative emotions that occur, for example, when seeing a person in a hospital bed may be increased by imagining that the person is a relative or decreased by imagining that the person is not related, under good care or that a speedy recovery is imminent (McRae, Ochsner, & Gross, 2011). The assessment and regulation of emotional intensity is also relevant to the experience of art, particularly during the continuously changing affective states described in Leder et al.'s (2004) model (Figure 1.3).

The rPFC has been implemented in a number of studies investigating emotion regulation but the conclusions are mixed. Banks, Eddy, Angstadt, Nathan, and Phan (2007) as well as Goldin et al. (2008) found greater dorsal and rostral PFC activation during the regulation of negative emotions and attributed this increase of activity to the involvement of higher order cognitive control, such as thought strategies used to reappraise negative emotions, applied to sensory processes. Etkin, Egner and Kalisch (2011) suggested that the rPFC is activated during the response to (negative) emotional stimuli, whereas the dlPFC is activated during the regulation of emotions. Ochsner and Gross (2004) argued that the vlPFC is involved in the amplification of the intensity of an emotion (e.g. increasing the feeling of happiness when meeting a friend) whereas dlPFC is involved in the reduction of the intensity of an emotion (e.g. reducing the sadness felt when the friend cancels last minute). Activation in the dorsal and ventral PFC has additionally been linked to deactivation in the amygdala after the successful decrease of the intensity of negative emotions (Ertl, Hildebrandt, Ourina, Leicht, & Mulert, 2013; Gray, Braver, & Raichle, 2002; Gyurak, Gross, & Etkin, 2011; McRae et al., 2011; Mitchell, 2011; Phan, Wager, Taylor, & Liberzon, 2002; Rueda et al., 2011). The rPFC has also been implemented in the processing of aesthetic emotions, such as pleasantness (Kirk, 2008; Vessel et al., 2012) or beauty (Cupchik et al., 2009; Jacobsen et al., 2006), along with memory processes related to the understanding of art (Ishai, Fairhall, & Pepperell, 2007; Wiesmann & Ishai, 2008). Thakral, Moo, and Slotnick (2012) found that rPFC was activated during pleasantness judgements of van Gogh paintings. The conclusions that can be drawn from this research are that the dlPFC and vlPFC are part of an emotion regulation network that utilises cognitive control processes to reappraise and re-evaluate the emotional salience of a situation. However, the interpretation of increased activation in the rPFC during emotion regulation strategies remains less clear.

One common denominator between these studies was the use of self-related introspection (how does this stimulus make me feel?) to experience and change emotional intensity. Goldin et al. (2008) asked participants to view a negatives scene form an outsider's perspective to decrease emotional intensity. Similarly, studies conducted by Banks et al. (2007), McRae et al. (2011; 2010) and Ertl et al. (2013) employed strategies that changed the emotional meaning of the situation by making content less self-relevant (e.g. thinking about a hospital scenes from an objective outside perspective such as a Doctor). Emotional processing may involve inferring experiences from bodily states and conscious thoughts about current and past experiences (Lee & Siegle, 2012), interpretation of affective meaning (McRae et al., 2010; Ochsner & Gross, 2005) or autobiographical memory (Lee & Siegle, 2012; Spreng, Mar, & Kim, 2009). Maier et al. (2012) suggested that the rPFC is involved in fear processing when the individual has enough time to consciously think about the threatening situation. If this was the case, activation changes in heart rate or skin conductance measures of fear would not necessarily be paralleled by activation changes in the rPFC. This would suggest that the rPFC is not directly involved in the generation or expression of fear responses but specifically in conscious threat appraisal. Maier et al. (2012) showed that neural activity in the rPFC (as well as the dorsal anterior cingulate cortex) is dissociated from responding at the peripheral-physiological level, making it unlikely that the area is directly engaged in the expression of physiological fear responses. Results from this study suggest that rPFC is involved in later appraisals of stimuli rather than initial fear detection. It may therefore be more likely that the rPFC is involved in the conscious cognitive evaluation of emotional stimuli.

Lee and Siegel (2012) conducted a meta-analysis on brain networks underlying explicit emotional evaluation. Their results suggested that the rPFC is an area commonly activated during the processing of stimulus-focused evaluation (e.g. focusing on features and meaning of stimuli/situations), evaluation of one's own emotion (e.g. 'How do you feel') and the evaluation of others' emotions (e.g. 'How does the person in this picture feel?'). Artworks can equally be interpreted in relation to the self (e.g. what does this painting mean to me?). The rPFC may therefore play a more general role of integrating emotional evaluations with autobiographical memories in order to form highly personal judgements of environmental stimuli.

1.6 The Rostral Prefrontal Cortex and Autobiographical/Prospective Memory

The close relationship between activation in the rPFC during autobiographical memories (AM) and emotions may provide an important link between rPFC activation and emotion regulation strategies. Autobiographical memories are the recollection of personal events from ones' own life and involve the recall of spatially and temporally bound information to vividly reconstruct the relevant scene (Spreng, Sepulcre, Turner, Stevens, & Schacter, 2013). These remembered events can elicit strong emotional reactions because they involve projecting the self back in time in order to construct past experiences; AMs are therefore sensitive to emotional cues during encoding as well as retrieval (Cabeza & St Jacques, 2007; Holland & Kensinger, 2013; Spreng et al., 2013). Holland and Kensinger (2013) found that activation in the rPFC during the modulation of negative emotion intensity was time sensitive. Participants were asked to increase or decrease emotional intensity of autobiographical memories (AM) using cognitive restructuring techniques (e.g. changing the focus of the memory). These authors reported increased activation in the rPFC during the early phase (the first 12 seconds after stimulus onset) when participants decreased negative emotions using cognitive strategies (i.e. finding an alternative meaning for the emotional event), but not when they increased the emotional intensity (i.e. by focusing on the emotion). This effect was reversed during the late phase in which increasing the emotional intensity significantly increased rPFC activation. Holland and Kensinger (2013) suggested that rPFC was not active during the late phase when the emotional intensity was decreased because the emotion regulation strategy was successful and the AMs that were related to the emotional event were supressed or changed. Autobiographical memory association, on the other hand, were encouraged during the increasing of emotional intensity which resulted in rPFC activation in the late phase. These findings suggest that memories are an important aspect during the experience of emotions. Holland and Kensiger's (2013) finding not only shows an interaction between memory and emotional processing, but may also account for inconsistent rPFC activation found between studies investigating emotion regulation.

Spreng et al. (2009) summarised literature that connected the rPFC to a single underlying process of remembering and future-oriented thinking. Prospection, imagining the self in the future, is important to successful goal pursuit by playing a role in planning and strategic behaviour plotting (Levine, Freedman, Dawson, Black, & Studd, 1999; Spreng et al., 2009). The mental simulation of possible future events and their outcomes help to avoid negative outcomes and maximises positive ones particularly in situations of uncertainty were the outcome is self-determined. Prospective memory is therefore the study of how actions are created, maintained and executed after a delay period (Burgess, Scott, & Frith, 2003; McDaniel, LaMontagne, Beck, Scullin, & Braver, 2013). For example, keeping in mind to form a value judgement (i.e. this is/is not beautiful) whilst contemplating visual art would be an act of prospective memory because the action, forming a value judgement, needs to be maintained and remembered over a certain period of time. A general finding in prospective memory research is that sustained top-down attentional control is required to maintain activation of the intention to carry out a specific action while carrying out other ongoing activities (Burgess, Quayle, & Frith, 2001; McDaniel et al., 2013). Prospective memory is also involved during open ended situations, such as approaching an artwork from an aesthetic orientation. Studies using functional magnetic resonance imaging (fMRI) have consistently shown activation in the rPFC, along with other components of the fronto-parietal attention system to be activated during prospective memory task that are associated with sustained attentional control (Benoit, Gilbert, Frith, & Burgess, 2012; McDaniel et al., 2013). It appears therefore that the rPFC plays an important part in future planning.

The involvement of prospective memory during the evaluation of art has been proposed by Cupchik et al. (2009) who argued that the evaluation of art constitutes an open-ended situation that requires the viewer to self-determine a successful outcome. This process would involve the monitoring of an internal goal (do I like this painting?) and external environment (the physical properties of the painting and the environment it is displayed in) to determine a successful outcome, which would in this case constitute of the successful evaluation of the painting. These authors found that instructions to approach paintings from a subjective orientation (i.e. personal reactions to stylistic and structural properties that help to form judgements about the beauty of a painting) activated the lateral rPFC that consist of the interface between the self-referential and cognitive demands of a task. Thus, Cupchik et al. (2009) argued that the activation in the lateral rPFC found in their study is a reflection of internal processing (i.e. directing attention to internal cognitions to form a value judgement). This corresponds to one particular account of rPFC activation during prospective memory which is described in the Gateway Hypothesis (Burgess, Dumontheil, & Gilbert, 2005; Burgess et al., 2003). According to this model, medial rPFC (medial BA10) plays a role in the maintenance of attention towards external stimuli (e.g. towards what is seen on a screen or canvas) whereas activation of the lateral areas (lateral BA10) are associated with the preservation of attention on internal cognitions (e.g. towards internal thoughts); this functional differentiation is proposed to act as a gateway between the direction of attention towards external and internal stimuli properties that are necessary for future planning and goal attainment (Burgess et al., 2007). The ability to switch between external and internal attention towards stimuli is a process that may be seen in a variety of tasks, such as future planning or multi-tasking that show changing demands for attention between the external and the internal. For example, remembering to appraise an item in a gallery from an aesthetic orientation requires attention to the external world (i.e. features of the painting such as colour, lines or shapes) and the attention to the internal world (assessing personal liking and remembering to maintain the aesthetic orientation).

The gateway hypothesis rests on four interlinked assumptions (Burgess et al., 2007). The first is that some forms of cognition are provoked by perceptual experiences (i.e. input through basic sensory systems) whereas other forms of cognition occur in the absence of sensory input (i.e. they are created internally). The second assumption is that some central representations are activated when an external stimulus is experienced and when it is merely imagined. The third assumption is that, if the first and second are true, then it is plausible that there is some brain system that can determine the source of activation of the central representation (i.e. whether it originates from the external or internal world). The fourth and last assumption is that rPFC plays a role in the central representational mechanism that distinguishes external and internal activation. Burgess et al. (2007) proposed that there is continuous competition for activation of central representations between the sensory systems and the reciprocal or associative activation from within the system. Attending behaviour may therefore rapidly change between internal and external attending to meet the demands of both systems in complex interactions (Figure 1.5). Therefore, the rPFC plays a key role in the goal-directed co-ordination of stimulus-independent/internal and stimulus-orientated/external cognitions, particularly in situations that require a novel response because of the requirement to integrate information from external and internal sources. Stimulus-independent cognitions include introspection or creative thoughts which can be provoked by or directed toward external stimuli. Stimulus-oriented cognitions represent the opposite category, being provoked and oriented towards sensory input. The rPFC would be typically activated in situations that are novel or where a specific demand for it has been determined (e.g. “I must pay special attention to…”, “I must think about…”; Benoit et al., 2012; Burgess et al., 2007; 2003; Gilbert et al., 2006; Gilbert, Frith, & Burgess, 2005; Volle, Gilbert, Benoit, & Burgess, 2010). However, in the absence of external stimuli, or when monotony has been achieved stimulus independent thought will tend to dominate (e.g. mind wandering).

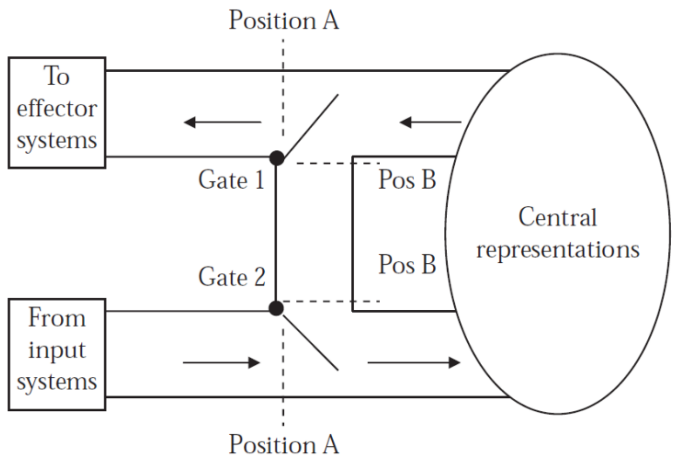

Figure 1.5 Representation of the "Gateway Hypothesis" of rostral prefrontal function. Rostral regions are hypothesised to support a system, which biases the flow of information between basic systems and central representations (i.e. is equivalent to the adjustment of the position of the "Gates"). The gates are shown in the neutral position where the bias is freely determined by context. If both gates are at position A, stimulus-independent thought is favoured. If both gates are at position B, full engagement with (external) stimuli is favoured (Taken from Burgess et al., 2005).

Evidence for the functional differentiation of the gateway hypothesis has been observed during the comparison of shapes (Henseler, Krüger, Dechent, & Gruber, 2011), letters (Gilbert et al., 2005; Benoit et al., 2012) and the identification of features between two different stimuli such as texture or aspects of geometric shapes (Volle et al., 2010). Prospective memory may also be influenced by emotions. Rea and colleagues (2011) investigated the proposal that modulatory effect of the emotional significance on prospective memory performance might be supported by the activity of the rPFC. These authors found that tasks prompted by aversive stimuli are specifically associated with activity in the right rPFC and in the left caudate nucleus. Their results show that the valence of prospective memory cues negatively affect prospective memory performance in comparison with neutral cues.

Research within memory shows that rPFC is involved in autobiographical as well as prospective memory. The gateway hypothesis suggests that lateral and medial rPFC may act as an interaction between the external and internal world during prospective memory; its strength is the functional differentiation between lateral and medial areas of the rPFC. The two different functions, external and internal processing of the gateway hypothesis would become relevant during different stages of Leder et al.'s (2004) aesthetic processing model. Focus on external features such as colour or lines would be relevant during the early perceptual analysis stage (Figure 1.6), whereas a switch to internal cognitions would be expected in later stages such as the cognitive mastering stage. During this later stage the viewer may turn their attention away from external features of the painting and towards internally generated cognition such as affective evaluation and autobiographical memories. However this is an ambitious hypothesis because the complexity of visual art may result in a constant interchange between internal and external attention making a differentiation between lateral and medial areas undetectable. Stimuli used in studies supporting the gateway hypothesis only used fairly simple symmetrical patterns or letters which do not take the complexity of an artwork or any possible emotional valence effects of the stimulus into account. The gateway hypothesis may therefore only apply to neutral and relatively simple stimuli.

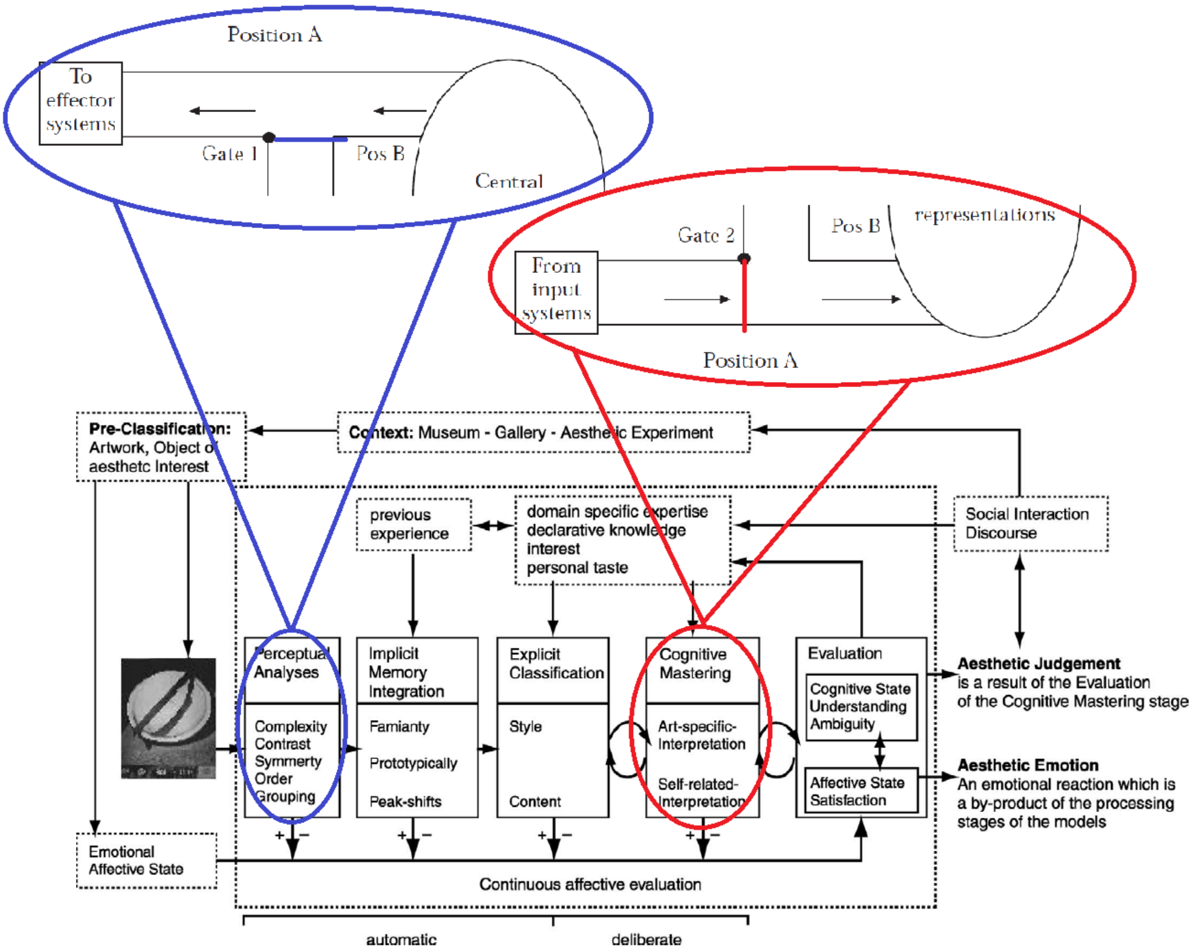

Figure 1.6 The Gateway Hypothesis may contribute to aesthetic experiences at different time courses. External processing, when the gate is in position B (top blue circle) may occur during early perceptual analysis, whereas internal processing, when the gate is in position A (top red circle) may occur during later stages such as cognitive mastering.

1.7 The Default Mode Network (DNM)

An alternative perspective on rPFC activation to the gateway hypothesis is provided by research on the Default Mode Network (DMN). The DMN is a network that is activated when participants are left to think for themselves undisturbed, for example, in free thinking situations during rest or free viewing tasks (Buckner et al., 2008; Mason et al., 2007). It has been suggested that activation in the DMN, particularly activation of the medial rPFC signals the relevance of a stimulus to the self (Andrews-Hanna, Reidler, Sepulcre, Poulin, & Buckner, 2010; Buckner et al., 2008; Ochsner et al., 2004). Evidence for the involvement of the DMN during aesthetic experiences has been provided by Vessel et al. (2012). These authors asked participants to indicate self-relevance by rating how moving they found the image. Medial rPFC activation was only found during the evaluation of art for images that were rated as most moving. Vessel et al. (2012) suggested that medial rPFC was only activated during the most moving images because these images induced internal reflection by 'striking a chord' in the viewer.

It has been proposed that the ubiquitous activation of the DMN during resting states plays an important adaptive role (Gusnard & Raichle, 2001; Raichle, MacLeod, Snyder, Powers, & Gusnard, 2001). Following Raichle et al.'s (2001) initial reports, the DMN has been implemented in a number of functions particularly those that encourage internal mentation (Andrews-Hanna et al., 2010; Buckner et al., 2008). The functions implemented in the DMN include autobiographical memory, thinking about one's future, theory of mind, self-referential and affective decision making and social cognition (reviewed in Andrews-Hanna et al., 2010; Buckner et al., 2008; Ochsner & Gross, 2004; Spreng et al., 2009). The DMN contains a set of interacting brain regions that are tightly functionally connected and are distinct from other systems in the brain (Buckner et al., 2008). Figure 1.7 shows a regional map of the areas involved in the DMN.

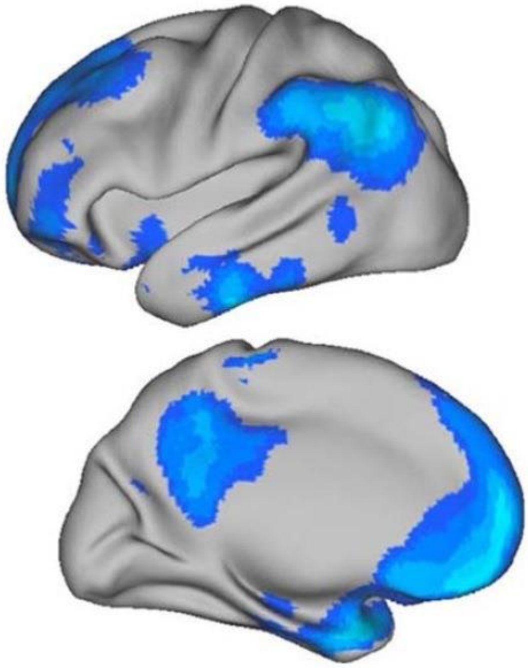

Figure 1.7 Regions of the DMN, images show the medial and lateral surface of the left hemisphere using a standard surface representation. Blue represents regions most active in passive task settings (Taken from Buckner et al., 2008).

Self-referential processing has been found to activate the frontal midline regions involved in the DMN which are the dorsal medial PFC (dmPFC: BA24, 32 and medial BA8, 9), the ventral medial PFC (vmPFC, BA24, 32, 11) and the rPFC (BA10) (Buckner et al., 2008; Mason et al., 2007). BA10 has been implemented during the judgement of character traits in relation to the self or familiar others, but to a lesser degree in the judgement of character traits of distant others (Benoit, Gilbert, Volle, & Burgess, 2010; Qin & Northoff, 2011; Whitfield-Gabrieli et al., 2011). These results have implied that BA10 plays an important role during social cognition (the act of thinking about the self and others as social entities) particularly with respect to understanding the intentions, goals and beliefs of ourselves and others. It has been argued that access to internal physical and mental states allows to gain insight into physical and mental states of others' via the processes of embodiment (the physical empathy with others) and mentalising (the mental empathy with others) (Molnar-Szakacs & Uddin, 2013; Singer, 2006). The cognitive process of simulating the mental state of another person has been associated with activity in BA10 (Molnar-Szakacs & Uddin, 2013). These authors suggested that BA10 is part of an area where embodied and mentalising processes integrate their signals to be 'mapped' onto internal representations and combined with information from memory to plan future behaviour, select a response and act. Other areas that have been proposed to be part of this network are: posterior inferior parietal lobule, posterior cingulate cortex/precuneus, inferior frontal gyrus/premotor cortex, anterior inferior parietal lobule, superior temporal sulcus and anterior insula. Molnar-Szakacs and Uddin's (2013) hypothesis would suggest that the DMN is involved in memory processes as well as self-referential processing indicating a system that has functionally specific subdivisions.

Andrews-Hanna et al. (2010) conducted a detailed characterisation of the architecture of the DMN and employed task-based fMRI to explore its different components. Their analysis revealed two subsystems that interact with two common cores. The first subsystem, termed the 'dorsomedial prefrontal cortex (dmPFC) subsystem' includes medial BA8/9 and dorsal BA32/24 of the prefrontal cortex, the temporoparietal junction (TPJ), the lateral temporal cortex (LTC) and the temporal pole (TempP). The second subsystem, termed the 'medial temporal lobe (MTL) subsystem' includes BA11 and ventral BA32/24 of the prefrontal cortex, the posterior inferior parietal lobule (pIPL), the retrosplenial cortex (Rsp), the parahippocampal cortex (PHC) and the hippocampal formation (HF). Both subsystems are connected via two central 'hubs' - the posterior cingulate cortex (PCC) and medial BA10 (Figure 1.8).

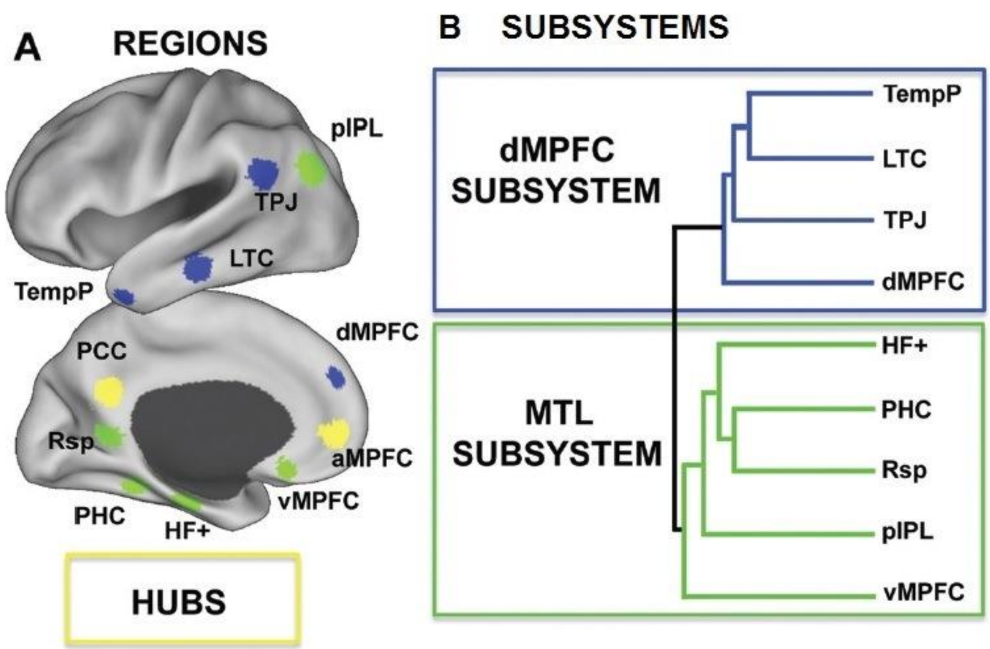

Figure 1.8 A) DMN subsystems and BA10 (labelled aMPFC)/PCC hubs projected onto a surface template, and B) hierarchical representation of the two subsystems. The dMPFC subsystem is represented in blue, the MTL subsystem in green and the hubs in yellow. (Adapted from Andrews-Hanna et al., 2010; Andrews-Hanna, 2012).

Andrews-Hanna et al. (2010) aimed to identify the functional contribution of the subsystems during prospective, episodic decisions about one's self (termed 'future self') compared to self-referential decisions about one's current situation or mental state (referred to as 'Present self'). The authors found greater activity in the MTL subsystem when participants made episodic decisions about their future. This finding led Andrews-Hanna et al. (2010) to argue that mnemonic scene construction based on autobiographic memory is an important component process of thinking about the future. The dmPFC subsystem, on the other hand showed more activation during self-referential processing in the present state, i.e. the present self. This activation was particularly relevant during the processing of self-relevant affective information. The rPFC and PCC shared functional properties of both subsystems suggesting their role in integration as default hubs. Andrews-Hanna et al.'s (2010) analysis additionally revealed that three particular variables correlated with activity in the rPFC/PCC hubs. These were: personal significance, introspection about one's own mental states and evoked emotion.

The overlap of activation in the rPFC/PCC hubs suggests that both play an integrative role in the integration of cognition – emotion activity during the processing of present and future information that are relevant to the self. Andrews-Hanna et al. (2012) concluded that it may be possible that rPFC and PCC hubs play a prominent role in the subjective valuation of personally significant and other salient information. Once a highly personal subjective value is attributed to information, it can be used to guide and motivate behaviour via the interaction of the midline cores with subcortical regions or by further internal processing conducted by the distinct subsystems. For example, the dmPFC subsystem may allow individuals to reflect on the mental states elicited by the stimulus and the MTL subsystem may allow individuals to integrate this introspective information into a goal-directed plan related to that stimulus. Each subsystem plays specific roles that are mediated by the rPFC/PCC hubs (Figure 1.9).

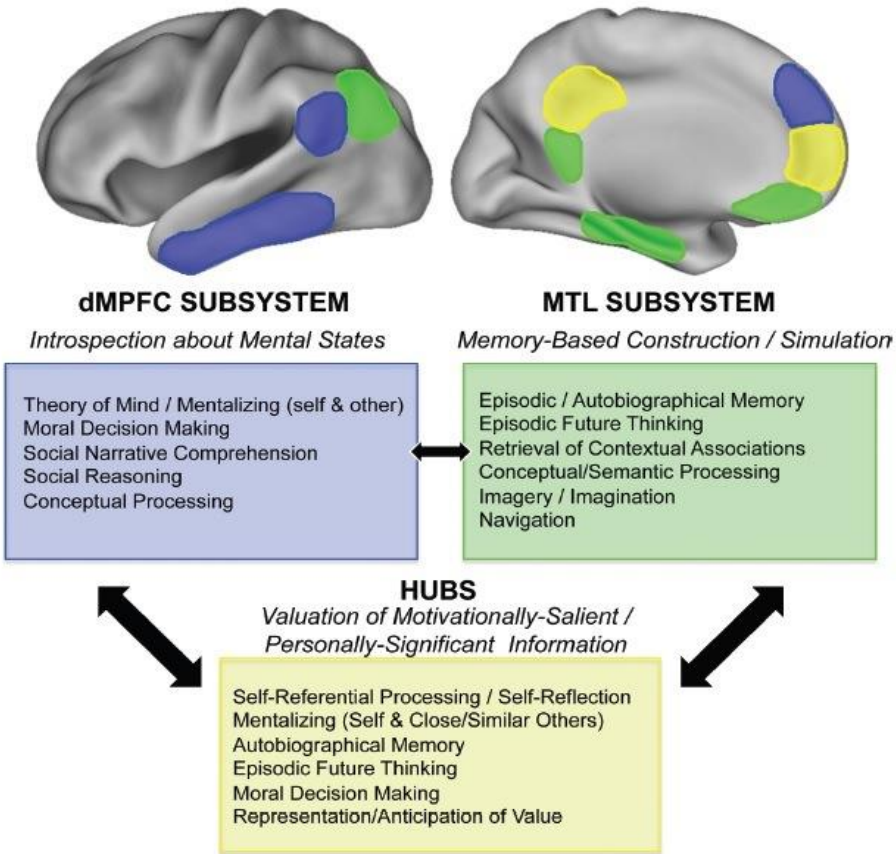

Figure 1.9 Andrews-Hanna et al.'s (2010) proposed functional-anatomic organisation of the major DMN components. A schematic drawing of the DMN hubs (yellow) and subsystems (blue = dmPFC; green = MTL) is highlighted along with each component's hypothesised functions and the tasks that frequently activate them. Arrows reflect approximate strength of connectivity between DMN components (Taken from Andrews-Hanna, 2012).

The integration of autobiographical memories, affective evaluation and the judgement of self-relevance are important to the cognitive processing and formation of aesthetic emotions during the contemplation of art. This process may be reflective of Leder et al.'s (2004; Figure 1.3) cognitive mastering, because it describes self-relevant interpretation that is related to autobiographical memories that interact with affective evaluations of the stimuli (Figure 1.10). This may be particularly relevant to art naïve individuals who will use their personal experiences, feelings and memories to a greater extend in the interpretation of artworks compared to experts who may rely more on factual knowledge (Batt, Palmiero, Nakatani, & van Leeuwen, 2010; Kirk, Skov, Christensen, & Nygaard, 2009; Leder et al., 2004; Leder, 2013). It is also in line with activation invoked in the rPFC for highly moving images as reported by Vessel et al. (2012).

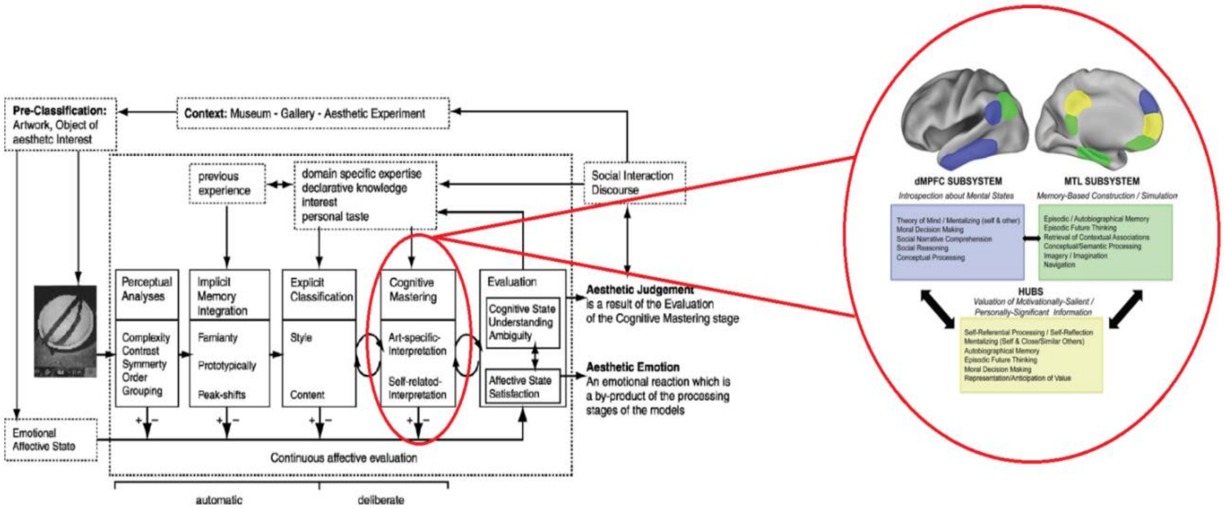

Figure 1.10 The functional-anatomic organisation of the DMN network may form an important part of the cognitive mastering stage proposed by Leder et al. (2004).

1.8 Conclusions

An aesthetic experience is a highly complex phenomenon that involves multi-sensory processes and complex brain mechanisms. Leder et al.'s (2004) model suggests that, in order to evaluate or appreciate an artwork sensory processes as well as processes such as cognition, emotion and memory are needed. Leder et al.'s (2004) model may be combined with Chatterjee's (2004) model to create a comprehensive framework of the aesthetic experience that can be tested with neuroscience methods. Early processes in Leder et al.'s (2004) model reflect early visual processing in Chatterjee's (2004) model whereas cognitive mastering and evaluation map onto late visual processes. It is these later stages that may be linked to activation in the prefrontal cortex and in particular to the rPFC through autobiographical memory, affective evaluation and self-referential processing as described by the DMN. The aim of this thesis is to investigate rPFC activation during the processing of visual art to gain an understanding of its role in relation to the aesthetic experience.

1.9 Aims

This thesis will investigate the role of the rPFC during cognitive and emotional processing of the aesthetic experience. The rPFC has been implicated during emotional and cognitive processing of art in previous research (e.g. Cupchik et al., 2009; Jacobsen, 2006; Vessel et al., 2012) but the exact role of the rPFC remains unclear. The experimental programme will focus on late visual processing (Chatterjee, 2004) or the cognitive mastering stage (Leder et al., 2004) and how these stages interact with continuously updating affective states. Two main approaches were taken (1) the manipulation of cognitive and affective properties of images to investigate the involvement of rPFC at different stages of aesthetic processing, and (2) the manipulation of viewing condition to investigate rPFC activation during the processing of self-relevance and autobiographical memory. The thesis aimed to investigate the following questions

- To investigate whether BA10 is implicated during early processing linked to perceptual analysis of image complexity (Chapter 5).
- To investigate whether BA10 is implicated in later processing stages linked to implicit memory formation such as image comprehension (chapter 6).
- To investigate whether BA10 is implicated in later processing stages linked to prospective memory, or the relevance of prospective memory to the aesthetic experience (chapter 7).
- To investigate whether BA10 is implicated in later processing stages linked to self-referential processing and the relevance of self-referential processing to the aesthetic experience (chapter 8).
- To investigate whether BA10 related to the process of continuous affective evaluation that occurs in parallel with perceptual/cognitive processes (chapter 5, 6, 7 and 8).

2. General Methods

This chapter will describe methodologies that were constant throughout the experimental chapters. This section will elaborate on the participant criteria (1.1), the ratings scales (1.2) and the stimuli (1.3) used. Further, functional near-infrared technology will be discussed in four sub-sections. Section 2.4.1 will discuss technical details of the device and data collection. Section 2.4.2 will briefly review the use of fNIRS devices in emotion and cognition research, section 4.4.3 will highlighting some of the strength and weaknesses of fNIRS technology for data collection in neuropsychological research and section 2.4.3 will discuss the analysis software fNIRSSoft.

2.1 Participants

Participants who volunteered for the experiments described in this thesis were recruited from the Liverpool John Moores University student/staff population and the general public. All participants were right handed, had no formal training in an art-related subject and no history of neurological disorder. The age range was restricted between 18 and 45 years of age with the exception of the pilot study described in Chapter 4. Participants were informed about the procedure and operating mode of the fNIRS prior to providing written consent. All procedures were approved by the institutional Research Ethics Committee prior to data collection.

2.2 Rating Scales

Visual rating scales, similar to the self-assessment manikin (SAM) (Lang, Greenwald, Bradley, & Hamm, 1993), were developed for the survey exercise to rate the psychological properties of artistic images. These scales were designed to capture six dimensions (complexity, comprehension, activation, attraction, novelty and valence). The properties can be divided into cognitive components (complexity, comprehension and novelty) that have been described as important aspects by Berlyne (1960) and Silvia

(2005; 2010) and emotional components (activation, attraction, and valence that are important aspects of two-dimensional models of emotions (Russell, 1980) and approach/avoidance (Davidson et al., 2004). These scales were used in the survey and the experimental studies to aid participants during the rating process. Each scale has a numerical 9-point Likert-scale that is accompanied by a visual representation of the concept to be rated. The visual representations were discussed by a team of researchers who agreed upon the design of the scales. All scales are represented in Figure 2.1.

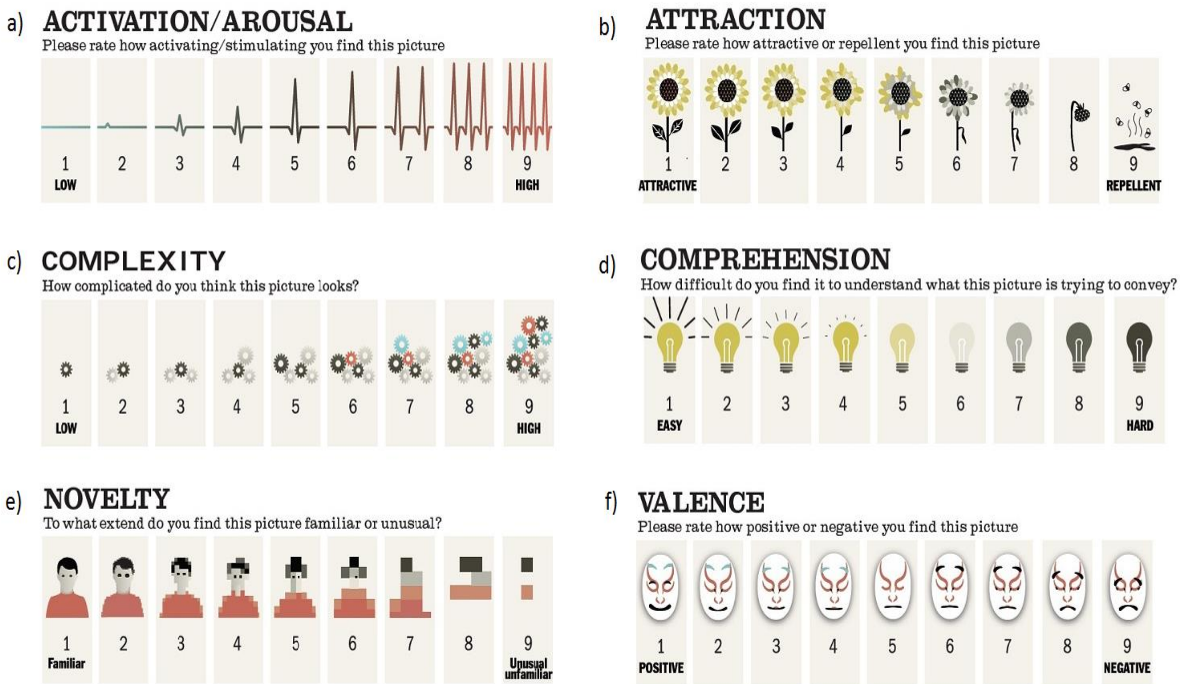

Figure 2.1 Ratings scales for (a) activation, (b) attraction, (c) complexity, (d) comprehension, (e) novelty and (f) valence. Designed by Megan Abel.

2.3 Stimuli

Sixty artworks were selected over the internet from little known artists who had either sold or exhibited their work. The artworks were selected to provide a database of images with a variety of psychological properties (e.g. positive/negative, high/low complexity, high/low novelty). Works from well-known artists were not included in order to avoid memory association or biases of opinions (e.g. the feeling a work needs to be liked because it is famous) that may be attached to them.

Vessel and Rubin (2010) highlighted the importance of carefully selecting stimuli in neuroaesthetics studies because of high individual differences in art preference. These authors criticised research that relied heavily on group averages of particular image properties, such as novelty, in their stimuli selection because group averages mask large individual differences in the experience of art or properties within art such as novelty. A pilot study (chapter 4) was conducted to test the feasibility of calibrating stimuli to the individual (i.e. everyone would see different images according to their impressions of them) whilst maintaining image categories. The aim of the pilot study was to manipulate image complexity (high/low) and valence. The stimuli were calibrated according to participants' ratings of 30 images taken from the two extreme ends of two categories (i.e. high/low complexity and positivity/negativity) from the database. The 30 images provided stimuli from which sixteen images were selected for each participant separately that conformed best to the two categories positive/negative and high/low complexity. The experience for each participant was consequently highly personalised and did not rely on group averages. However, this came to a great loss of experimental control and proved to be untenable for future experiments.

All experimental studies, apart from (chapter 4) relied in the first instances on group averages to instigate a stimulus set but only included a reduced number of images within each set in the final analysis which were when individual participants' rating of the image were in accordance with the group norm. This factor meant that the survey data was used as a first 'filter' in order to determine image categories, but that individual differences were considered by only selecting a subset of these images. Using this method, experimental categories can be preserved to assure maximum control over the stimuli whilst at the same time accounting for individual differences in art preference. This approach was successfully applied in the remainder of the experimental studies.

2.4 Functional Near-Infrared Spectroscopy (fNIRS)

2.4.1 Data Collection

Functional near-infrared spectroscopy (fNIRS) was used to record blood oxygenation changes in the rPFC. Functional NIRS is a non-invasive neuroimaging method that monitors haemodynamic changes related to brain activation on the basis that neural activation and vascular responses are tightly coupled (Ayaz et al., 2011; 2012; Boas, Elwell, Ferrari, & Taga, 2014; Elwell & Cooper, 2011; Ferrari & Quaresima, 2012; León-Carrión & León-Domínguez, 2012; Scholkmann et al., 2014). Measuring haemodynamic changes is a commonly used method to assess cerebral activity in neuroscience studies using, for example, blood oxygen level dependent (BOLD) signals as assessed by fMRI (Ferrari & Quaresima, 2012; León-Carrión & León-Domínguez, 2012; Scholkmann et al., 2014).

Data for this thesis was collected using fNIR Imager1000 and COBI data collection suit (Biopac System Inc.). This device is a continuous wave (CW) system that applies light to tissue at constant amplitude providing measurements of oxygenated (HbO) and deoxygenated (HHb) haemoglobin relative to baseline concentrations HbO and HHb, usually taken at the beginning of a test-session or immediately before a stimulus onset (Irani, Platek, Bunce, Ruocco, & Chute, 2007; Izzetoglu, Bunce, Izzetoglu, Onaral, & Pourrezaei, 2007). The fNIRS probe was 17.5 cm long and 6.5 cm wide. It contained four light sources surrounded by ten detectors, for a total of 16 voxels of data acquisition, covering an area of 14 X 3.5 cm on the forehead and had a temporal resolution of about 500 ms for one complete data acquisition cycle (about 2Hz). The 16 channel probe was placed on the forehead aligned to Fp1 and Fp2 of the international 10-20 system, and rotated so that Fpz corresponded to the midpoint of the probe (Ayaz et al., 2006; Figure 2.2). Areas underlying the 16 voxels are right and left superior and inferior frontal gyrii (BA10, BA45 and BA46 Figure 1.4). Cognitive and emotional functions associated with BA10 and BA45/46 have been explored using fNIRS applications similar to the device used in this work (Ernst et al., 2012; Izzetoglu, Bunce, Onaral, Pourrezaei, & Chance, 2004;

Izzetoglu et al., 2007; Leon-Carrion et al., 2006; León-Carrión et al., 2007; Plichta et al., 2006).

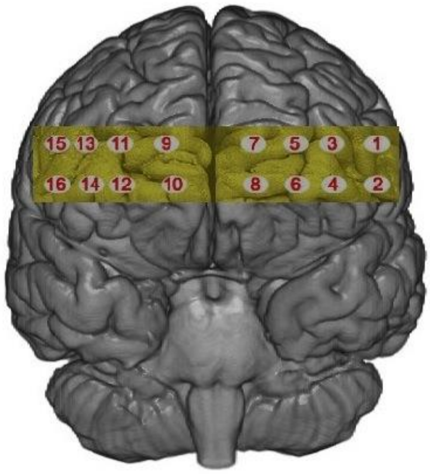

Figure 2.2 the positions of the 16 voxels of the fNIRS Imager1000 over the rPFC.

Functional NIRS technology uses light emitting diodes (LED) and photo detectors to quantify blood oxygenation changes in the cortex. Light enters the cortex via the LED following a banana-shaped path enabling the transmission of light back to the surface of the skin (Figure 2.3). The characteristics of the light received by the detectors will have changed in respect to the original light emitted by the LED because of the absorption and dispersion capacity of the nervous tissue and haemoglobin (Ayaz, 2010; Chance, Zhuang, UnAh, Alter, & Lipton, 1993; Elwell & Cooper, 2011). Functional NIRS technology takes advantage of the relatively transparency of human tissue to light in the NIR spectral window (650 – 900 nm) which allows NIR light to pass through tissue relatively unobstructed. Oxygenated and deoxygenated haemoglobin on the other hand have different absorption and dispersion capacities at the NIR light range which allows spectroscopy measures to assess their respective concentrations (Figure 2.4). Oxygenated and deoxygenated haemoglobin either absorb or scatter NIR light, with scattering being typically about 100 times more probably than absorption (Ferrari & Quaresima, 2012). An increase or decrease of oxygenation in the blood results in increased scattering of NIR light which can be measured by the photo detectors.

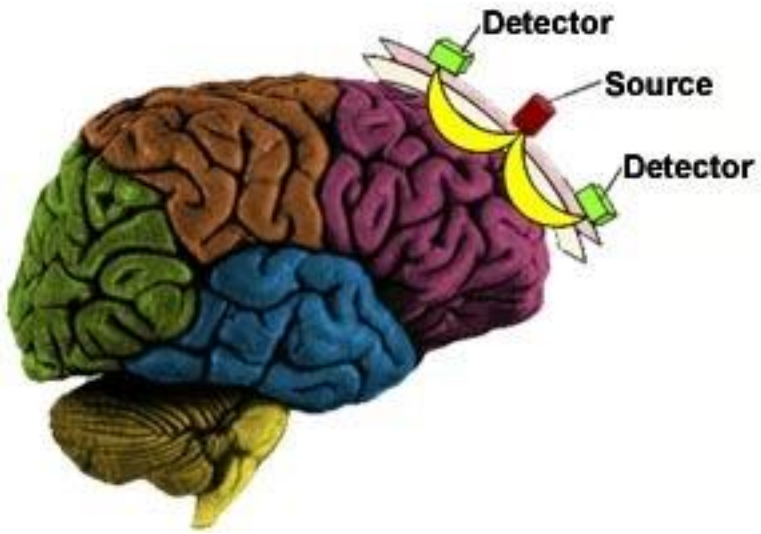

Figure 2.3 Banana shaped curve taken by the NIR light of an fNIRS device. Figure taken from Ayaz (2010).

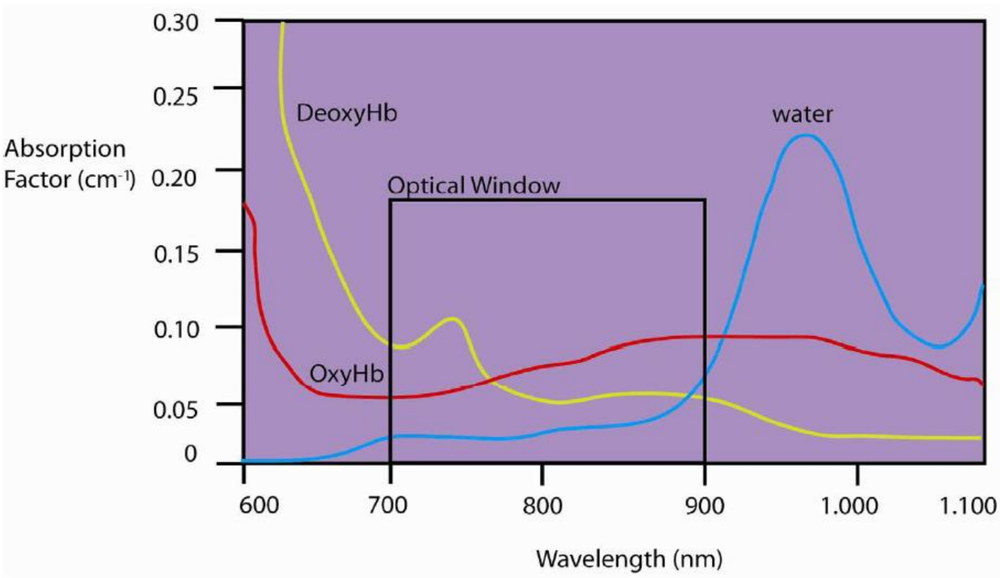

Figure 2.4 NIRS absorption window taken from León-Carrión and León-Domínguez (2012).

Continuous wave (CW) based systems are the most commonly used instruments in neuroscience studies assessing human brain function (Scholkmann et al., 2014). These devices use light sources which emit light at a constant frequency and amplitude which can be quantified using a Modified version of the Beer-Lambert Law (MBLL) (Ferrari & Quaresima, 2012; Gervain et al., 2011; León-Carrión & León-Domínguez, 2012; Scholkmann et al., 2014). The MBLL calculates changes in relative concentrations of haemoglobin in relation to changes in light intensity and differs from the original in its conception of the effect of dispersion and absorption (León-Carrión & León-Domínguez, 2012). The MBLL makes use of the knowledge that the mean path length of light is six times as long as the distance between sender (LED) and receiver (photo detector) in a typical transcranial study of the human brain (Duncan et al., 1995; León-Carrión & León-Domínguez, 2012). A new term (Differential Path-length Factor DPF) is therefore added to represent the longest path length of light in the MBLL. A second term (G), which measures photon loss due to dispersion, is added because not all photons reach the photo detector due to the dispersion effect. The MBLL is expressed as:

$$OD = Log_{10}(I_{in}/I_{out}) = \varepsilon * c * l * DPF + G$$

Where *OD* is the optical density or attenuation, I_{in} is the detected light intensity, I_{out} is the emitted light intensity, ε is the extinction coefficient, *c* is the chromophore concentration, *l* is the distance between source and detector and *DPF* is the differential path length factor, and *G* is a geometric factor associated with scattering. When the extinction coefficients ε are known, constant scattering loss is assumed, and the measurements are treated differentially, the equation reduces to:

$$\Delta c = \Delta\ OD / (\varepsilon * d.DPF)$$

Where *d.DPF* is the total corrected photon path-length. Using a dual wavelength system, measurements for HbO and HHb can be solved from non-singular F matrix (Ayaz, 2010):

$$
\begin{bmatrix}\Delta OD_{\lambda 1} \\ \Delta OD_{\lambda 2}\end{bmatrix} = \underbrace{\begin{bmatrix}\varepsilon_{\lambda 1}^{HHb} d.DPF & \varepsilon_{\lambda 1}^{HbO} d.DPF \\ \varepsilon_{\lambda 2}^{HHb} d.DPF & \varepsilon_{\lambda 2}^{HbO} d.DPF\end{bmatrix}}_{F} \begin{bmatrix}\Delta c^{HHb} \\ \Delta c^{HbO}\end{bmatrix}
$$

The MBLL is able to provide relative haemodynamic changes following this calculation, and can therefore be used in neuropsychological studies. The unit of HbO and HHB signals changes is expressed in µmolar*cm or mmolar*mm considering that the tissue optical path length is longer than the distance between the source and the detector because of the scattering effect of different tissue layers (Ferrari & Quaresima, 2012). Studies using CW based fNIRS systems have shown good test-retest reliability (Plichta et al., 2006) and compatibility with findings from fMRI BOLD signal changes (Schroeter, Kupka, Mildner, Uludağ, & von Cramon, 2006).

2.4.2 Common Uses

Continuous wave fNIRS devices, such as the fNIR Imager1000, have been successfully employed to study cognitive and emotional factors. The increasing popularity and development of fNIRS and its analysis tools (Scholkmann et al., 2014) has led to an increasing number of publication using fNIRS in a variety of domains over the last few years. A simple search of a scientific database returned over 400 publications using fNIRS for the year 2013 demonstrating its increasing popularity in neuroscience using human participants. It has been shown that fNIRS is a reliable method to assess rPFC activation in relation to increasing cognitive demands using an n-back tasks. N-back task require participants to hold increasing numbers of items in working memory which leads to an increase in task complexity and rPFC activation (Ayaz et al., 2012; Izzetoglu & Bunce, 2004; Leon-Carrion, Izzetoglu, Izzetoglu, & Martin-Rodrigues, 2010). The n-back paradigm has been used in numerous neuroimaging studies to investigate the neural base of working memory and cognitive load (Owen, McMillan, Laird, & Bukkmore, 2005). It has therefore been shown that fNIRS is suitable to assess increases in cerebral blood flow that are related to greater executive control caused by an increase in stimuli complexity and cognitive task demand.

Research investigating the emotional domain explored aspects of the time course of emotional processing (Leon-Carrion et al., 2006; León-Carrión et al., 2007), prefrontal asymmetry (Ernst et al., 2012), emotion regulation (Glotzbach et al., 2010; Tupak et al., 2014) and emotion recognition (Hoshi et al., 2011; Tai & Chau, 2009). Investigations into the time domain of emotional responses using the fNIRS Imager1000 found, for example, that haemodynamic responses showed an overshoot into the baseline period highlighting the importance of extended exposure times to capture the haemodynamic response to emotional stimuli fully (León-Carrión & León-Domínguez, 2012). These findings are important in two ways. Firstly it provides evidence that the fNIRS Imager1000 can be successfully applied to measure oxygenation changes in relation to emotional stimuli and secondly it shows that exposure times to stimuli need to be considered carefully to capture the full haemodynamic response.

Ernst et al. (2012) demonstrated prefrontal asymmetrical activation during the processing of approach or avoidance emotions over the PFC (including rPFC) using a 52 channel fNIRS device. Their findings showed greater right sided PFC activation during the processing of negative visual information (e.g. scenes of mutilation shown on pictures from the IAPS database). This is in line with previous research demonstrating prefrontal asymmetry for the processing of positive and negative emotions using EEG (Allen, Harmon-Jones, & Cavender, 2001; Craig, 2005; Davidson, 2004; Sutton & Davidson, 2000) demonstrating the suitable use of fNIRS in studies exploring frontal asymmetry. Ernst et al. (2012) provides evidence that frontal asymmetry in relation to approach/avoidance emotions can be measured using fNIRS.

Glotzbach (2010) demonstrated the use of fNIRS during the assessment of emotion regulation strategies successfully. Their task instructed participants to re-appraise fearful stimuli (pictures taken from the IAPS database) by imagining either a positive outcome or imagining that the scene was not real. Reappraising fearful stimuli resulted in greater

DLPFC activation, which has also been associated with fear appraisal in studies using fMRI (e.g. McNaughton & Corr, 2004). Glotzbach (2010) demonstrated that fNIRS can be effectively deployed to investigate emotional processing in the PFC. These studies show that fNIRS technology is an effective tool to assess changes in haemodynamics in the rPFC in relation to cognitive and emotional processing.

2.4.3 Strength and Weaknesses of fNIRS Systems

Using fNIRS devices has a number of advantages over more widely used techniques such as fMRI. Firstly, fNIRS is relatively inexpensive, portable and easy to use. The fNIRS Imager1000, for example, consist of a headband, a hardware box and a software package (Figure 2.5). It is therefore easy to set up and can be used in environments that are more natural than the fMRI scanner. This is an important aspect during the study of aesthetics as it enables greater ecological validity of the aesthetic experience. Participants throughout the experimental studies were able to sit upright and were not distracted by loud scanner noises or confined environments. Its second advantage is that it can be used with populations that are adverse to the exposure to fMRI or position tomography (PET). Although this was not directly relevant to this thesis, future research may look at populations that are affected by psychiatric illness and are adverse to scanning environments.

Figure 2.5 The fNIRS Imager1000. Taken from Ayaz (2010).

Continuous-wave based fNIRS devices have a number of advantageous over other non-invasive imaging techniques. Functional near-infrared systems are, in comparison to fMRI, MRI or PET, relatively inexpensive. The technique does not require the ingestion of radioactive agents as is the case with PET. A further advantage of fNIRS technology is its compatibility with EEG systems allowing for simultaneous explorations of spatial and temporal properties (Elwell & Cooper, 2011; Scholkmann et al., 2014). This approach cannot be used with fMRI for example because of signal interference from the two devices. Functional NIRS and EEG compatibility may aid neuroaesthetics research in the future to explore spatial and temporal properties of the aesthetic experience simultaneously.

However, there are a number of limitations of CW fNIRS devices. All CW fNIRS devices are restricted by their depth measurement capacity which is limited to about 3cm (Elwell & Cooper, 2011; León-Carrión & León-Domínguez, 2012; Lloyd-Fox, Blasi, & Elwell, 2010; Scholkmann et al., 2014). The penetration depth is constrained by the optic window because wavelength greater than 900nm penetrate tissue poorly due to the spectrum's high water absorption capacity at greater depths (Figure 2.4) (León-Carrión & León-Domínguez, 2012). fNIRS therefore only measures blood flow in the cortex and is unable to reach deeper brain structures. Emotional experiences towards art may therefore activate emotion related centres that are located deeper in the brain such as the amygdala or anterior cingulate cortex. However, the special interest of this research in the role of the rPFC warrants the use of the fNRI Imager1000.

A shortcoming of the measurement of CW-based NIRS instruments is that it only captures haemoglobin changes of HbO and HHb with respect to an initial value arbitrarily set equal to zero, calculated using the MBLL. Continuous-wave based devices can therefore not fully determine the optical properties of tissue (i.e. light scattering and absorption coefficients) and HbO and HHb are determined in relation to an arbitrary value (Ayaz, 2010; Elwell & Cooper, 2011; León-Carrión & León-Domínguez, 2012; Scholkmann et al., 2014). However, the MBLL can be used to calculate relative changes in HbO and HHb, which can be statistically modelled. This been shown to be more important than absolute quantification of HbO and HHb during neuropsychological studies (Scholkmann et al., 2014).

As with other imaging techniques, fNIRS devices are sensitive to sources of signal noise that need to be considered carefully during the process of fitting the device to the participant and data analysis (Scholkmann et al., 2014). Firstly, noise coming from light sources other than the intended carriers is problematic and the apparatus works best in environments with minimal lighting. A black headband was used throughout all experimental studies of this thesis to keep light from external sources to a minimum and increase the signal to noise ratio. Secondly, the signal strength is influenced by hair colour and density, and skin pigmentation (Elwell & Cooper, 2011; Scholkmann et al., 2014). Some devices, such as the fNIRS Imager1000 used in this thesis, are limited to hair free areas, such as the forehead below the hair line. These devices have the advantage that the obtained measurements are not confounded by hair providing that all hair has been carefully remove from the forehead to assure good conductivity. However, hair may still affect recordings at the most outer voxels, mainly voxel 1, 2, 15 and 16 (Figure 2.2) (Ayaz, personal communication), of the fNIRS Imger1000. Recordings from the four outer voxels were therefore excluded or treated with caution throughout the experimental studies. The fNIRS signal is affected by head movement which can create large movement artefacts, particularly if the head is moved forward and downwards, such as a nodding movement. Although some movement artefact can be removed using SMAR in fNIRS-Soft, initial experimental protocols were modified to eliminate excessive head movement (see chapter 4 for a further discussion on movement artefacts).

2.4.4 Data Analysis – fNIRSSoft

There is currently no standardised approach to the analysis of data from multi-channel fNIRS systems either for creating absolute tomographic images or topographic maps, or for determining the statistical significance of change in haemodynamics and oxygenation (Scholkmann et al., 2014). The standalone software package fNIRS-Soft, which is designed to process, analysis and visualise fNIRS signals through a graphical user interface and/or scripting that has been developed for the use of the fNIRS Imager1000 (Ayaz, 2010) was therefore chosen for the data reduction and analysis in this thesis. Raw data were subjected to a Sliding-window Motion Artefact Rejection (SMAR) algorithm to remove motion artefacts and saturated channels (Hasan Ayaz, Izzetoglu, Shewokis, & Onaral, 2010). Oxygenated haemoglobin (HbO) and deoxygenated haemoglobin (HHb) were calculated using the modified Beer-Lambert Law according to a baseline taken immediately before each stimulus. A finite impulse response linear phase low-pass filter, with order 20 and cut-off frequency of 0.1 Hz was applied to attenuate high frequency noise, respiration and cardiac effects (Ayaz, 2010; Ayaz et al., 2010; Scholkmann et al., 2014). Outliers that diverged three standard deviations from the mean were excluded form analysis. Greenhouse-Geisser correction was applied where necessary.

There is currently no strong consensus in the literature regarding the optimal parameter of brain activation that can be derived from fNIRS data (Elwell & Cooper, 2011; Scholkmann et al., 2014). Research investigating emotional processes using fNIRS has reported significant changes in the PFC for HbO alone (Leon-Carrion et al., 2006), for HHb alone (Ernst et al., 2012) or for both HbO and HHb (Glotzbach et al., 2011). It has been argued that HHb is sensitive to local haemodynamic changes, less prone to influences from psychophysiological noise, such as breathing or heart rate and has a close association with the blood oxygenation dependent (BOLD) signal obtained from fMRI (Ernst et al., 2013; Izzetoglu et al., 2007; Plichta et al., 2006). However, HbO is the parameter which is less sensitive to variation in probe placement due to head size and shape because HbO activation is more global compared to HHb activation (Hoshi, 2005; Plichta et al., 2006; Scholkmann et al., 2014; Wobst, Wenzel, Kohl, Obrig, & Villringer, 2001). A compound score was therefore calculated for oxygenation (OxyHB = HbO – HHb) in order to capture both measures whilst controlling for changes in blood volume (Izzetoglu et al., 2007).

3. Study I - The Survey[1]

3.1 Abstract

A shortcoming in neuroaesthetics research is the inconsistent use of stimuli and associated difficulties surrounding experimental control. This survey aimed to create a database of art images that have been rated on six psychological properties by a large audience for use in subsequent laboratory-based experimentation. An online survey was developed with sixty artworks from little known artist and rated by over 1000 participants for activation, complexity, comprehension, novelty, attraction and valence. Participants viewing time for each image was also recorded. A multiple regression analysis showed that high comprehension, high complexity and negative valence resulted in longer viewing times, which has been used as an indicator for interest in previous research. The images from the database created in this survey can be used as experimental stimuli with known psychological properties that have been related to the aesthetic experience in future neuroaesthetics research.

3.2 Introduction

Di Dio and Gallese (2009) identified the inconsistent use of stimuli within neuroaesthetics as shortcoming of the field. These authors argued that this inconsistent has led to a general disagreement of the definition of aesthetic experience and inconsistent findings within neuroaesthetics. This emphasises the need for a database of standardised images that allow for better comparison of studies, better control in the selection of aesthetic stimuli and replications of studies across the field. The purpose of this study was to

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[1] Part of the survey reported in this chapter was published in: Karran, A. J. and Kreplin, U. (2014). *The Drive to Explore: Physiological Computing in a Cultural Heritage Context*. In S. H. Fairclough and K. Gilleade (eds.) "Advances in Physiological Computing". Elsevier: London.

develop a database of art images with known psychological properties for experimental manipulation.

Previous research has developed normative stimuli for the use in emotion research. The most widely used database of emotion evoking stimuli is the International Affective Picture System (IAPS) (Ito, Cacioppo, & Lang, 1998; Lang, Greenwald, Bradley, & Hamm, 1993). IAPS consist of colour photographs of emotion evoking stimuli that have been evaluated on three dimensions (valence, arousal, dominance). IAPS was evaluated through participants' ratings using the self-assessment manikin (a 9-point Likert scale with figures depicting valence, arousal and dominance), for positive, negative and neutral colour photographs. Scenes varied from pleasant pictures of smiling babies to unpleasant pictures of, for example mutilations. IAPS was developed for experimental manipulation of stimuli in fear and emotion research. The IAPS database used Russell (1980) two-dimensional model to map out the emotional space. Dimensional models of emotions comprise of a 2D circular array of affect descriptors with valence and arousal as consistently emerging dimensions. Christie (2004; see also Russell, 1980) suggested that emotional experiences operate on a continuum, with distinct patterns on both ends and ambiguity in the middle. IAPS's adaptation of the two dimensional space appears limited in the context of a rich aesthetic experience and lacks finesse to encompass cognitive, emotional and motivational components.

Silvia (2008; 2010) highlighted emotions such as interest or curiosity that drive exploration and learning as important during the perception of visual art. Interest, according to Silvia, is experienced through a combination of novelty, complexity and unfamiliarity as well as the ability to understand the perceived stimuli. The origin of Silvia's concept of 'interest' stems from Berlyne's (1960) work on curiosity and exploratory behaviours; Berlyne assumed that people would prefer medium levels of emotional engagement experienced through arousal. Accordingly, interest is generated if the stimulus is new and complex as these qualities increase arousal within the system. New knowledge is gathered to resolve this conflict and arousal levels are lowered. Anxiety or boredom would be caused if arousal is too high or too low. Silvia (2008; 2010) placed interest within appraisal theory of emotions. Interest is appraised through the novelty, uncertainty and complexity of a stimulus, and the individual's ability to comprehend the new complex thing. As with Berlyne, anxiety or boredom are experienced if the stimulus is too complex to be comprehend. Cognitive components suggested to contribute to interest are novelty, complexity and comprehension (Silvia, 2008).

However, Silvia overlooks emotional components, such as valence and arousal; aspects described in the two-dimensional model of emotion (Russell, 1980). A comprehensive model should include the cognitive evaluation of an artwork, but also an emotional/motivational aspect. To capture the relationship between cognitive and affective aspects a conceptual model of affective experience that includes approach/avoidance (as motivational domain), complexity, novelty and comprehension (as cognitive domain) and negative and positive affect (as emotional domain) was developed. Furthermore, interest toward an image has been linked to the amount of time an image is viewed (Berlyne, 1960). Viewing time (VT) can be used as a behavioural measure of interest towards an image and was also included in the model.

This survey had therefore two aims. Firstly, it aimed to validate a database of contemporary artworks to create a standardised set of stimuli for experimental investigation. The database comprises of contemporary artwork making it more relevant to the investigation of the aesthetic experience. Secondly, it aimed to validate a conceptual model comprising of novelty, complexity and comprehension reflecting cognitive appraisals of emotions (Berlyne, 1960; Leder et al., 2004; Silvia, 2008, 2010) and valence, attraction and arousal reflecting emotional/motivational elements (Christie, 2004; Davidson, 2003; Leder et al., 2004; van Honk & Schutter, 2006). We hypothesised that the cognitive components comprehension, complexity and novelty would be independent of the emotional domain valence, arousal and attraction. We also predicted that images with high levels of complexity, novelty and comprehension, paired with emotional valence will be seen as more interesting and result in longer viewing times.

3.3 Methods

3.3.1 Participants

Participants (N = 1028) were recruited over the internet. Recruitment was conducted via email, poster campaigns, and social networking site such as Twitter or Facebook. The mean age of participants was 33yrs. (s.d. 14.24), with a range between 18 and 80 yrs. Half of the participants (49%) did not have any formal training in an art related subject; 63% were female. Participants were predominantly from Europe (N = 808, of which 644 from the United Kingdom), but also from North America (N = 145), South America (N = 4), Africa (N = 3), Asia (40) and Australasia (N = 28). All instructions were given in English. Participants had to be in command of the English language to participate.

3.3.2 Materials

Sixty-three colour images were selected from the internet (Figure 3.1 for an example, see Appendix 11.2 for a full list of images and artists). The criteria comprised of relatively unknown contemporary artworks; images were included if artist sold or exhibiting their work. A combination of abstract and representational paintings was chosen as previous research indicated different levels of processing between representational and abstract art (Batt et al., 2010). Permission to use the images was obtained from all artists.

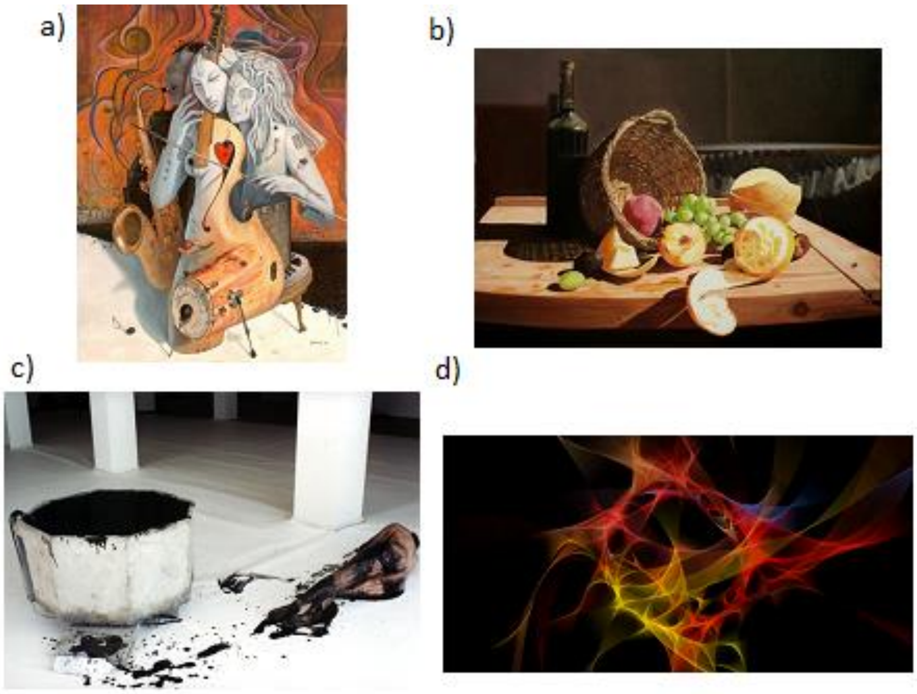

Figure 3.1 An example of images used in the survey (a) 'Artist in Love' © Adrian Borda, (b) 'Best Abstract' © Adrian Borda, (c) 'Elytron' © 2003 Monika Weiss, self-photography, performance, installation, sculpture and video. Courtesy the artist and Chelsea Art Museum, New York, (d) 'Ablaze' © Patrick Gunderson.

The pictures were assigned to four sets, three surveys with 20 images each and one with three images forming a practice set. Participants were given the choice to complete one, two or three sets to increase completion rate. Each set took twenty minutes to complete and was given a name (Leonardo, Raphael, Donatello); because not all participants completed all sets the number of responses between sets varied slightly (Leonardo N = 324; Raphael N = 371; Donatello N = 333; Total N = 1028) appearance of the surveys was counterbalanced. A price draw for amazon vouchers was offered with increasing value for the completion of sets (1 set = £10, 2 sets = £25, 3 sets = £50). Images from the practice set were not included in the analysis.

In order to assess the six domains rating scales similar to the Self-Assessment Manikin (SAM, Lang et al., 1993) were developed (Figure 3.2). Ratings were made on visually represented 9-point Likert scales. In addition, viewing time was used as a behavioural measure of interest (Berlyne, 1960).

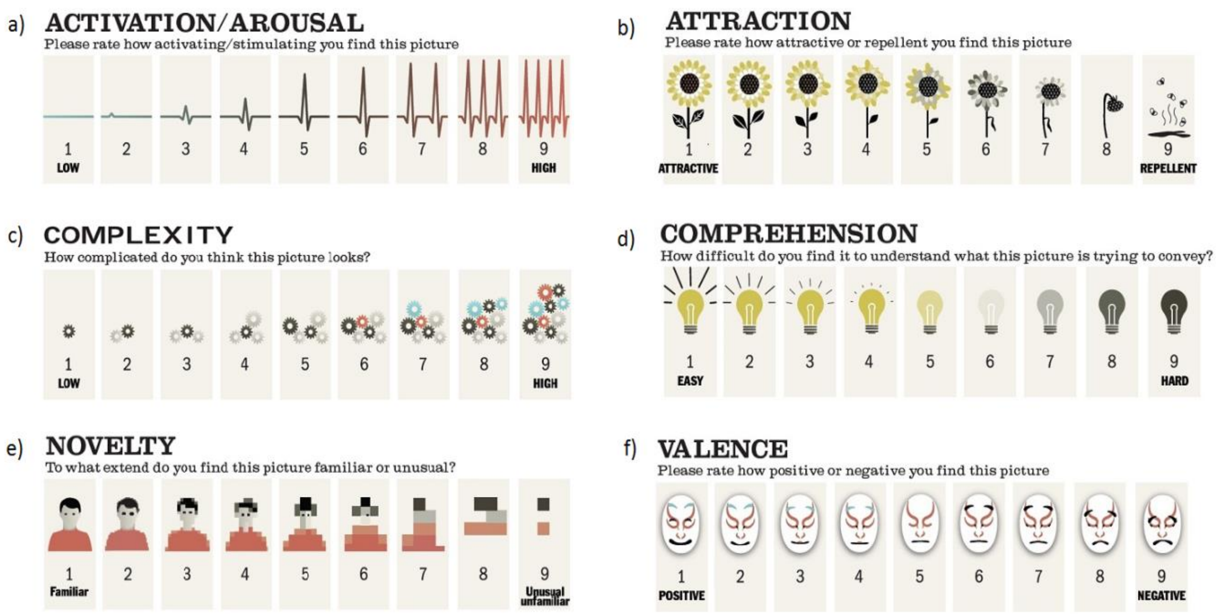

Figure 3.2 The six rating scales depicting (a) activation, (b) attraction, (c) complexity, (d) comprehension, (e) novelty and (f) valence. Designed by Megan Abel (www.meganabel.co.uk).

Images were presented in random order within each image set. Scales were counterbalanced for each participant providing one order for each set. A client side timer recorded the viewing time for each picture. Pictures were shown for a minimum of five seconds before participants could proceed to the ratings via a button press and a maximum of 60 seconds before the scales would be shown automatically. Hence viewing time was at the discretion of the viewer.

The survey was implemented in PHP and Javascript and was deployed over Apache webserver[2]. Each image was preloaded onto the participants' computer to ensure instant display. Users' ratings were submitted to a MySQL database via PHP scripts. Database security was included to prevent MySQL injections and other types of attack over the web. The systems functionality was evaluated using both black-box (testing the internal functionality of the programme) and white-box (testing the external behaviours of the programme) testing procedures to ensure submissions were correctly recorded. Data was extracted to an excel spread sheet for further analysis.

3.3.3 Procedure

Participants were invited to follow an online link to the survey and given the opportunity to rate three practice images to familiarise themselves with the scales and content of the images.

Participants were asked to rate between one and three sets containing 20 images each. Participants were instructed that they could view the images for up to 60 seconds, but that they could make a rating after the first five seconds if they felt they had comprehended the image fully. Five seconds after the image came into view a button at the bottom of the screen enabled the participant to proceed to the rating scales; scales appeared automatically after one minute. Ratings for each of the six scales were given by clicking a circle underneath the icon with the mouse. There was no time limit to complete the ratings. Participants were thanked for their participation and shown a list of accreditations to the artists. All procedures were approved by the university ethics committee.

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[2] I would like to thank Kiel Gilleade for his work on the implementation of the online survey as part of the ARtSENSE project.

3.4 Results

Each picture was rated by an average of 342 participants (minimum number of respondents per image = 324). Ratings were averaged across participants for each image (Appendix 11.1 for mean ratings for all images) Correlations were computed to assess the relationships between each construct. Viewing Time (VT) was moderately correlated to comprehension, novelty, valence and activation, and strongly correlated with complexity. Viewing time was excluded from further analysis due to technical issues and high standard deviations (see Discussion p. 74). Activation was positively correlated with novelty and complexity but unrelated to valence and attraction. Attraction and valence showed a strong positive correlation and it was decided to collapse them. Novelty was strongly correlated with most other constructs (Table 3.1 for the correlation matrix).

Table 3.1 Correlation matrix for mean Viewing Time, Activation, Attraction, Complexity, Comprehension, Novelty and Valence.

	Activation	Attraction	Complex.	Compreh.	Novelty	Valence
VT	0.61**	0.31*	0.73**	0.50**	0.57**	0.40**
Activation		0.12	0.70**	0.43**	0.62**	0.33**
Attraction			0.45**	0.59**	0.71**	0.93**
Complex.				0.84**	0.86**	0.55**
Compreh.					0.90**	0.64**
Novelty						0.77**

Note: VT = Viewing Time; Complex. = Complexity; Compreh. = Comprehension * $p<0.05$, ** $p<0.001$

A standard multiple regression was used to assess the ability of the six psychological properties (activation, attraction, complexity, comprehension, novelty and valence) to predict viewing time. Preliminary analyses were conducted to ensure no violation of the assumptions of normality, linearity, multicolinearity and homoscedasticity. Novelty showed a stronger relationship to both the cognitive and the emotional domain on close examination of the correlation matrix (Table 3.1). The unique contribution of novelty may be ambiguous and should be analysed with caution. Valence and attraction were highly correlated suggesting that they were either highly dependent on each other or had not been considered as sufficiently different during the ratings (see Table 3.1). Novelty and attraction were excluded from the model following a tolerance level below .10. Viewing time was used as dependent variable with the predictors activation, complexity, comprehension, and valence, all variables were entered at the same time using the enter methods. The total variance in viewing time explained by the model was 60%, i.e. R^2 = 0.60, and the model achieved statistical significance ($F(4,57) = 23.85$, $p<0.001$). The predictors complexity (beta = 1.11), comprehension (beta = -.59) and valence (beta = .22) significantly predicted viewing time. Activation did not reach significance in the final model (Table 3.2). It was shown that longer viewing times were associated with greater complexity, high comprehension and negative affect.

Table 3.2 results from the multiple regression analysis.

Predictor	β	*t*	Sign.
Activation	-0.008	-0.06	ns
Valence	0.24	2.06	0.04
Complexity	1.11	5.21	0.001
Comprehension	-0.59	-3.23	0.002

Note: $R^2 = .64$

3.5 Discussion

The main purpose of this survey was to create a database of images that were rated on a variety of psychological properties related to the cognitive and emotional evaluation of art. Sixty artworks from little known artist were rated on comprehension, complexity, novelty, valence, attraction and valence. In addition VT was recorded. This set of images will allow for systematic manipulation of stimuli according to these psychological properties.

The correlations suggested that there was variation between cognitive and emotional components of the model. Valence and activation showed a low correlation which is consistent with dimensional models of emotions (Christie, 2004; Russell, 1980). Comprehension, novelty and complexity loaded highly on the cognitive domain, with comprehension and complexity showing lower correlations to valence and activation. Consistent with Silvia (2008), comprehension and complexity are part of the cognitive appraisal of interest experienced towards art. Novelty showed a high correlation with valence (i.e. negative images), but also greater correlations with all other concepts suggesting that it may lie between the cognitive and emotional domain.

A multiple regression analysis showed a positive correlation with complexity and valence and a negative correlation with comprehension suggesting that images that were negative and more complex but also easier to comprehend were looked at more. Silvia (2008) suggested that interest towards an image is experienced when novelty and complexity are high but comprehension is also high. The results from this study only partially support this. It was found that novelty did not bring any unique variance to the model, but that high complexity and high comprehension (i.e. easy to understand images) predicted viewing time which has been demonstrated as a reliable predictor of interest (Berlyne, 1960). Furthermore, negative valence increased viewing time indicating that valence may an important construct to be taken into account when studying aesthetic experiences.

The survey provided us with a database of images that can be manipulated in neuropsychological experiments. The results from the analysis showed that particularly two cognitive (complexity and comprehension) and one emotional (valence) component may be important to the aesthetic experience as they increased viewing time and therefore participants’ interest.

3.6 Limitations

Further analysis may have been possible by grouping images using a more classical categorisation strategy (e.g. faces, landscapes, abstract art etc.). Analysis using these subcategories may have produced results that showed a different set of variables to predict VT. For faces, for example, attraction novelty and arousal may have been more important than complexity, comprehension and valence. Further, valence and attraction showed a high correlation in our results, indicating that participants did not differentiate sufficiently between these two scales. This may have been different in a face category where attraction is not necessarily related to valence.

The analysis of VT showed also large standard deviations which were often greater than the mean itself. This variation may be attributed to factors that could not be controlled in the survey design. One of the main aspects was variability in screen size. Participant using screens smaller than 1024px would have increased their viewing time by scrolling down to get to the ratings button. Participants using bigger screens would not have had this delay. Not all aspects of this could be controlled, although a minimum screen size was imposed. Viewing time was therefore excluded from further analysis.

3.7 Conclusion

The database will allow manipulation of images in experimental studies using the ratings obtained in the survey. Images may be manipulated through their complexity, valence or comprehension or a combination of two or more properties. This will allow for a viewing experience that controls for image properties (e.g. complexity) as well as the coping potential of viewer (e.g. comprehension). This survey will help overcome the shortcomings highlighted by Di Dio and Gallese (2009) by allowing the manipulation of consistent stimuli along a range of psychological properties.

4. Study II - The Pilot

4.1 Abstract

The contemplation of visual art draws upon cognitive and emotional evaluations, processes that have been associated with the rostral prefrontal cortex (rPFC). The complexity and valence of an image may differentially activate rPFC. This study influenced participants' experiences by changing two psychological properties of sixteen visual artworks. An emotional component (valence) with two dimensions (positive and negative) and a cognitive component (complexity) with two dimensions (high and low complexity) were manipulated whilst brain activation was assessed using functional near-infrared spectroscopy (fNIRS). Emotional responses were also assessed via facial electromyography (fEMG) over the zygomaticus major and corrugator supercilii muscle. No significant results were found for the fEMG data. Results showed an increase in oxygenation at the medial rPFC during the experience of positive affect. No effect of complexity on rPFC activation was observed. The results suggest that medial rPFC is important to the experience of positive emotions during the experience of visual art.

4.2 Introduction

The contemplation of rich psychological stimuli, such as visual art, draws upon structures of the brain that are involved in sensory, cognitive and emotional processes (Chatterjee, 2006; Leder et al., 2004). Research within neuroaesthetics contends that artworks are evaluated through bottom-up sensory driven mechanism, such as recognition of lines and colours, or by attentional top-down feedback, such as cognitive control. The latter processes are hypothesised to be generated outside the visual cortex in areas such as the prefrontal cortex (PFC); in particular Brodmann's area (BA) 10 (Figure 1.4 Three schematic views of the human brain with frontal cytoarchitectonic areas indicated according to Brodmann's map (1909). (Taken from Faw, 2003). The contemplation of a painting, for example, involves visually identifying an object, the classification and categorisation of features within the object and its cognitive and emotional evaluation. Few studies have investigated the emotional evaluation in the rPFC during the contemplation of visual art and the interaction with cognitive process, such as a paintings complexity. It remains therefore unclear how emotions and cognition impact on rPFC activation in an aesthetic context.

Neuroaesthetics provides some insights about cognitive processes during the contemplation of visual art. Augustin et al. (2011), for example, investigated two aspects defined as central to the evaluation of representational art: object identification and extraction of stylistic features in an Electroencephalography (EEG) study. The authors looked at the lateralised readiness potential (LRP), the increase in electrical activity of the brains surface in preparation to a response selection, between the availability of stylistic compared to object related information; stylistic information was 40 – 94ms later available than object related information. The delay in processing of stylistic features distinguishes perception of art from that of everyday object recognition.

Investigations on the role of the rPFC in affective states or its involvement in emotional evaluations of visual art are less prominent in the literature. Vartanian and Goel (2004b) observed differential patterns of activation in the right caudate nucleus and bilateral occipital gyri, left cingulate sulcus and bilateral fusiform gyri in response to aesthetic preference ratings. The authors concluded that activation in these structures is a specific example of their role in evaluating reward-based stimuli that vary in emotional valence. However, Vartanian and Goel (2004b) did not focus their analysis on the rPFC. Furthermore these authors did not report any direct manipulation or control for the valence of their stimuli and conducted their study using abstract and representational paintings that were either in their original form, slightly modified or filtered (slightly blurred). Increases in right PFC activation during the visual contemplation of art have been associated with the experienced pleasantness of the painting (Thakral et al., 2012; Vessel et al., 2012). There have been no studies that simultaneously investigated the effects of complexity and valence in the rPFC during the presentation of art. This area has been associated separately with emotional and cognitive process as well as being an area that has been associated with the integration of emotion-cognition processes (Gray et al., 2002). The rPFC is therefore highly relevant to the contemplation of visual art.

Cupchik et al. (2009) proposed that the perception of art is concerned with stylistic and structural properties compared to everyday perception that is concerned with object identification. The authors proposed that aesthetic experience requires the suppression of object identification in order to focus attention on the stylistic features of the artwork. Cupchik et al. (2009) suggested that top-down control, a process associated with the prefrontal cortex, is geared toward attenuating object identification and may be necessary to engage with art. In contrast, emotion regulation i.e. the up and down regulation of positive and negative affect has been thought of as a bottom-up modulator of stimulus representation (Mitchell, 2011). Affective information will be given enhanced access to processing sources during situations where multiple demands are made on attention. The valence of stimuli may therefore bias activation in the rostral parts of the PFC through bottom-up influences.

EEG studies have shown that affective valence, i.e. positive and negative emotions can be associated with left and right hemispheric activation (Coan and Allen (2004) for a review). Davidson (2003) found that participants that displayed greater right-sided cortical activity at rest, compared to those showing greater left-sided activity, showed greater fear responses to negative stimuli. A person's affective style, the extent to which positive and negative emotions are experienced, is therefore partly moderated by asymmetries in frontal cortical activity. However, Harmon-Jones, Lueck, Fearn, and Harmon-Jones (2006) demonstrated that motivational direction rather than affective style accounts for asymmetrical cortical activation. Thus, right hemispheric activation is greater for withdrawal emotions such as fear, whereas left sided activation is greater for approach emotions such as anger or curiosity. Frontal asymmetry has been found at sites Fp1/Fp2, F3/F4 and F7/F8 of the 10-20 system (Harmon-Jones & Sigelman, 2003; Sutton & Davidson, 2000). Although F3/F4 and F7/F8 are located more posterior to the rPFC, the fNIRS device used in this study aligns with Fp1/Fp2 (Ayaz, 2010). Furthermore Ernst et al.

(2012) reported frontal asymmetry in areas corresponding to the rPFC that were measured using fNIRS. Art images that elicit fear, disgust or awe may be moderated by asymmetrical activation in the rPFC.

This study aimed to investigate how complexity and valence influenced activation in the rPFC. Functional near-infrared spectroscopy (fNIRS) was used to capture rPFC activation. Feelings of pleasure or unhappiness may be expressed via facial musculature and can be measured via facial electromyography (fEMG) (Boxtel, 2010; Larsen, Norris, & Cacioppo, 2003). For the purpose of experimentation, activation of the corrugator supercilli (located in the eyebrow) and the zygomaticus major (located at the corner of the mouth) was measured. Activity from these muscles is associated respectively with frowning and smiling, and may be detected in the absence of observable changes in facial expression. Greater overall PFC activation for high complexity images compared to low complexity images was hypothesised. An interaction between valence and complexity that showed more activation for negative images compared to positive images and rPFC asymmetry with more left sided activation for positive images and more right sided activation for negative images.

4.3 Methods

The experiment had two parts. Part one consisted of an online study were participants pre-rated 36 art images varying in complexity and valence taken from the database created in the survey (chapter 3). Part one was conducted to further calibrate the experience of the artwork for each person to maximise the experience rather than relying on group averages from the survey. Part two was conducted 2 – 4 weeks later at the laboratory at LJMU where psychophysiological signals were recorded during the free viewing of 16 artworks.

4.3.1 Participants

Twenty participants (12 female) were recruited via email and posters from the LJMU student and staff population and the general public with a mean age of 25 yrs. (s.d. 8).

4.3.2 Procedure

Part 1

Participants used the six scales developed for the survey (chapter 3) to rate 36 randomly presented colour images that were selected from the two opposing ends (positive/negative and high/low complexity) of the database created in the online survey. Presentation of the scales was counterbalanced. Images were presented for 10 seconds. There was no time limit to complete the ratings. The study was conducted online and implemented in PHP and Javascipt and used a MySQL database. Please refer to page 37 of Study I for further details. Data was extracted to excel where it was used to select 16 images varying in complexity (high/low) and valence (pos/neg) to be presented as stimuli in part two of this study.

Part 2

Stimuli selected in part one were assigned to four categories positive high (PH), positive low (PL), negative high (NH) and negative low (NL) (Figure 4.1). Images were selected according to the highest/lowest complexity/valence rating for each participant generated in the pre-rating in part one of this study. Each category contained four images, making a total of 16 experimental stimuli. The survey therefore served to narrow the use of stimuli to accurately allow for the calibration of stimuli to the individual, whilst preserving stimuli categories.

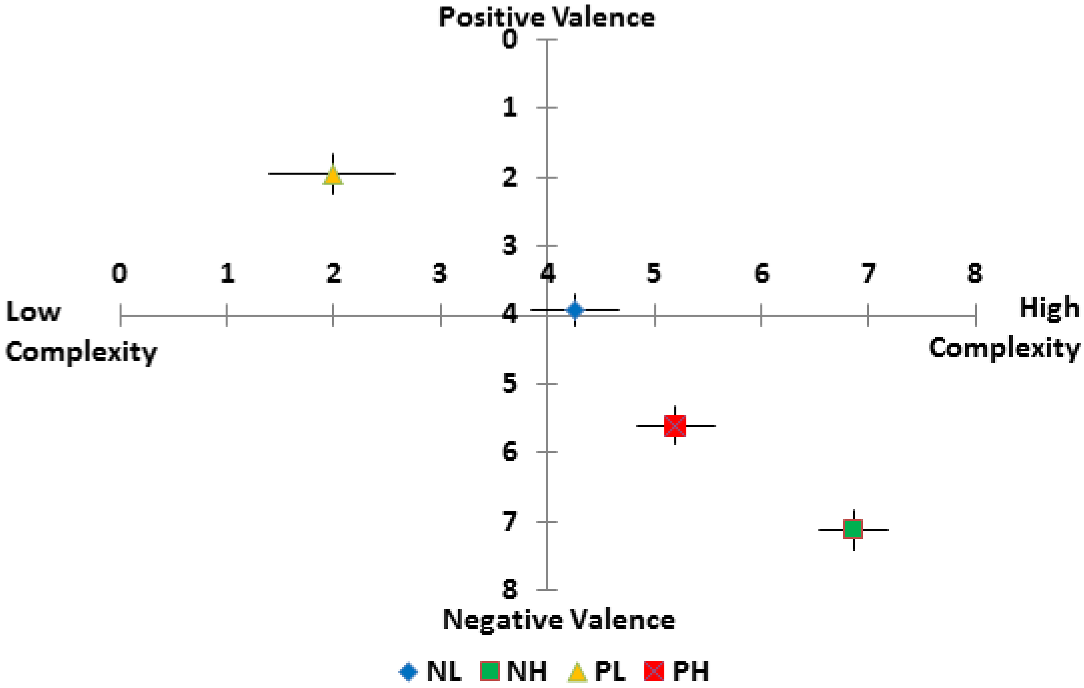


Figure 4.1 Mean ratings for each category with standard error, NL = Negative/Low complexity, NH = Negative/High complexity, PL = Positive/Low complexity and PH = Positive/High Complexity.

The 16 images were presented in random order for 30 sec using E-prime 2.0 on a 1920x1980 pix computer screen. A 30 sec baseline measure was taken before each image. Following each image participants were asked to complete a simple paper and pen join-the-dots puzzle as distractor task between images (Figure 4.2). The puzzles were introduced to distract participants from the previous image in order to eliminate the emotional impact from the previous image. Puzzles represented images such as a pumpkin, had no more than 25 dots and took no more than 30 seconds to complete.

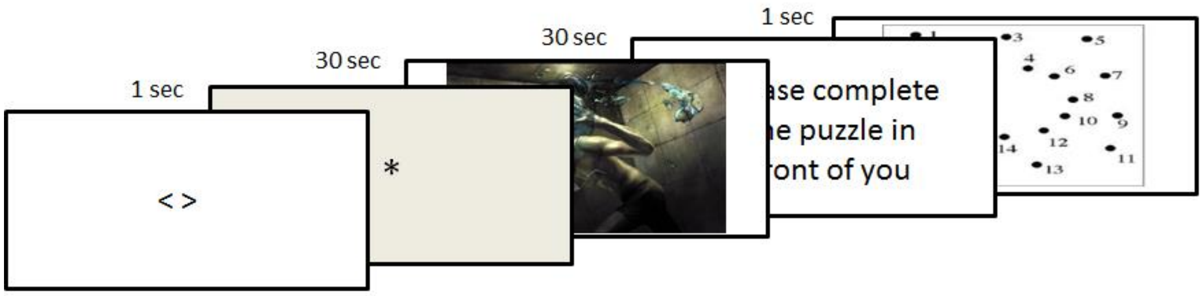


Figure 4.2 Experimental procedure and time-line. Participants viewed images for 30 sec before completing a join the dot puzzle.

4.3.3 Psychophysiological Measure and Data Reduction

Facial EMG was recorded over the left corrugator supercilii and zygomaticus major as measure of emotion (Lang et al., 1993). Fridlund and Cacioppo (1986) suggested that these muscles reflect separate components of the affect system that can be reliably measured. Electrodes were placed according to system described by Stern, Ray, and Quigley (2001). Signals were recorded through a shielded cable and send to a BIOPAC EMG100C Electromyogram Amplifier (Biopac System Inc). Signals were amplified x5000 and digitised at 1000Hz. Offline data was submitted to a 15Hz high-pass filter to remove blink-related artefacts, then full-rectified using Acqknowledge software (Biopac System Inc). Using synchronisation markers, 32 segments (16 baseline segments, 16 images segments) were extracted and exported to Excel. Segments were averaged according to condition (pos/high complexity, pos/low complexity, neg/high complexity, neg/low complexity) for baseline and image segments separately in Excel. Image segments were baselined by subtracting the baseline segment, which occurred immediately before the image segment, from the image segment. Each segment contained 20 seconds of data. SPSS was used for statistical analysis.

Functional near-infrared spectroscopy (fNIRS) was used to measure rPFC activation (see General Methods). Oxygenated haemoglobin (HbO) and deoxygenated haemoglobin (HHb) were calculated using the modified Beer-Lambert Law in fNIR-Soft (Ayaz, 2010). A finite impulse response linear phase low-pass filter, with order 20 and cut-off frequency of 0.1 Hz was applied to attenuate high frequency noise, respiration and cardiac effects (Ayaz, 2010; Ayaz et al., 2010; Scholkmann et al., 2014). Using synchronisation markers, 32 segments (16 baseline segments, 16 image segments) were extracted. Segments were averaged according to condition (pos/high complexity, pos/low complexity, neg/high complexity, neg/low complexity) for baseline and image segments separately. Each segment contained 20 seconds of data. Averaged oxygenated (HbO) and deoxygenated (HHb) haemoglobin data for each participant was exported to Excel for further analysis.

4.4 Results

A two (valence) x two (complexity) ANOVA was conducted on the behavioural ratings as a manipulation check. Results showed a significant main effect for valence ($F(1,19) = 82.25$, $p<0.001$, $\eta2=.81$) and an interaction between complexity and valence ($F(1,19) = 6.70$, $p<0.01$, $\eta2=.26$). No significant main effect for complexity was observed. Paired sample t-tests revealed a significant difference between all variables (Table 4.1).

Table 4.1 t-test results for the behavioural data including descriptive statistics.

Complexity	Mean	s.d.	*t*	*p*	Valence	Mean	s.d.	*t*	*p*
LowP	1.98	0.93			PosL	1.90	0.78		
HighP	5.19	1.75	-8.92	0.001	NegL	3.91	1.74	-5.91	0.001
LowN	4.19	1.27			PosH	5.48	1.95		
HighN	6.85	1.12	-7.61	0.001	NegH	7.10	1.02	-3.05	0.006
LowP	1.98	0.93			PosL	1.90	0.78		
LowN	4.19	1.27	-7.35	0.001	PosH	5.48	1.95	-7.07	0.001
HighP	5.19	1.75			NegL	3.91	1.74		

HighN	6.85	1.12	-3.73	0.001	NegH	7.10	1.02	-9.41	0.001

Note: Low/L = Low Complexity, High/L = High Complexity, Pos/P = Positive, Neg/N = Negative.

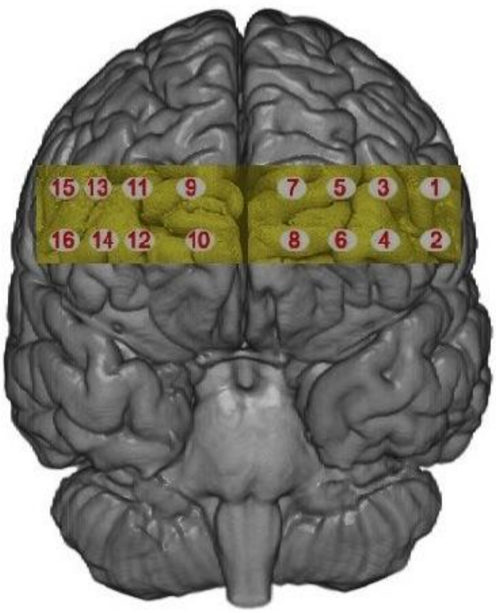
The fEMG data was averaged according to condition (Pos/High, Pos/Low, Neg/High and Neg/Low). A baseline period was taken before each stimulus. Baselined data was subjected to a one-way ANOVA. No significance was found (Table 4.2 for descriptive statistics).

Table 4.2 Descriptive statistics for the fEMG data (in millivolts) with mean and standard deviation for each condition.

	Zygomaticus		Corrugator	
Condition	Mean	s.d.	Mean	s.d.
NH	0.03	0.16	0.05	0.05
NL	0.03	0.18	0.05	0.14
PH	0.02	0.08	0.02	0.11
PL	0.04	0.10	0.0016	0.10

Note: NH = negative/high complexity, NL = negative/low complexity, PH = positive/high complexity, PL = positive/low complexity.

To test for increases in relative blood flow, a Blood Volume (BV) score was calculated by adding HbO and HHb (Izzetoglu & Bunce, 2004). Blood Volume was baselined and one outlier (3 s.d. above/below the mean) was excluded from the HbO data set. A two (valence) x two (complexity) ANOVA was calculated for each voxel separately for HbO, HHb and BV. Results for HbO yielded a significant main effect for valence at voxel 7 ($F(1,19) = 6.64$, $p<0.01$, $\eta2=0.25$) and voxel 10 ($F(1,18) = 4.61$, $p<0.04$, $\eta2=0.2$). The contemplation of positive images resulted in a greater increase of HbO at voxel 7 and voxel 10; both are located in the medial area of the rPFC (see Figure 4.3). Results for HHb showed a significant main effect for valence at voxel 10 ($F(1,19) = 5.75$, $p<0.02$, $\eta 2=0.23$), showing that the contemplation of positive images resulted in greater deoxygenation. Results for BV showed a main effect of valence at voxel 7 ($F(1,19) = 6.58$, $p<0.01$, $\eta 2=0.25$), voxel 8 ($F(1,19) = 4.83$, $p<0.04$, $\eta 2=0.2$) and voxel 10 ($F(1,19) = 6.34$, $p<0.02$, $\eta 2=0.25$). A greater increase in BV was seen during the contemplation of positive compared to negative images.



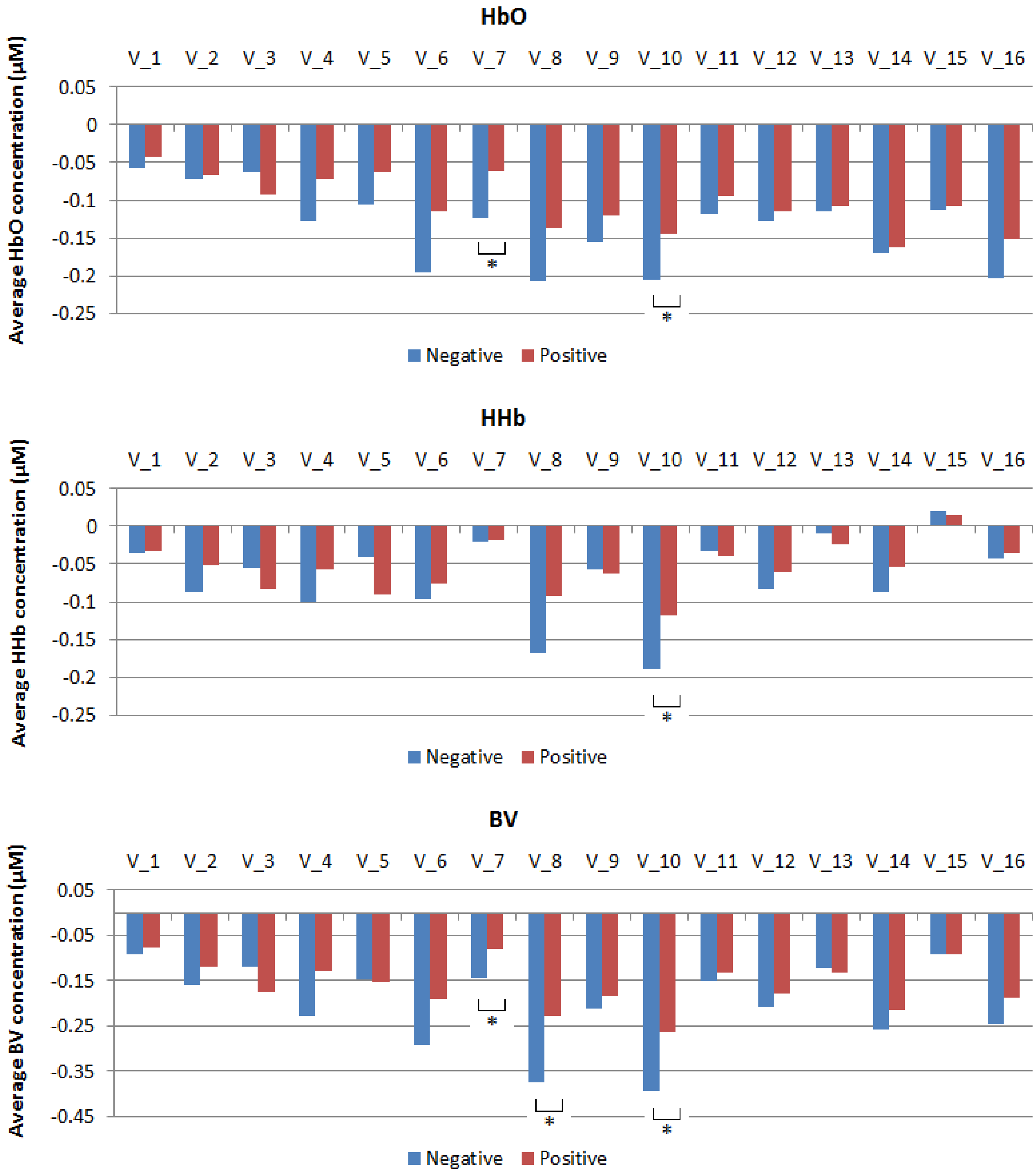


Figure 4.3 Averaged activation for HbO, HHb and BV and a topographic map of the fNIRS device (V_1 = voxel 1, V_2 = voxel 2, V_3 = voxel 3. V_4 = voxel 4, V_5 = voxel 5, V_6 = voxel 6, V_7 = voxel 7, V_8 = voxel 8, V_9 = voxel 9, V_10 = voxel 10, V_11 = voxel 11, V_12 = voxel 12, V_13 = voxel 13, V_14 = voxel 14, V_15 = voxel 15, V_16 = voxel 16; p<0.05).

4.5 Discussion

The results of the fNIRS analysis indicated greater activation in the medial area of the rPFC (voxel 7, voxel 8 and voxel 10) when participants viewed images that were associated with positive affect. No effect of complexity or an interaction was found. The lack of an effect of image complexity on rPFC activation may indicate that image complexity is processed in areas other than the rostral PFC that are not accessible using the current fNIRS apparatus. Complexity may be an aspect of early visual processing as described by Chatterjee (2004, Figure 1.2) that occurs in areas such as the visual cortex, the sensory cornices or the thalamus.

Vessel et al. (2012) found greater rostral medial PFC activation for images rated as highly pleasing and suggested that the rPFC is involved in signalling personal relevance and allowing for a heightened integration of external (sensory/semantic) sensation related to an art object and internal (evaluative/emotional) states. Furthermore, Vessel et al. (2012) reported this finding only for images that were liked the most and only to the left side. We found bilateral medial activation during the evaluation of positive art, which may indicate the participants' experience of pleasantness of those images. It may therefore be that participants in our study showed increased medial PFC activation during the experience of beauty that was only present in positively valenced images.

Asymmetrical activation in the PFC has been associated with processing differences in positive (approach) and negative (avoidance) emotions (Harmon-Jones et al., 2003). This research showed evidence for greater left sided cortical activation for approach related emotions and greater right sided activation for avoidance related emotions. However, our results did not indicate that there was hemispheric asymmetry in the rPFC during the contemplation of visual art. The lack of frontal asymmetry observed within this study may have been a result of the passive nature of the task. Harmon-Jones et al. (2003) found that only participants who believed that they could influence their situation displayed greater left sided activation and concluded that motivational direction (approach/withdrawal) rather than affective valence (positive/negative) are mediated by cortical asymmetries, particularly if the outcome is motivational in nature. Further support was provided by van Honk and Schutter (2006) who used repetitive transcranial magnetic stimulation (rTMS) to induce greater left/right sided cortical activation whilst participants performed an emotionally biased memory test. Findings showed reductions in the processing of anger after rTMS deactivated the left PFC compared to a sham condition and right sided rTMS. Neither left nor right sided rTMS influenced the processing of positive stimuli. Van Honk and Shutter (2006) concluded that memory for anger was affected by asymmetrical activation as it has a motivational component whereas happiness is a biological state of wellbeing that does not display motivational direction. Frontal asymmetries may influence frontal cortical systems that mediate emotional reactions when the outcome is motivational, rather than being part of the affective style of the individual as argued by Davidson (2003). Viewing negative emotions in art may not create strong emotional reactions that warrant an approach/avoidance response and are therefore not processed asymmetrically.

The experiment yielded first results into the involvement of emotion and complexity in the processing of art which may be interpreted within the framework of aesthetic experiences of beauty and the experience of pleasantness of a stimulus. Further experimentation will enable to examine the exact nature of these effects.

4.6 Limitations

The image selection was intended to increase experimental control by accounting for interpersonal differences in art by selecting images that were tailored to the individual's experience of complexity and valence. The survey exercise was intended to be used as a filter to allow for greater individualisation of the stimuli. However, this design introduced variability in the stimulus selection, including a significant interaction between complexity and valence ratings ($F1,19) = 6.07$, $p<0.01$, $\eta 2=.26$) (Table 4.2 Descriptive statistics for the fEMG data (in millivolts) with mean and standard deviation for each condition.). This resulted in a poor separation between image categories, particularly between positive high complexity and negative high complexity (Figure 4.1). It is therefore unclear if complexity is processed in areas outside of the rPFC or if the absence of an effect for complexity was caused by inadequate control over the stimuli categories. The interaction between complexity and valence may have invalidated the experimental findings. Future experiments would benefit from a clear assignment of images according to condition which would also make better use of the survey data.

We introduced a join-the-dots puzzle as a distractor task between images. However, this caused greater than anticipated movement. Participants had a tendency to lean forward during the completion of the join-the-dots puzzles dipping their head towards the floor, this movement created artefacts that could not be filtered out, resulting in exclusion of data and consequently the analysis of shorter time epochs (20 sec instead of 30 sec). León-Carrion et al. (2008) found that participants displayed greater activation for emotional stimuli up to 20 seconds after stimuli offset. Their findings undermine the analysis of short time epochs, emphasising longer exposure periods to fully observe the time course of activation assessed by fNIRS to emotionally valenced artwork. Future studies should take the time course of the fNIRS into consideration through the use of longer exposure times to investigate the full emotional experiences during the evaluation of visual art using fNIRS.

Our results may have been confounded by the use of a single generic baseline, taken at the beginning of the experiment to calculate HbO and HHb. The fNIRS device uses by default the first 20 usable samples of a recording as a predefined baseline in the Modified Beer-Lambert Law (MBLL) to calculate HbO and HHb. However, these first 20 seconds may be considerably higher at the beginning of the experiment due to possible apprehension of the participants than at the end of the experiment because of the long time period the fNIRS device was used to record data in this experiment (the duration of the experiment was approx. 50 min). Furthermore, cardiovascular responses such as heart rate are known to slow when individuals remain in a sedentary position for longer periods of time (Stern et al., 2001). The slowing of heart rate may have resulted in a decline of blood volume overall as a function of time on task. It would therefore be more appropriate to use a baseline taken just before each stimulus to calculate the MBLL (see General Methods for a detailed discussion).

Lastly, the placement of fEMG electrodes on the corrugator muscle in conjunction with the use of fNIRS (both mounted on the forehead) may have been incompatible resulting in the failure to observe significant effects in the left hemisphere, as fEMG electrode placement was left sided (Figure 4.4). Similarly, the fNIRS device may have restricted muscle movement in the forehead and interfered with the recording of fEMG over the corrugator supercilii accounting for the lack of activation found in the fEMG data.

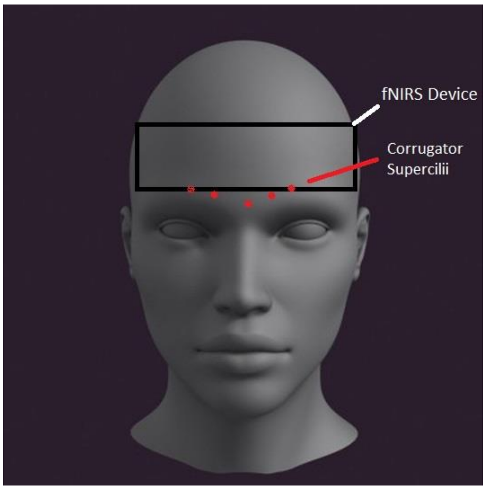


Figure 4.4 fEMG electrodes with the fNIRS placement mapped to a standard head.

4.7 Future Research

Future research may benefit from studying different cognitive dimensions such as the novelty or comprehension of the stimulus. Judging an image in relation to one's own understanding may be more reflective of Leder et al.'s (2004) cognitive mastering stage (Figure 1.3) and of greater relevance to rPFC activation. However, the methodological issues of this study were profound making a replication of the study recommendable to assure its results. Methodological issues that are vital to be resolved are:

- The use of fNIRS without the interference of fEMG electrodes
- The use of a baseline taken directly before each stimulus instead of one central baseline at the beginning of the recording session
- The use of stimuli that has been clearly assigned to a category (e.g. positive/high complexity) to assure that there is a clear distinction between image categories.
- The omission of the spot-the-difference task to avoid unnecessary movement artefacts
- The use of longer exposure times to the stimuli

4.8 Conclusion

The current study manipulated complexity and valence of visual art to gain an understanding of the involvement of the rPFC during aesthetic experiences. The tentative results of this study suggest that emotional processing is relevant to the experience of visual art and coupled to activation in the rPFC. This study provided a pilot of the methodologies that can be used in the study of emotional and cognitive processes during the contemplation of visual art. Important limitations to the experimental protocols have been highlighted that can be taken into consideration in future studies.

5. Study III – Complexity and Valence

5.1 Abstract

This study aimed to investigate the influence of image complexity and valence on rostral prefrontal cortex (rPFC) activation. Positive and negative images were viewed by 20 participants under two conditions: (1) high complexity and (2) low complexity. This study is a repetition of Study II - The Pilot with an improved methodology. Results showed no significant main effect for complexity suggesting that image complexity may be processed in areas outside the rPFC such as visual cortices. An interaction between emotion and time showed that positive emotions resulted in higher rPFC activation during the early period of stimulus presentation. In comparison, negative emotions resulted in higher rPFC activation during the late period. This may indicate that positive and negative emotions follow different latencies and highlights the importance of long exposure times during emotion research using fNIRS.

5.2 Introduction

The frontal cortex plays an important role in complex human thought. It has been associated with working memory (Duncan & Owen, 2000; McDaniel et al., 2013), attention (Mccaig, Dixon, Keramatian, Liu, & Christoff, 2011), cognitive load (Christoff & Gabrieli, 2000; Christoff, Keramatian, Gordon, Smith, & Mädler, 2009) and emotion (Mitchell, 2011). The rostral prefrontal cortex has also been implemented in aesthetic experiences (Cupchik et al., 2009; Vessel et al., 2012). It is however unclear how emotional and cognitive components interact in the rPFC.

Cupchik et al. (2009) suggested that identifying stylistic features of an artwork is different from identifying everyday objects (e.g. identifying an apple as an apple).These authors suggested that processing stylistic features follows object identification and is therefore processed later and in areas outside the visual cortex such as the rPFC. These later processing stages may interact with emotional evaluations which have also been associated with rPFC activation (Mitchell, 2011). The rPFC may therefore provide an area where cognitive and emotional information is combined in order to achieve higher behavioural goals, such as the evaluation of an artwork.

Previous research within neuroaesthetics has relied on the use of non-standardized stimuli, making the systematic manipulation of cognitive and emotional elements difficult. The aim of this study was to investigate the influence of cognitive and emotional processing in the rostral PFC during the contemplation of visual art. To achieve this goal art images that were pre-rated in a survey were used for a cognitive component (high/low complexity) and an emotional component (positive/negative valence). Visual art was either positive or negative and viewed during two conditions (high complexity, low complexity). Rostral PFC activation is amplified during periods of increased cognitive load because of greater demands on attention and working memory (Kalisch, Wiech, Herrmann, & Dolan, 2006). Furthermore, regulating negative emotions has been associated with an increase in rPFC activation (Mak et al., 2009). Our hypothesis was that a) high complex images would result in greater rPFC activation and b) negative images would activate the rPFC more than positive images.

5.3 Methods

5.3.1 Participants

Twenty Participants (10 female), with a mean age of 22 yrs. (s.d. 5.4) were recruited via email and posters from the LJMU student and staff population, and the general public.

5.3.2 Experimental Task

Stimuli were presented in blocks of four images using E-prime 2.0 (PST Inc.). Each block represented a specific category of images, i.e. negative/high complexity, negative/low complexity etc. In comparison to Study II - The Pilot which used data from a viewing period of 20 seconds, extended viewing periods of 60 seconds were used in this study. Leon-Carrion et al. (2006) reported an increase in HbO after stimulus cessation when participants viewed emotionally valenced video clips during an fNIRS investigation. Our extended viewing period was chosen to eliminate loss of data that may provide important temporal information during the processing of emotional stimuli. Each image was presented for 60 seconds on a 32” screen with a resolution of 1920x1200 pixels and a viewing distance to the screen of approximately 1.90 m. A blank screen with a fixation cross was presented for 60 sec. after each stimulus to provide a baseline. The baseline was shown post stimulus to assure that no carryover effect of the processing of valence was observed (Leon-Carrion et al., 2006). Following each block of four images, participants were asked to provide subjective ratings of valence and complexity for each image based on the same scales used in the survey exercise. The scales were counterbalanced between participants with 10 (5 female) rating valence first and 10 (5 female) rating complexity first. Each image reappeared briefly to cue the provision of a subjective rating. Figure 5.1 shows the timeline of the experiment. Participants were in a seated position and behavioural responses were provided via a keypad and recorded in E-prime 2.0. The presentation of images within each block was randomised as was the order of presentation of the four blocks of images.

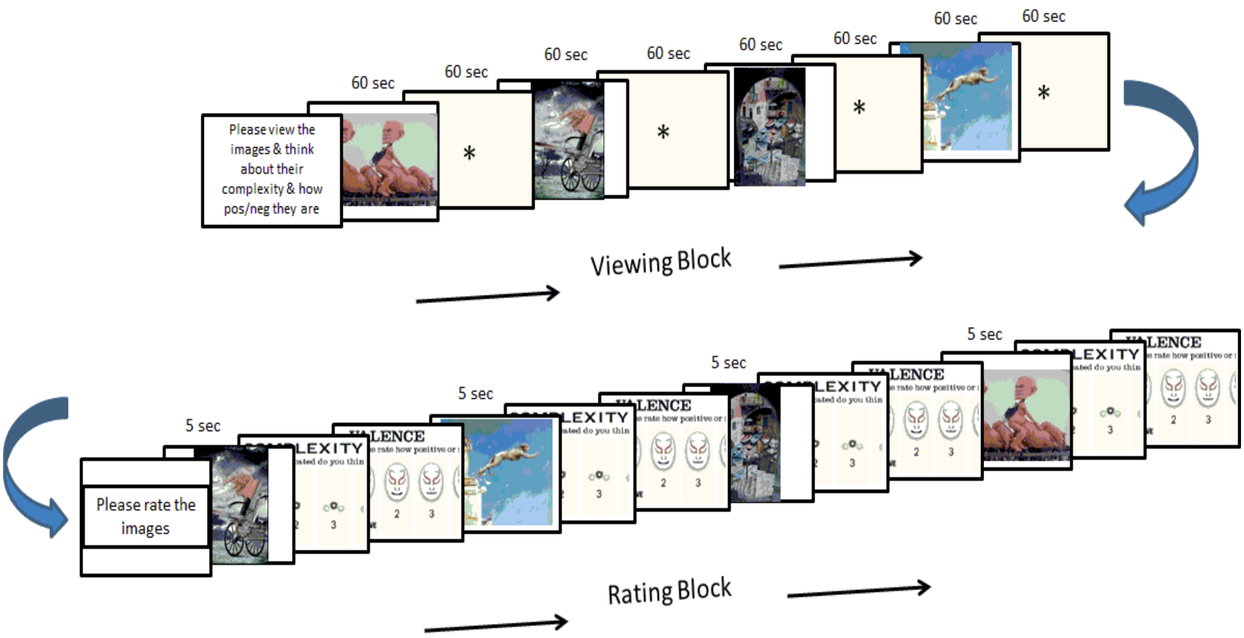


Figure 5.1 Experimental procedure and time-line; participants viewed one block of four images before proceeding to rate them. Overall four blocks were viewed.

5.3.3 Stimuli

The stimuli consisted of 16 artworks. Images were selected according to their complexity and valence ratings generated in the survey (see chapter 3). The images were assigned to four categories (negative/high complexity [NH], negative/low complexity [NL], positive/high complexity [PH], positive/low complexity [PL]), with four images in each category. Valence and complexity ratings were matched between each category (see Table 5.1).

Table 5.1 Behavioural data for subjective ratings of four images with mean and standard deviations.

	Valence		Complexity	
	Mean	s.d.	Mean	s.d.
Negative/High Complexity	6.34	0.23	6.23	0.24
Negative/Low Complexity	6.35	0.59	4.17	0.77
Positive/High Complexity	4.81	0.36	6.04	0.69
Positive/Low Complexity	4.08	0.59	4.20	0.50

Note: low valence score = positive valence.

5.3.4 Procedure

Participants were informed about the nature of the study upon arrival and provided written consent before the fNIRS device was fitted. Participants were informed about the study tasks through written instructions projected onto the screen in front of them. Participants had the opportunity to ask questions before and during a practice trial for each task that was shown after the instructions. The experimental protocol began after the experimenter was satisfied that the participant understood the experimental tasks. Participants were thanked for their participation following the experiment and compensated with a £10 voucher for their time.

5.3.5 fNIRS Data Collection and Analysis

fNIRS was recorded using fNIR Imager1000 and COBI data collection suit (Biopac System Inc.) (see General Methods for a full discussion). Thirty-two episodes (16 stimuli and 16 baselines) were extracted using time markers. Each episode had durations of 60 seconds; episodes were split into three time periods (early, middle and late) lasting 20 seconds each to assess the time course of the fNIRS during emotional evaluations in the context of aesthetic experiences. Data was extracted into Excel and SPSS for further analysis.

5.4 Results

5.4.1 Behavioural Results

A manipulation check of the subjective ratings to assess differences between the four categories of image was conducted. Visual inspection of the behavioural data revealed that the distinction between the four categories (NH, NL, PH, and PL) was not as definite as expected (Figure 5.2). This issue highlights the problem of generalising subjective responses from a survey sample to specific group of individuals. Therefore two images from the sample of four that were most representative of the independent variables (complexity/valence) were selected in order to create the best representation of each category of images for each individual participant; i.e. the two images in the high complexity/positive valence group, with maximum scores for complexity and low scores for valence, were assumed to represent the best example of high complexity/positive valence for that particular person (Figure 5.2). Behavioural ratings were subjected to a two (valence) x two (complexity) ANOVA. The ANOVA yielded a significant effect for complexity ($F(3,54) = 100.59$, $p<0.00$, $\eta 2=0.84$), and valence ($F(1,18) = 12.78$, $p<0.00$, $\eta 2=0.41$). Images received significantly higher ratings for high complex images (mean 6.93, s.d. 1.03) compared to low complex images (mean 2.96, s.d. .98) and negative images were rated as more negative (mean 7.68, s.d. .68) than positive images (mean 3.6, s.d. 86). No interaction was found.

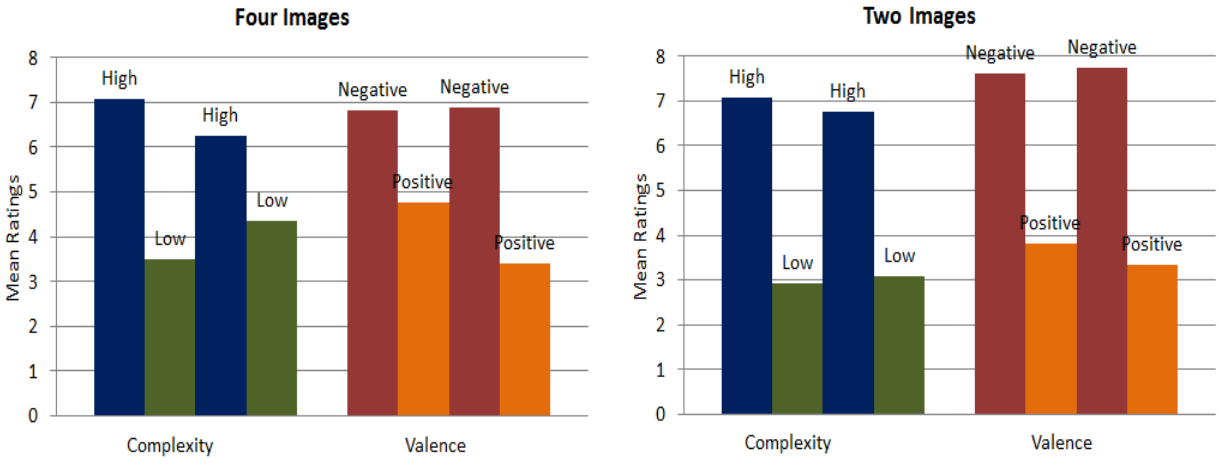


Figure 5.2 Mean behavioural ratings for all four images and after using only two images that most conformed to each category.

5.4.2 FNIRS Results

To test increases in relative haemoglobin changes for HbO and HHb were subjected to a three (time) x two (complexity) x two (valence) ANOVA for each voxel separately. One Outlier (3 s.d. above/below the mean) was excluded from the HHb data set. A Greenhouse-Geisser correction was applied where necessary. The analysis yielded a significant main effect for valence at voxel 5 ($F(1,19) = 4.74$, $p<0.04$, $\eta 2=0.20$) for HbO. For HHb, a main effect of valence at voxel 5 ($F(1,18) = 4.65$, $p<0.04$, $\eta 2=.20$) and voxel 10 ($F(1,18) = 5.40$, $p<0.03$, $\eta 2=0.23$) and an interaction between time and complexity at voxel 10 ($F(2,36) = 10.12$, $p<0.00$, $\eta 2=0.36$) and voxel 11 ($F(2,34) = 3.88$, $p<0.03$, $\eta 2=0.18$) was found.

However, HbO and HHB may be compromised by overall increases in blood volume distorting decreases and increases at specific voxels (Izzetoglu et al., 2007). This may be reflected in the different activation patterns between HbO and HHb. For the former activation at voxel 5 and voxel 7 can be seen whereas for the latter activation for voxel 5, 10 and 11 can be seen. This difference may have been caused by increases in overall blood volume. Because there is no direct consensus in the literature to a definite advantage of one measure over the other (see General Methods for details) it was decided to calculate an oxygenation (oxy) compound score by subtracting HbO from HHb (Izzetoglu et al., 2007). Identical to the analysis for HbO and HHb, the compound score oxy was subjected to a three (time) x two (complexity) x two (valence) ANOVA for each voxel separately. A Greenhouse-Geisser correction was applied were necessary. The results for oxy yielded an interaction for time and valence at voxel 5 ($F(2,38) = 4$, $p<0.02$, $\eta2=0.17$) and voxel 7 ($F(2,38) = 3.77$, $p<0.03$, $\eta2=0.16$). No main effect reached significance.

Further analysis revealed that there was no difference in activation between positive and negative images directly, but that there was a temporal difference in activation for positive and negative images. Paired sample t-test showed that for negative images there was more oxygenation at the middle period compared to the late period at voxel 5 (Neg/middle mean -0.14, s.d. 0.32; Neg/late mean -0.03, s.d. 0.36; $t(1,19) = 5.57$, $p<0.01$) and voxel 7 (Neg/middle mean -0.09, s.d. 0.18; Neg/late mean -0.009, s.d. 0.21; $t(1,18) = 2.62$, $p<0.01$). In comparison, paired samples t-test showed that there was greater oxygenation at the early period compared to the middle period for positive images at voxel 5 (Pos/early mean -0.09, s.d. 0.30; Pos/middle mean -0.20, s.d. 0.28; $t(1,19) = 2.53$, $p<0.02$) and voxel 7 (Pos/early mean -0.002, s.d. 0.24; Pos/middle mean -0.10, s.d. 0.05; $t(1,18) = 2.87$, $p<0.01$). Oxygenation at voxel 5 and voxel 7 showed a decrease for negative images at the middle period followed by an increase for the late period (Figure 5.3). Greater activation was found during the early period, followed by a decrease in the middle period for positive images (Figure 5.3). All other results were not significant ($p<0.1$).

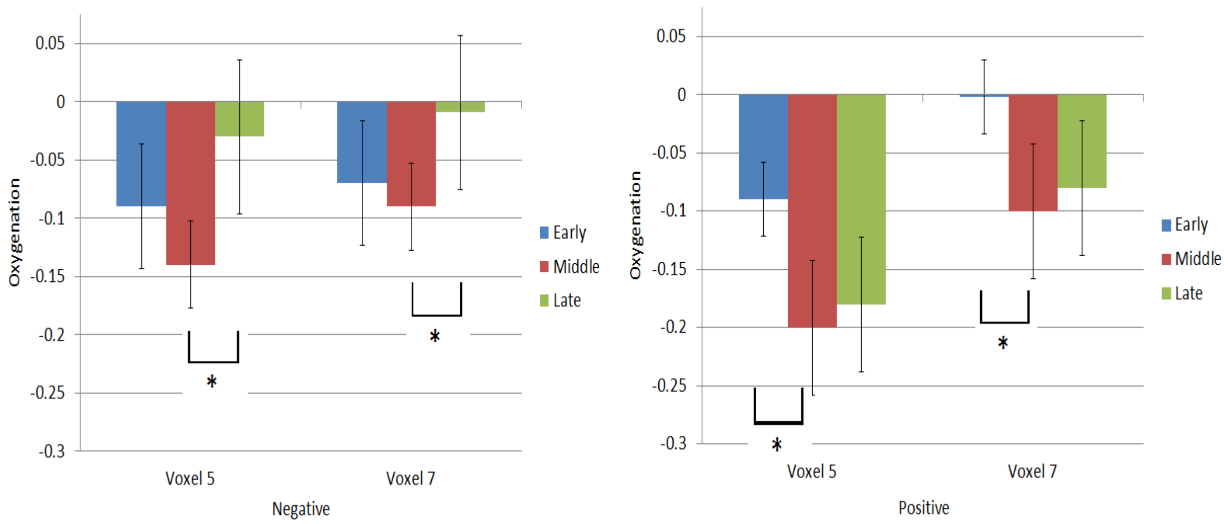


Figure 5.3 Descriptive statistics for positive and negative images at three time periods for oxygenation changes at voxel 5 and voxel 7.

5.5 Discussion

Behavioural ratings showed that participants perceived high complexity images as more complex than low complex images, and positive images scored significantly lower on the valence rating compared to negative images. Nonetheless, results from the fNIRS analysis showed no significant differences in rPFC activation for high/low positive or negative images. There was a temporal differentiation during the processing of positive and negative images regardless of complexity. Greater oxygenation was found at voxel 5 and voxel 7 during the early period for images with a positive valence and greater oxygenation for negative images was found during the late period.

Although these results are unexpected, they support a temporal differentiation during the processing of valence (Leon-Carrion et al., 2006; 2007). Temporal differences during the experience of emotions were found when participants viewed video clips in Leon-Carion et al. (2006). These authors found a pronounced overshoot of activation even after stimulus presentation, particularly for distressing scenes. The duration of stimuli in this earlier study was no longer than 20 seconds followed by a 20 second blank screen. The total response time in Leon-Carion et al. (2006) was therefore 40 seconds. Stimuli in this study were shown for 60 seconds. The late response to negative images may therefore be reflective of the overshoot observed in Leon-Carion et al. (2006; 2007) suggesting that long exposure times are important to capture emotional responses using fNIRS. However, Leon-Carion et al. (2006; 2007) did not find an interaction with emotional valence, making it distinct from our results. Leon-Carion et al. (2007) noted that the overshoot observed in the period following stimulus presentation was dependent on arousal. They asked participants to rate stimuli for valence and arousal and found that images that were rated as more arousing demonstrated a greater overshoot in the period following stimulus presentation. It may have been that participants in this study found negative images more arousing than positive images which resulted in the different time course of oxygenation. Although complexity was controlled for arousal was not and has therefore no individual arousal ratings. However, arousal ratings from the survey data suggest that this was not the case. Mean arousal ratings were NH = 4.94 (s.d. 0.31), PH = 5.19 (s.d. 0.10), NL = 4.56 (s.d. 0.50) and PL = 4.39 (s.d. 0.32). Paired samples t-test showed no significant differences between arousal ratings for positive and negative images ($p<0.1$).

The findings suggest that the temporal characteristics of stimuli associated with viewing time may be an important aspect during the experience of emotions that need to be considered during fNIRS research. Haemodynamic changes occur relatively slow which will impact emotional assessments and oxygenation changes in the rPFC. Mackert et al. (2008) reported a delay of 1 -4 seconds between time-resolved NIRS signals and DC-magnetoencephalography signals whereas Leff et al. (2011) reported a consistent temporal offset of HHb and HbO of 1 -2 seconds using CW fNIRS. These authors showed that HHb and HbO return to baseline about 9 – 10 seconds after a brief motor stimulus. The delay of HHb and HbO to return to baseline may also be relevant to cognitive and affective tasks as indicated by León-Carrión et al. (2006; 2007). Furthermore the fNIRS imager 1000 has a resolution of 2Hz making its temporal resolution relatively slow. Both of these warrant longer exposure time during testing.

Others have suggested that the rPFC is relevant during the modulation of attention towards valenced stimuli. For example, Mitchell (2011) suggested that emotional stimuli would gain greater access to attentional resources resulting greater activation in rPFC. Our study may not have shown differential rPFC activation because positive and negative emotional stimuli were attended to equally. The lack of a neutral condition in our study design made it difficult to verify this assumption.

5.6 Limitation

The complexity of the images may have been processed in an area outside of the reach of our fNIRS device, making the task unsuitable for the assessment of fNIRS. Processing the complexity of a stimulus may be part of early visual processing stages (Chatterjee, 2004) that occur outside the rPFC in areas such as the visual cortices, sensory cortices or the thalamus. Future research may benefit from using different imaging techniques such as fMRI to very this.

Participants were presented with the images in blocks of four with each image being shown for 60 seconds. Following this, participants rated the images after a short (5 sec.) prompt as to which image to rate. The delay between the initial viewing of the image and the rating of the image may have confounded complexity and valence ratings. It may therefore be that the ratings did not accurately reflect the initial impression gained from the image. Future studies would benefit from a study design where the images are rated immediately after the first exposure.

The baseline in this study was shown after the stimulus to assure no carry over effects of emotional processing as suggested by Leon-Carion et al. (2006; 2007). However, the long exposure times of 60 seconds assured that a full response was measured and no effects were found in the baseline periods. Future research would therefore benefit from showing the baseline before each stimulus.

5.7 Future Research

Studies investigating cognitive and emotional processes in the rPFC may benefit from manipulating psychological properties such as comprehension or novelty. Particularly comprehension may be associated with Leder et al.'s (2004) cognitive mastering stage (Figure 1.3). Understanding an image may draw on processes such as working memory, self-relevance or prospection which have been associated with rPFC activation (Andrews-Hanna et al., 2010; Burgess et al., 2007; Nee et al., 2013). Future research may therefore manipulate comprehension and valence to gain an understanding of the role of the rPFC during aesthetic experiences.

5.8 Conclusion

This study investigated the effect of complexity and valence on rPFC activation in an aesthetic context. Findings suggest that a stimulus' complexity is processed in structures outside the rPFC. An interaction between time and valence suggests that the time course of emotional processing in art as assessed by fNIRS is an important aspect to be considered in future research. Long exposure times assure that full haemodynamic responses are captured and the relationship between emotional processing and rPFC activation is assessed.

6. Study IV – Comprehension and Valence

6.1 Abstract

Evaluative judgements, whether an image is pleasing or beautiful, is an important part of the aesthetic experience, but processes in the brain that underpin the formation of these judgements are not well understood. It has been suggested that evaluative judgements are formed through cognitive and emotional evaluations of an artwork and both processes are associated with activation in the rostral prefrontal cortex (rPFC/BA10). The aim of the current study was to assess the impact of cognitive and emotional factors on rPFC activation during the processing of visual art using functional near-infrared spectroscopy (fNIRS). The comprehensibility (the ease with which the meaning of an image was understood) and the emotional valence (positive/negative) of the image were manipulated, providing four categories: negative/low comprehension, negative/high comprehension, positive/low comprehension and positive /high comprehension. Increased activation was found at bilateral sites of the rPFC when viewing negative images that were difficult to understand whilst positive images that were easy to understand increased activation at the right lateral side of the rPFC. In conclusion, rPFC activation may be modulated by the ease with which an image can be comprehended and its affective properties. If the image is positive and comprehensible, aesthetic pleasure is experienced; if the image is negative and difficult to comprehend anxiety/threat is experienced.

6.2 Introduction

The act of aesthetic perception may be understood as a process of acquisition, interpretation and organisation of the elements of an artwork in order to frame an evaluative judgement (Giannini, Tizzani, Baralla, & Gurrieri, 2013; Hagtvedt, Hagtvedt, & Patrick, 2008; Leder et al., 2004). The emotional valence of an image enables the viewer to form a personal connection to the artwork, which is an important aspect of the formation of value judgements, such as beauty, in the art naïve viewer (Leder et al., 2004). However, the comprehension of an artwork (the ease by which an individual can understand and assimilate the content and meaning of the piece) may be the primary goal of the aesthetic experience. Understanding an artwork is central to the aesthetic appreciation because visual perception, cognitive analysis and emotional appraisal come together during this stage to form a judgement of the artwork (Leder et al., 2004).

Aesthetic evaluations are underpinned by a literal act of perceptual-cognitive comprehension (What are the objects in this painting? What is going on in the painting? Is there a narrative?), and a process of emotional appraisal (What emotions are conveyed by the paining? How does it make me feel?). It has been argued that the affective component of aesthetic experience can be divided into two parts (Leder et al., 2004). The first part consists of changing one's emotional states in response to the contemplation of visual art that aids the understanding of the image by forming an emotional connection to the piece. The second part is a result of the global experience of the evaluative process which is often a feeling of pleasure derived from the act of having engaged with a piece of art. This latter aesthetic emotion is therefore the outcome of the process of evaluating art. Thus an image may be experienced as unpleasant, but the process of having engaged with art, in an evaluative sense, results in a feeling of pleasure.

The appraisal of visual art is often a novel and complex task with no prerequisite or guidance as how the work should be perceived or evaluated (Cupchik et al., 2009; Silvia, 2008). The act of viewing novel art may create a sense of ambiguity in the viewer that can be resolved through the integration of new information with existing knowledge (Berlyne, 1960; Cupchik et al., 2009; Silvia, 2008; 2010). Resolving ambiguity in art often involves the facilitation of self-referential evaluations (i.e. what does this picture mean to me? Do I understand what the content is depicting?). The perception of the emotional content of the work can aid understanding and resolve ambiguity. The emotional stimulation provoked in the viewer can be described and understood at different levels, such as the pleasure experienced following cognitive understanding (Leder et al., 2004). The cognitive comprehension of art can be achieved through aspects of fluency (the ease with which visual features are recognised) (Kuchinke, Trapp, Jacobs, & Leder, 2009) or familiarity (how familiar the content depicted is to the viewer) (Mastandrea, Bartoli, & Carrus, 2011) which in turn may lead to the experience of pleasant emotions due to evaluative engagement. Images are judged as less pleasant if they lack fluency and familiarity (Reber, 2012; Reber et al., 2004). If the successful interpretation of an artwork is related to aspects of familiarity and fluency, processes related to recall from long-term memory may be important to the comprehension of art. Particularly the search for familiarity may be dependent on representations in long-term memory (Reber et al., 2004). The integration of long-term memory with currently salient information, as well as the processing of emotional stimuli has been linked to activation in the rostral prefrontal cortex (Rea et al., 2011).

Neuropsychological processes related to emotional awareness and regulation have been linked to activation in the rostral PFC (Euston, Gruber, & Mcnaughton, 2012; Herrmann, Ehlis, & Fallgatter, 2003; Lindquist & Barrett, 2012), e.g. negative emotions have been associated with bilateral medial PFC activation (Glotzbach et al., 2010). Amting (2010) has argued that the rostral PFC plays a significant role during the conscious awareness of emotional processes that may be generated through sensory experiences. Gaining cognitive awareness of emotional states may be closely related to the retrieval and integration of relevant episodic memories with the newly appraised sensory information (e.g. the memory that a racing heart in relation to a negative stimulus is an indicator of fear). Rea et al. (2011) combined the presentation of emotionally salient stimuli with a memory task to investigate the influence of emotions on memory performance in the rPFC. These authors found significantly greater activation in the right lateral rPFC during the viewing of faces displaying negative emotion, indicating that the cuing of negative emotions has a direct impact on memory performance. They concluded that rostral PFC shows greater activation during emotionally salient stimuli because of a higher recruitment of attentional resources. The rostral PFC has been associated with higher order cognitive tasks such as episodic memory retrieval (Christoff et al., 2009), high level cognitive processes like internal thought (Ramnani & Owen, 2004) or changing between externally driven thought and internal mental processes (Burgess et al., 2007).

This study manipulated the two dimensions; comprehension and valence, creating four categories of images (positive/high comprehension, positive/low comprehension, negative/high comprehension and negative low/comprehension), investigate the effect of comprehension and emotional valence on rPFC activity using fNIRS. The images were taken from the survey (see Study I) and selected according to their comprehension and valence ratings. We hypothesised an increase in blood oxygenation in the rPFC for low comprehension images (i.e. images that were rated as hard to understand). Stimuli that evoke negative emotions have been associated with greater activation in the prefrontal cortex (Ochsner & Gross, 2004; Ramnani & Owen, 2004) and therefore rPFC activation was predicted to be greater for negative compared to positive images.

6.3 Methods

6.3.1 Participants

Twenty right-handed art naïve participants (10 female) were recruited from the student population. Participants had a mean age of 25.9 yrs. (s.d. 4.88).

6.3.2 Experimental Task

The stimuli were projected onto a white wall in front of the participants using E-prime 2.0 (PST Inc.); the image dimensions were 2040 x 786 pixels. The viewing distance to the screen was approx. 1.90m. Each stimulus was presented for 60 sec and preceded by a 60 sec baseline consisting of a light grey screen with a fixation point (Figure 6.1). The participants were presented with written instructions asked to think about the meaning of the picture and whether they felt the image were positive or negative in affective valence. Instructions were worded as follows:

"You will be asked to rate if you think the artwork was easy or difficult to understand and how happy or sad the picture made you feel. Please think about this when you look at the artwork”.

Following image presentation, participants were asked to provide ratings for valence and comprehension on the scales used in the survey; ratings were not time restricted and recorded in E-prime via a keypad. The scales were counterbalanced with half of the participants rating valence first and half rating comprehension first. Participants completed a practice trial and were given the opportunity to ask questions before the start of the experiment.

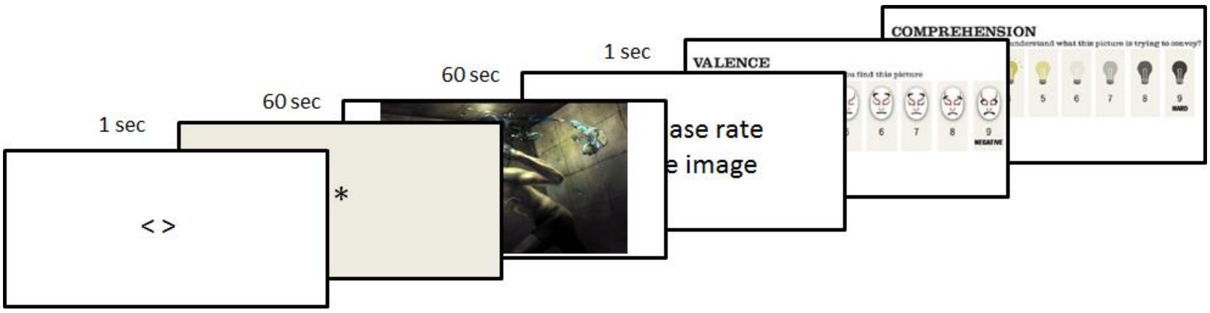


Figure 6.1 Experimental procedure and time-line.

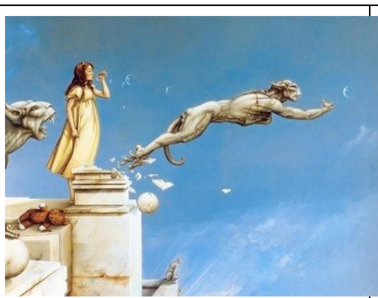
6.3.3 Stimuli

Sixteen images (four in each category) were selected according to ratings of valence and comprehension obtained during the survey (see chapter 3; Figure 6.2). Mean valence ratings for positive images derived from the survey were 4.22 (s.d. 0.52) and negative images 6.08 (s.d. 0.51). Ratings for comprehension were 3.47 (s.d. 0.32) for high comprehension images and 5.08 (s.d. 0.36) for low comprehension images. Images were assigned to four conditions; negative/low comprehension (NL), positive/low comprehension (PL), negative/high comprehension (NH) and positive/high comprehension (PH) (Figure 6.2). Images were presented in random order for each participant.

a) Negative Low Comprehension (NL)

b) Positive Low Comprehension (PL)

c) Negative High Comprehension (NH)

d) Positive High Comprehension (PH)

Figure 6.2 a – d. Representations of stimuli used in the (a) negative/low comprehension (NL), (b) positive/low comprehension (PL), (c) negative/high comprehension (NH) and (d) positive/high comprehension (PH) category.

6.3.4 fNIRS Data Collection

Functional near-infrared spectroscopy used to record blood oxygenation using fNIR Imager1000 and COBI data collection suit (Biopac System Inc) (see General Methods). Sixteen segments with durations of 60 seconds were extracted using synchronization markers. For each 60 second segment the range of change in oxygenation was calculated using the modified Beer-Lambert Law. Oxygenation changes were calculated relative to 40 seconds of the baseline collected during the rest period immediately before each stimulus onset. Segments were averaged according to condition (NH, NL, PH, PL). Averaged oxygenation data for each participant was exported to Excel for further analysis.

6.3.5 Procedure

Participants were informed about the nature of the study upon arrival and provided written consent before the fNIRS device was fitted. Participants were informed about the study tasks through written instructions projected onto the wall as part of the experimental stimuli presentation. Participants had the opportunity to ask questions before and during a practice trial for each task that was shown after the instructions. The experimental protocol began after the experimenter was satisfied that the participant understood the experimental tasks. Participants were thanked for their participation following the experiment and compensated with a £10 voucher for their time.

6.3.6 Behavioural Data

Individual differences in the subjective evaluation of visual art have been highlighted as a problem in previous studies (e.g. Cupchik et al., 2009; Vessel et al., 2012). Our participants were exposed to four groups of images (PH, PL, NH, NL), each of which contained four individual images as defined by the survey exercise (see chapter 3). In order to control for individual differences (i.e. where the perceptions of the images from these participants may have deviated from the ratings provided by the survey), only those two images from each of the four categories of images that were most representative of their group designation were selected in order to create the best representation of that category for each participant, i.e. two images in the PH group with maximum scores for valence (rated on a 9-point Likert scale; 1 = positive, 9 = negative) were assumed to represent the best example of PH for that particular person.

We conducted a manipulation check of the subjective valence ratings to assess differences between PH, PL, NH and NL. Paired samples t-tests revealed that positive images were rated significantly more positive (mean 3.0, s.d. 0.73) than negative images (mean 7.45, s.d. 0.7; $t(1,19) = 17.26$, $p<0.001$), and low comprehension images (mean 5.4, s.d. 1.46) were rated as significantly more difficult to understand as high comprehension images (mean 2.41, s.d. 0.91; $t(1,19) = 10.01$, $p<0.001$) (Figure 6.3).

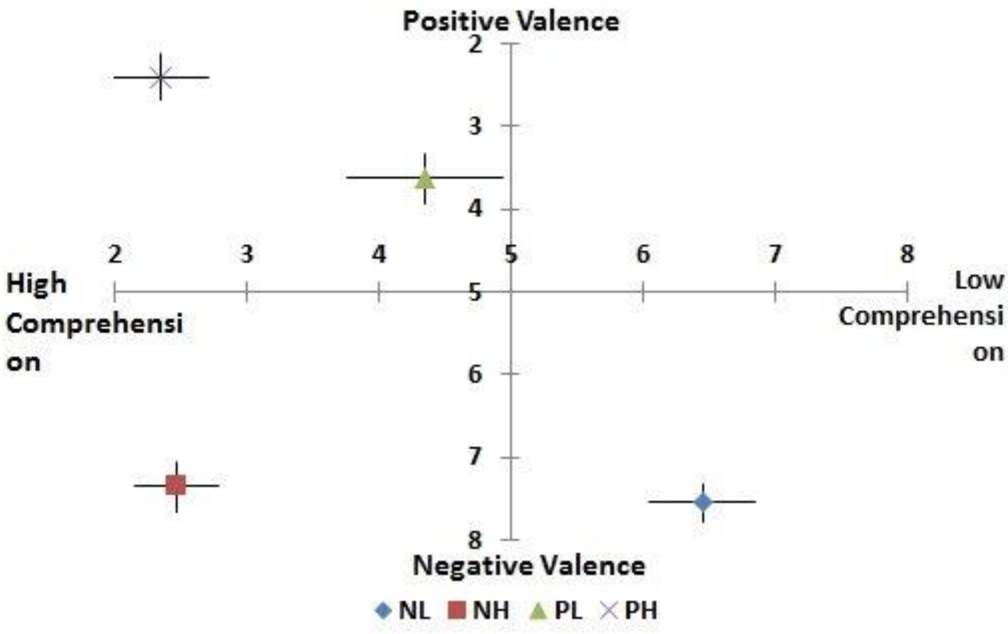
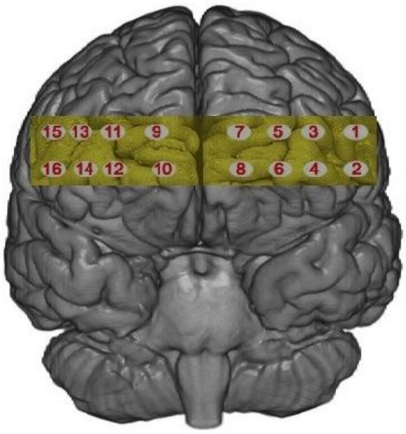


Figure 6.3 Subjective ratings and standard errors for images used in the study: negative/low comprehension (NL), positive/low comprehension (PL), negative/high comprehension (NH) and positive/high comprehension (PH).

6.4 Results

We separated 60 second segments into three time epochs, corresponding to early, middle and late periods of viewing, each of which consisted of 20 sec of data. Separate 3 (time) x 2 (comprehension) x 2 (valence) ANOVAs were conducted for each voxel using the compound score oxygenation (Oxy) calculated by subtracting HHb from HbO. Greenhouse-Geisser corrections were applied to violations of sphericity. Outliers above and below three standard deviations were excluded from each analysis. Results yielded a number of significant interactions between valence and comprehension at voxel 4, voxel 5, voxel 10, voxel 11, voxel 12, voxel 13, voxel 14 and voxel 16 (see Table 6.1). There were no significant main effects for time, comprehension or valence.



Voxel	15	**13**	**11**	9	7	**5**	3	1
df	1,19	**1,18**	**1,18**	1,19	1,19	**1,17**	1,18	1,19
F	0.42	**6.15**	**5.19**	2.47	0.16	**5.09**	0.13	1.26
η	0.02	**0.25**	**0.22**	0.11	0.009	**0.23**	0.008	0.06
p	ns	**0.02**	**0.03**	ns	ns	**0.03**	ns	ns

Voxel	**16**	**14**	**12**	**10**	8	6	**4**	2
df	**1,18**	**1,17**	**1,19**	**1,19**	1,19	1,19	**1,18**	1,19
F	**6.67**	**5.62**	**7.81**	**4.43**	0.86	2.65	**6.69**	3.14
η	**0.27**	**0.24**	**0.29**	**0.18**	0.04	0.12	**0.27**	0.14
p	**0.01**	**0.03**	**0.01**	**0.04**	ns	ns	**0.01**	0.09

Table 6.1 ANOVA results for oxygenation for all voxels for the interaction valence*comprehension, shown according to voxel location over the rPFC seen above.

Greater oxygenation was observed for negative/low comprehension images (mean -0.05) compared to positive/low comprehension images (mean -0.33) at voxel 4 (t(1,18) = 2.14, p<0.04). Voxel 12 showed greater oxygenation for positive/high comprehension images (mean -0.53) compared to negative/high comprehension images (mean -0.17) (t(1,19) = 2.78, p<0.01). At voxel 16, greater oxygenation was found for negative/low comprehension images (mean -0.15) compared to positive/low comprehension images (mean -0.36) (t(1,19) = 2.08, p<0.05). Voxel 16 also showed greater oxygenation for positive/high comprehension images (mean -0.2) compared to negative/high comprehension images (mean -0.35) (t(1,19) = 2.37, p<0.02); as well as greater oxygenation for positive/high comprehension images (M = -0.2) compared to positive/low comprehension images (mean -0.33) (t(1,19) = 2.75, p<0.01). See Figure 6.4 and Figure 6.5 for visualisation of these trends.

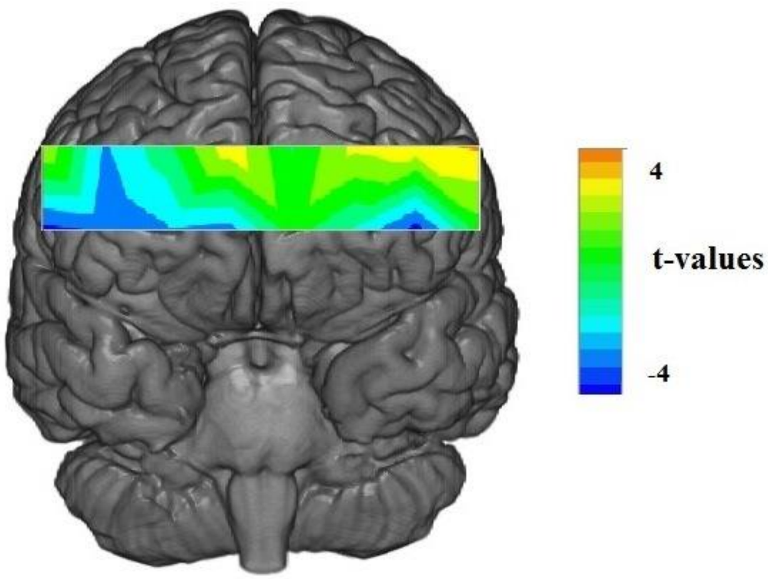


Figure 6.4 Statistical map showing t-values for oxygenated blood for positive – negative valence for the low comprehension images (difficult to understand).

A decrease in oxygenation for positive images can be seen on the right lateral rPFC at voxels 11-14 and at the left lateral rPFC at voxel 4 in Figure 6.4. However, post-hoc analysis revealed that only voxel 4 and voxel 16 showed significantly greater deoxygenation for positive compared to negative images in the low comprehension category of image.

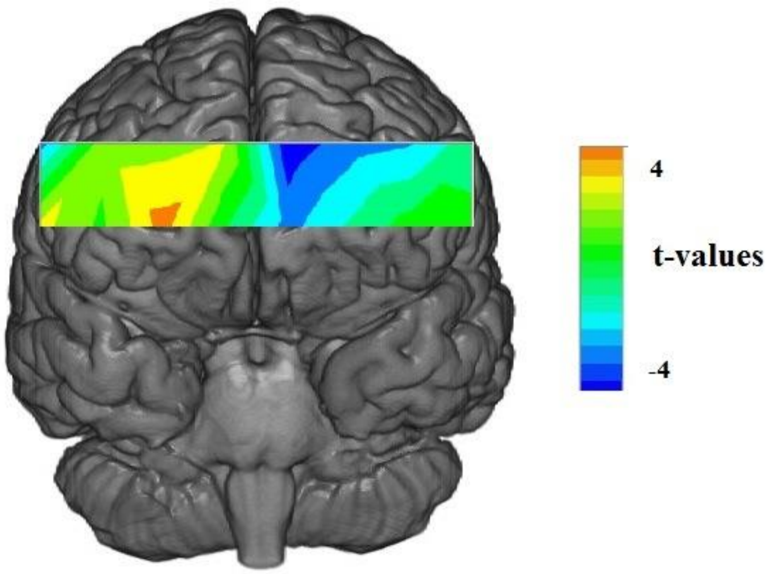


Figure 6.5 Statistical map showing t-values for oxygenated blood for positive – negative valence for the high comprehension images (easy to understand).

An increase for oxygenation for positive images can be seen at the right lateral rPFC at voxel 12 and voxel 16 for the high comprehension category in Figure 6.5.

6.5 Discussion

Art naïve participants were exposed to four pre-rated categories of visual art that differed in terms of comprehension and valence. As predicted, greater oxygenation for low comprehension images was found but only when the image was classified as negative with respect to emotional valence. This effect was located bilaterally at voxel 4 and voxel 16 (Table 6.1 ANOVA results for oxygenation for all voxels for the interaction valence*comprehension, shown according to voxel location over the rPFC seen above.and Figure 6.4). In the high comprehension category when the picture was easy to understand, results indicated greater activation of the right rPFC at voxel 12 and voxel 16

(Table 6.1 and Figure 6.5) during images with positive valence, which contradicts the original hypothesis. Positive/high comprehension images also yielded greater activation in the right rPFC (voxel 16) than positive/low comprehension images but no equivalent effect was observed for images with negative valence.

These results indicate that rPFC activation in response to positive and negative images was mediated by comprehension. When images were easy to understand, there was greater activation of the right side of the rostral prefrontal cortex. Previous studies indicated that images that are liked or rated as aesthetically pleasing show activation in rostral PFC (Jacobsen et al., 2006; Vartanian & Goel, 2004b; Vessel et al., 2012). In particular Vessel et al. (2012) demonstrated that only images that were rated as most aesthetically pleasing activated the left rPFC. Our analysis revealed that images in the positive/high comprehension category yielded greater activation in the right rPFC compared to positive/low comprehension images. The behavioural data (Figure 6.3) showed that positive/high comprehension images were rated as significantly more positive than positive/low comprehension images indicating that only the most pleasing images resulted in increased rPFC activation. Although it is unclear why our results indicated right sided activation, compared to Vessel et al. (2012) finding of left sided activation, Jacobsen et al. (2006) also found right sided activation when they asked participants to rate geometrical patterns as aesthetically pleasing. We would therefore suggest that the right-side activation of the rPFC in regards to positive/high comprehension images was a reflection of aesthetic pleasure resulting from the combined effect of the picture being both positive in emotional valence and easy to understand.

Increased activation during the evaluation of negative/low comprehension images may have resulted from the regulation of negative affect when viewing complex images. Silvia (2005; 2010; Berlyne, 1960) suggested that art is experienced as pleasant if the content is easily understood and appraised as congruent with the values and goals of the viewer. Decreasing the ease of comprehension poses a challenge to the ability of the viewer to understand the image thus creating a sense of anxiety. The viewers are threatened by both the negative emotional tune and their inability to easily ascribe a definite meaning or interpretation to the image. The interaction between negative emotions experienced because of the affective properties and the anxiety provoked by the difficulty to understand the image reinforce one another resulting in a strong bilateral response in the rPFC that may be reflective of the viewers' attempts to understand the image and regulate negative emotions.

The PFC has been implemented as an important brain area in the regulation of emotions (Lindquist, 2012) particularly when the emotions are related to the self (Mitchell, 2011), during motivational processes (Berridge & Kringelbach, 2008; Delgado, Nearing, Ledoux, & Phelps, 2008) and the regulation of negative emotions in the face of uncertainty (Causse et al., 2013; Jollant et al., 2010). The medial PFC, including the rostral PFC (BA10), has been particularly related to the expression and regulation of negative emotions (Etkin et al., 2011; Maier et al., 2012). Etkin et al. (2010) found that the rostral part of the medial PFC is specifically sensitive to the conscious appraisal of fearful stimuli, confirming the involvement of rostral areas to threat appraisal and the expression of fear. Kalisch et al. (2006) argued that the regulation of fear in the medial and lateral rPFC (including rPFC/BA10) is influenced differently by high-, and low-level appraisals. High-level appraisals are described as conscious, controlled and requiring attentional and working memory resources. High-level appraisals are triggered during situations requiring increased cognitive interpretation of the situation (i.e. cognitive control). Low-level appraisals are described as non-conscious pre-attentive, automatic and 'hard-wired' processes (i.e. sensory process). Kalisch et al. (2006) demonstrated that high-level appraisal, compared to low-level appraisal, of anxiety-related activity in medial and lateral rPFC is diminished during a distractor task with high cognitive load. These authors concluded that mPFC and lateral rPFC activity during anxiety inducing events reflected high-level appraisal. Differences in activation between negative/low comprehension and negative/high comprehension images observed in the current study may have resulted from this process of high-level appraisal. Images in the negative/low comprehension category may have engaged high-level appraisal whereas images in the negative/high comprehension category, although negative in affective tone, were to easily comprehend to engage high-level appraisal. Activation for positive images on the other hand may have been the results of the experience of positive affect. Images in the positive/high comprehension category yielded greater activation because of the experience of pleasure derived from positive affect, which was reinforced by the ease of a meaningful interpretation. Images in the positive/low comprehension category, although positive in valence, may not have been understood fully diminishing the feeling of pleasure. It may be that the increased activity of the rPFC is a reflection of the aesthetic pleasantness or attractiveness of the positive/high comprehension images, whereas increased activation for negative low/comprehension images reflects high-level appraisal of complex negative stimuli.

6.6 Limitations

Participants in this study were asked if they thought that they understood the image they were viewing. The phrasing of this question is open to ambiguity and may have introduced variance in the data because of different interpretations of the question by participants. Participants may have, for example, thought about their interpretations of the image, or the interpretations the artist may have had in mind. There is a growing body of literature that suggests that self-related and other-related thoughts are processed differently in the rPFC (see chapter 8 for a discussion). The possible difference in interpretation may have therefore had a consequential impact on our data. Future studies may look at the difference between self and other processing of visual art with varying emotional content.

A further limitation was the difference between comprehension rating for negative/low comprehension and positive/low comprehension images. The magnitude of difference for negative images on the comprehension scale was larger than for positive images, which resulted in a manipulation of comprehension that was not equivalent across both affective categories (Figure 6.3). Furthermore, positive/high comprehension images were seen as more positive than positive/low comprehension images indicating that high comprehension images were experienced as more positive or attractive than their low comprehension counterpart. Similar to our findings, Vessel et al. (2010) found increased rPFC activation only for images that were rated as most pleasing.

We did not assess liking or beauty of the images and are therefore unable to determine if images that were liked more resulted in a different pattern of activation in the rPFC than those that were not liked. Future studies may take this aspect into consideration in an attempt to differentiate between changing emotional states experienced during the evaluation of art, compared to those that are experienced as a result of the successful judgement of the art as a whole. This approach may allow researchers to identify if a separation between the experiences of a negative valenced artwork with the overall experience of pleasantness derived from the evaluative process of the same artwork.

6.7 Future Research

Future research may focus on changing the experience of the viewer through different instructions instead of changing the viewer's experience through a variance in image properties. Future studies may manipulate the viewer's comprehension through the information provided about the image or artist that painted the images. A comparison may be made between images that are presented with a short synopsis of the artwork (high comprehension) or no information (low comprehension). This may control for individual differences in comprehension as assessed by rating scales. Vessel and Rubin (2010) suggested that neuroaesthetics would benefit from a greater emphasis on study designs that manipulate individual experiences instead of image properties such as complexity or comprehension. These authors suggested that memories, which provide a shared frame of reference, are of great importance to the understanding of visual art. Memory processes underlying the aesthetic experience can also be studied through differential instructions instead of the manipulation of image components such as complexity or comprehension. Instructions to approach artworks from a subjective view point may create a situation in which the maintenance and execution of the internally generated goal is to approach the artworks from an aesthetic orientation (Cupchik et al., 2009). This process has been described as prospective memory which requires the maintenance of intentions and goals in memory for delayed actions (Thayer, Ahs, Fredrikson, Sollers, & Wager, 2012). Recent research in prospective memory suggested a functional differentiation between medial and lateral areas of the rPFC (Burgess et al., 2003; 2005; 2007), a result that has also been associated with aesthetic experiences (Cupckik et al., 2009). However, prospective memory has not been directly explored during the contemplation of visual art. Future studies may therefore directly investigate the interface between internal and external processing of information as proposed by Burgess et al. (2003; 2007) and Cupchik et al. (2009) in the context of the aesthetic experience.

6.8 Conclusion

This study assessed rPFC activation during the experience of positive and negative images that were either easy or difficult to comprehend. The results suggest that rPFC activation during the experience of emotions in an aesthetic context is mediated by the viewer's understanding of the image. Greater oxygenation was found in the rPFC when images were positive and easy to understand and when images were negative and difficult to understand. This may represent how emotional processes are modulated by familiarity and ease of processing. Memory processes may therefore play an important part during the contemplation of visual art because images are assessed for familiarity which will aid understanding in art naïve individuals. The rPFC may therefore be related to the regulation of threat in negative images with high uncertainty and the experience of pleasure in positive easy to understand images.

7. Study V – External Focus vs. Emotional Introspection[3]

7.1 Abstract

The contemplation of visual art requires attention to be directed to external stimulus properties and internally generated thoughts. It has been proposed that the medial rostral prefrontal cortex (rPFC; BA10) plays a role in the maintenance of attention on external stimuli whereas the lateral area of the rPFC is associated with the preservation of attention on internal cognitions. An alternative hypothesis associates activation of medial rPFC with internal cognitions related to the self during emotion regulation. The aim of the current study was to differentiate activation within rPFC using functional near infrared spectroscopy (fNIRS) during the viewing of visual art selected to induce positive and negative valence, which were viewed under two conditions: (1) emotional introspection and (2) external object identification. Thirty participants (15 female) were recruited. Sixteen pre-rated images that represented either positive or negative valence were selected from an existing database of visual art. In one condition, participants were directed to engage in emotional introspection during picture viewing. The second condition involved a spot-the-difference task where participants compared two almost identical images, a viewing strategy that directed attention to external properties of the stimuli. The analysis revealed a significant increase of oxygenated blood in the medial rPFC during viewing of positive images compared to negative images. This finding suggests that the rPFC is involved during positive evaluations of visual art that may be related to judgment of pleasantness or attraction. The fNIRS data revealed no significant main effect between the two viewing conditions, which seemed to indicate that the emotional impact of the stimuli remained unaffected by the two viewing conditions.

[3] The study reported in this chapter was published in: Kreplin, U. and Fairclough, F.H. (2013). Activation of the rostromedial prefrontal cortex during the experience of positive emotion in the context of aesthetic experience. An fNIRS study. *Frontiers in Human Neuroscience*, Volume **7**:879.

7.2 Introduction

The experience of viewing art is influenced by a modulation of attentional focus between external features of the stimuli and internal feelings/thoughts. Internal cognitive processes such as object recognition, memory recall and mental imagery facilitate content recognition during the viewing of visual art (Fairhall & Ishai, 2008). Recognition of familiar content evokes a pattern of activation in multiple extrastriate ventral and dorsal regions, the hippocampus, intra parietal sulcus and inferior frontal gyrus (Fairhall & Ishai, 2008; Ishai et al, 2007; Nadal et al, 2008; Nadal & Pearce, 2011). According to a MEG time frequency analysis, a peak of activity around 170ms has been related to the commencement of coding for object identity and transformation of sensory code to cognitive processing has been associated with a peak of activity at approx. 170ms during the observation of visual art (Munar et al., 2011). This process of feature extraction from visual art and the generation of associated thought and feelings have a distinct temporal window.

The rostral prefrontal cortex (rPFC) may be an important site of activity during the processing of art; this region has been associated with higher order cognitive processes such as prospective memory (McDaniel et al, 2013; Volle et al, 2010), emotional regulation strategies (Amting, 2010; Campbell-Sillls et al., 2011; Viviani, Lo, Sim, & Beschoner, 2010) and sustained attention (Ernst et al, 2012; Veen & Carter, 2006). However, there is little consensus regarding the functional specificity and cytoarchitecture of the PFC, particularly the rostral area of the PFC. Ramnani and Owen (2004) suggested that the rostral PFC is activated when the outcomes of two or more separate cognitive operations require integration in the pursuit of a higher behavioural goal. Other accounts emphasised the involvement of medial rPFC during the processing of self-related information (Denny et al, 2012; Seitz et al, 2009).

The gateway hypothesis (Burgess et al, 2007; 2003) was developed to connect activation in the rostral PFC (rPFC) to higher-order self-referential processing and the evaluation of internally generated information. According to this model, rostromedial areas of the PFC (medial BA10) are implicated in the maintenance of attention towards external stimuli whereas activation of the rostrolateral areas (lateral BA10) are associated with the preservation of attention on internal cognitions; this functional differentiation is proposed to act as a gateway between the direction of attention towards external and internal stimuli (Burgess et al, 2007). The central proposal of the model is that the rPFC is part of a system that allows conflicts to be resolved during ambiguous situations (where information activating relevant schemata has low triggering input) or increases activation of schemata in accordance with higher-level goal representations (Cupchik et al, 2009; Henseler et al, 2011; Volle et al., 2010). Evidence for this functional differentiation has been observed during the comparison of shapes (Henseler et al., 2011), letters (Benoit et al, 2012; Gilbert et al, 2005) and the identification of features between two different stimuli such as texture or aspects of geometric shapes (Volle et al, 2010).

The general function of the rPFC as described by the gateway hypothesis is twofold. This area enables the activation of schemata in a situation where no schema is sufficiently triggered by incoming stimuli, e.g. if the stimulus is entirely novel and cannot be associated with existing information. Secondly, the rPFC enables attentional bias when many schema are simultaneously activated (e.g. if a situation is very difficult or complex) or if there are a multitude of possible established outcomes without an obvious advantage to one of them (Burgess et al, 2005). The rPFC plays a key role in the goal-directed co-ordination of stimulus-independent and stimulus-orientated cognitions in situations where established patterns of behaviour are insufficient. Stimulus-independent cognitions include introspection or creative thoughts which are neither provoked by nor directed toward external stimuli. Stimulus-oriented cognitions represent the opposite category, being provoked and oriented towards sensory input. The rPFC would be typically activated in situations that are novel or where a specific demand for it has been determined (e.g. “I must pay special attention to…”, “I must think about…”; Burgess et al, 2003; 2005; 2007; Benoit et al, 2012; Gilbert et al 2005; Volle et al, 2010). The contemplation of visual art requires a shift from stimulus-dependent processing to those stimulus-independent processes that permits an assessment of stimuli as being aesthetically pleasing or not. It may be hypothesised that attention is directed to external properties of the stimulus (identification of physical properties within the painting), the reinvestment of attention onto internally generated thoughts (what does the artist want to say with this painting), and the reinvestment of attention onto subjective self or personal entity (what does the painting mean to me). It is plausible that the rPFC is involved in object identification as well as directing attention to those self-referential states that are relevant to aesthetic appreciation, but the roles of medial and lateral areas of the rPFC during the contemplation of visual art as defined by the gateway hypothesis remains unclear.

There is evidence connecting activity in the rPFC to aspects of cognition that are implicit within emotional processing, e.g. attention to emotion, emotion regulation, appraisal or interpretation of emotion. For instance, Phan et al, (2002) reported strong connections between the PFC (BA9/10) and the anterior cingulate cortex (ACC) and suggested that both areas of the PFC could serve as top-down modulators of intense emotional responses (see also Amting et al., 2010; Holroyd & Yeung, 2012). Evidence for this interpretation stems from human lesion studies where damage to the PFC leads to socially inappropriate expressions of emotions and impairment in making advantageous personally relevant decisions suggesting a lack of awareness/comprehension of emotionally 'loaded' situations (Damasio, 1999; Leopold et al., 2012; Maier & di Pellegrino, 2012). Similarly, activation of the rPFC was related in a linear fashion with an emotion induction task that required different degrees of self-monitoring (identifying with the feelings/emotions depicted in a picture compared to just viewing a picture) (Herrmann et al, 2003, see Denny et al, 2012 for a review).

Studies relating activity in the rPFC to the process of emotional regulation present an alternative to the gateway hypothesis. The regulation of emotions has been associated with activation of the rPFC during the up- and down regulation of emotions (Mitchell, 2011). Furthermore medial BA10 has been linked to activity related to the subjective self or personal entity (Amting et al, 2012; Denny et al, 2012). Seitz et al (2009) suggested that nodes in the medial PFC participate in early processing of sensory information and mediate the value judgement of the stimulus by assessing self-relevant meaning to the sensations. An aesthetic experience, or more specifically the contemplation of visual art, is a highly subjective process. It is therefore important that the experiences are self-referential, particularly if the viewer is not trained in an art-related subject and bases his/her evaluation largely on personal experiences. Evidence supporting this interpretation and the involvement of the medial rPFC was provided by (Vessel et al, 2012) who reported an increase of activation in the medial rPFC for those paintings subjectively judged as most aesthetically moving. This activation of the medial rPFC was specific to the assessment of aesthetic pleasure. This study suggested that a highly-subjective emotional connection to visual art is important to the aesthetic experiences and activation in the rPFC was associated with this type of experience. Alternatively, the involvement of the lateral rPFC during aesthetic experiences was reported by Cupchik and colleagues (2009) who investigated how cognitive control/perceptual facilitation and the experience of emotion contributed to aesthetic perception. Participants in this study were instructed to view a painting from either a pragmatic everyday viewpoint or from an aesthetic viewpoint. Pragmatic viewing was associated with activation of the fusiform gyrus and areas related to object recognition whereas the aesthetic viewing condition activated the insula and left lateral rPFC (BA 10). The authors interpreted activation of the latter in terms of stimulus-independent thought related to the contemplation of visual art.

The aim of the current study was to differentiate activation within the rPFC using functional near infrared spectroscopy (fNIRS) during the viewing of visual art selected to induce positive and negative mood. Both categories of image were viewed under two conditions (emotional introspection and external object identification) designed to draw attention to stimulus-independent and stimulus-dependent features respectively. Images were viewed for 60 seconds overall and split into three viewing periods (early, middle and late) for the analysis. The extended viewing time was chosen because temporal differences have been observed during activation of the PFC during emotional experiences measured by fNIRS, where an overshoot of activation into later periods was reported (León-Carrion et al., 2008), and during the experience of art (Munar et al., 2011). Our primary hypothesis was that emotional introspection would activate lateral areas of the rPFC whereas viewing the image with an emphasis on external object identification would selectively activate the medial rPFC. Our alternative hypothesis was that emotional introspection would activate the medial rPFC as predicted by the studies conducted by Seitz et al (2009) and Vessel et al (2012).

7.3 Methods

7.3.1 Participants

Thirty right handed participants (15 female) with a mean age of 22 yrs. (s.d. 3.26) were recruited from Liverpool John Moores student and staff population.

7.3.2 Experimental Task

The stimuli were projected onto a white wall in front of the participants using E-prime 2.0 (PST Inc.); the image dimensions were 2040 x 786 pixels. The viewing distance to the screen was approx. 1.90m. Each stimulus was presented for 60 sec and preceded by a 60 sec baseline consisting of a light grey screen with a fixation * (Figure 7.1). Following image presentation, participants were asked to provide ratings for valence and complexity on the scales used in the survey; ratings were recorded in e-prime via a keypad. The tasks were designed to induce different demands on attending to external properties of the stimulus (the spot-the-difference (SD) task) and to internal cognitions (the emotional introspection (EI) task).

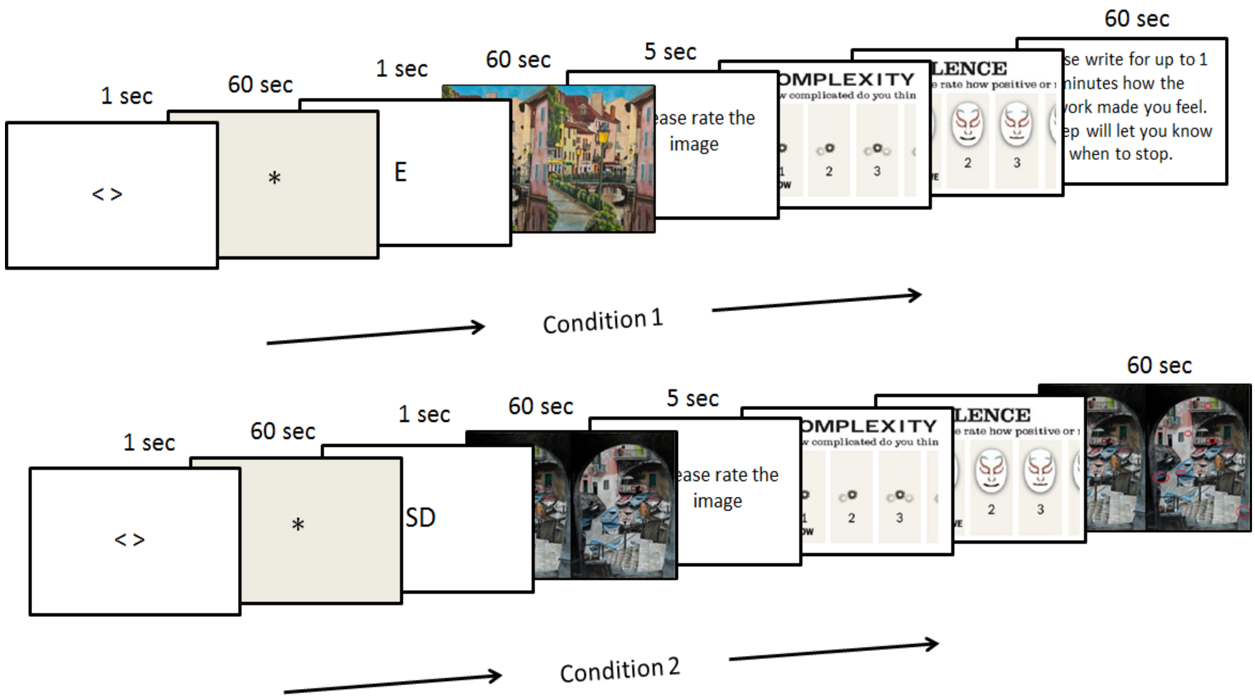


Figure 7.1 Experimental procedures and time-line for condition one (emotional introspection) and condition two (spot-the-difference task).

We closely considered the prerequisites stated by Burgess et al. (2005) that a task requires to draw attention to external stimulus processing when designing the SD task. According to Burgess et al. (2005) an external attentional task requires: (1) that the information to be processed is currently available (i.e. present in the sensory environment), (2) that the attention is directed to external stimuli or stimulus features, and (3) that the operations involved prior to responding are relatively automatic or well-learnt. To elicit attending to external stimuli features during the SD task, all images were duplicated to form a pair and between three and six aspects of the image on the right were modified using PaintShopPro (Figure 7.1). Instructions in the SD condition stated: ‘If you see 'SD' on the screen you will be asked to spot the differences between two images. You will be able to see the answers after the image’. Following the ratings in the SD task participants were provided with the same picture but with the differences highlighted with a red circle. All images were used in the spot-the-difference (SD) task and the emotion induction task. Participants were prompted with SD or E before the image appeared as indicator which task to perform next during testing.

The emotional introspection condition was designed to initiate internal processes with respect to: (1) the information attended to is being processed internally, (2) that this information is self-generated or comes from a previously witnessed episode, and (3) that the response to be made are triggered by these internal representations. Instructions were as follows: ‘If you see an 'E' on the screen you are asked to think about how the artwork makes you feel, i.e. what emotions does it trigger in you? Does it make you feel sad/happy/angry etc.? Does it remind you of an emotional event you have experienced in the past? Don’t worry about the message the artist tried to bring across, just think about how the image makes YOU feel or if it makes you think of something that you found emotional’. Participants were asked to write, using pen and paper, brief notes about these associations following the picture presentation. Participants were not asked to hand these notes to the experimenter and took them away upon completion of testing to assure confidentiality. The images were presented as identical pairs during the emotional introspection (EI) task to ensure consistency with the SD viewing condition (Figure 7.2). A practice trial was completed for each condition, and the opportunity to ask questions was given to insure the instructions were fully understood before the start of the experiment. The presentation of positive/negative images and EI/SD was randomised.

7.3.3 Stimuli

Sixteen images (eight in a positive valence category and eight in a negative valence category) were selected according to ratings of valence and complexity obtained during the survey (see chapter 3). Mean ratings for positive images were 2.57 (s.d. 1.27) and negative images 7.17 (s.d. 1.3), whilst subjective ratings of image complexity were constant between positive and negative images (mean 4.58, s.d. 2.22 and mean 4.07, s.d. 2.14 respectively).

Figure 7.2 Stimuli Example (1) pictures used in the positive SD task ("Best Abstract" ©Adrian Borda). The right image has slight differences to the left image, differences are circled in red; (2) two identical images used during negative EI ("Elytron" © 2003 Monika Weiss, Courtesy of Chelsea Art Museum, New York). Participants were asked to think about how the images made them feel.

7.3.4 Procedure

Participants were informed about the nature of the study upon arrival and provided written consent before the fNIRS device was fitted. Participants were informed about the study tasks through written instructions projected onto the wall in front of them. Participants had the opportunity to ask questions before and during a practice trial for each task that was shown after the instructions. The experimental protocol began after the experimenter was satisfied that the participant understood the experimental tasks. Participants were thanked for their participation following the experiment and compensated with a £10 voucher for their time.

7.3.5 fNIRS Data Collection

fNIRS was recorded using fNIR Imager1000 and COBI data collection suit (Biopac System Inc) and is described in detail elsewhere (Ayaz, 2010; General Methods). fNIRS data were analysed offline using fNIRS-Soft (Ayaz et al, 2010). Sixteen segments with durations of 60 seconds were extracted using synchronization markers. An oxygenation compound score (oxy) was calculated by subtracting HHb from HbO and used in all further analysis. Segments were averaged according to condition (Positive EI, Negative EI, Positive SD, Negative SD).

7.4 Results

Individual differences in the subjective evaluation of visual art have been highlighted as a problem in previous studies (e.g. Cupchik et al, 2009; Vessel et al, 2012). Our participants were exposed to four groups of images (EI/positive, EI/negative, SD/positive, SD/negative), each of which contained four individual images. In order to control for individual differences, only those three images from the sample of four that were most representative of their group designation were selected in order to create the best representation of that image category for each participant, i.e. the three images in the EI/negative valence group with maximum scores for valence (rated on a 9-point Likert scale; 1 = positive, 9 = negative) were assumed to represent the best example of EI/negative valence for that particular person.

We conducted a manipulation check of the subjective valence ratings to assess differences between positive and negative images under the two viewing conditions. A 2 (condition) x 2 (valence) analysis of variance (ANOVA) was conducted on subjective ratings from three images in each valence/viewing condition. A significant main effect for valence ($F(1,29) = 720.50$, $p<0.01$, $\eta 2=0.96$), and an interaction between condition and valence ($F(1,29) = 5.06$, $p<0.03$, $\eta 2=.014$) was found. Negative images (mean 7.17, s.d. 1.07) were rated as significantly more negative than positive images (mean 2.57, s.d. 0.85). Post-hoc analysis showed no significant difference between the EI and SD condition for negative images. For positive images a marginal trend was identified with images in the EI (mean 2.57, s.d. 0.85) condition being rated as more positively than those viewed in the SD condition (mean 2.98, s.d. 0.78 $p<.06$).

We separated 60 seconds of data into three time epochs, early, middle and late, each consisting of 20 sec of data. Separate three (time) x two (condition) x two (valence) multivariate analysis of variance (ANOVA) was conducted for each voxel for the compound score oxygenation (Oxy), Greenhouse-Geisser corrections were applied to violations of sphericity. One outlier (three standard deviations above or below the mean) was excluded from further analysis. Results yielded a significant main effect for valence at voxel 5 (Figure 7.3 for voxel location) ($F(1,28) = 8.74$, $p<0.001$, $\eta 2=0.23$) and voxel 9 ($F(1,26) = 4.32$, $p<0.04$, $\eta 2=0.14$), all showing greater oxygenation for positive images. This effect is illustrated in Figure 7.3 where heat maps were generated across the rPFC region based on the 16 voxels.

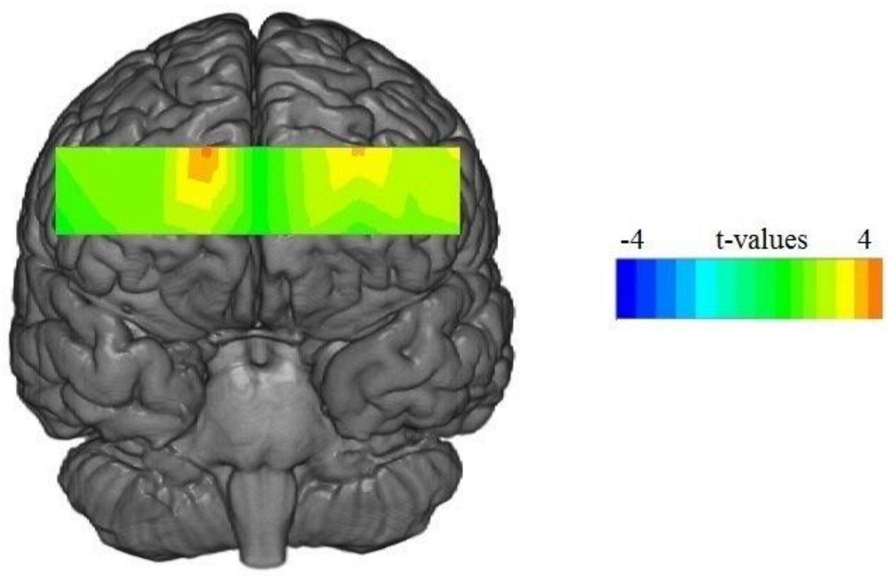


Figure 7.3 Statistical maps showing t-values for oxygenated blood for the main effect of valence for the 60 sec. period.

7.5 Discussion

The subjective self-report data supported the face validity of the valence manipulation, i.e. positive and negative images were rated appropriately by participants. Our analysis indicated that activation of medial BA10 (as defined by an increase of Oxy) was enhanced during the viewing of visual art that induced positive emotions compared to those paintings that provoked negative emotion (Figure 7.3). The fNIRS data showed no main effect for viewing condition, which indicated that activation of the medial rPFC was unaffected by the two different viewing conditions.

The increase of activation in response to positive stimuli was unexpected but is not without precedence in the literature (Ernst et al, 2012). It is suggested that positive images activated the medial rPFC because aesthetic pleasantness was associated with this category of picture and this effect was unaffected by viewing condition. Previous studies have reported that activation in the medial rPFC is positively correlated with aesthetic evaluation (Di Dio & Gallese, 2009; Ishizu & Zeki, 2011; Vartanian & Goel, 2004). When

Vessel et al. (2012) found greater activation in the medial rPFC for aesthetically pleasing images, they speculated that intense aesthetic experiences had high personal relevance, which created a heightened integration of external (sensory/somatic) sensations and internal (evaluative/emotional) states, as the individual experienced an emotional connection to the art. In support of this position, Seitz et al. (2009) suggested that the medial prefrontal cortex is involved in the attribution of self-relevant, immediate and intuitive meaning. Therefore increased activation of the medial rPFC in the current study may have been the result of self-monitoring of positive emotions or pleasantness judgements during the contemplation of art.

The medial area of the rPFC has been implicated in emotional processing in studies with a primary focus on emotion induction (Euston et al, 2012; Glotzbach et al., 2011; Gray et al, 2002; Lindquist & Feldman-Barrett, 2012). Increased prefrontal activation and medial areas in particular, have been associated with self-regulatory strategies designed to minimise negative affect in fMRI studies (for a review see Mitchell, 2011). However, studies investigating self-regulatory strategies during emotional experiences have a tendency to focus on negative emotions such as fear (Glotzbach et al, 2011), anger, sadness, or disgust (Lindquist & Feldman-Barrett, 2012). Hermann et al. (2003) used positive and negative stimuli to investigate the change of oxygenation in the PFC using fNIRS during two types of emotional induction, one with a higher and one with a lower self-monitoring component. The task with the high self-monitoring component resulted in higher levels of oxygenated blood in the medial rPFC regardless of valence. This study suggests that the rPFC is highly sensitive to emotional induction tasks where an element of self-monitoring is implicated. However, activation was only found for positive images, regardless of viewing condition, and it is unclear why negative emotions would not have activated the rPFC unless the emotional response was specific to aesthetic pleasure or the beauty of the picture.

The gateway hypothesis proposed a functional differentiation between activation for stimulus-dependent and stimulus-independent cognitions in the rPFC (Burgess et al., 2003; 2007). However, the current study found no evidence to support this position because the two viewing conditions had no significant effect on activation in the rPFC. It could be argued that the SD task may not have been suitable to draw attention toward external properties of the stimulus. However the same task was successful in eliciting the functional differentiation in rPFC activation described by the gateway hypothesis in a previous study (Volle et al., 2010). Our stimuli consisted of complex visual art which contrasts with previous research that used simple geometric patterns (Volle et al., 2010) or shapes (Henseler et al., 2011) to demonstrate the effect described by the gateway hypothesis. The increased complexity of our stimuli may account for the absence of any effect on rPFC activation.

Our results suggested that emotional processing took precedence over differing viewing instruction during visual contemplation of art. Emotional salience may have been brought to the forefront because of participants search for personal meaning of the art images. Thus participants will have drawn onto their own evaluations and personal association of the art to form a subjective judgement about their value.

7.6 Limitations

It could be argued that the EI task did not conform to the prerequisites set out by Burgess et al. (2005) for internally generated thoughts because the stimulus was present at all times. To invoke self-referential thoughts, participants were instructed to think about how the images made them feel, how they felt connected to them and what images or memories it provoked in them. The presence of the image throughout the introspective task may have confounded the result but it was believed that the EI task used in the current study was ecologically valid with respect to real-life behaviour in gallery spaces. Previous findings have reported activation of lateral areas during the contemplation of visual art, and attributed this to a focus on internally generated thought related to the artwork (Cupchik et al., 2009). However, these authors did not manipulate their viewing conditions to investigate the gateway hypothesis during the contemplation of art, but rather used the gateway hypothesis as a possible explanation of increased activity in the lateral rPFC. Nonetheless, future investigation may study the gateway hypothesis during the contemplation of visual art using a paradigm where the stimulus is not present during the EI task.

7.7 Future Research

Future studies investigating the gateway hypothesis may benefit from an emotionally neutral condition during the contemplation visual art and the inclusion of a scale asking for subjective experiences of aesthetic pleasantness or beauty. Questions remaining unanswered regarding the absence of rPFC activation during negative emotions and the interaction between a self-relevant and other-relevant focus during the contemplation of art. Future research may consider whether pictures with negative valence can be aesthetically pleasing and how this is related to rPFC activation would be of benefit to neuroaesthetics.

7.8 Conclusions

This study investigated rPFC activation between attention directed to external stimuli using a spot-the-difference task and internal cognition using emotional introspection during the contemplation of visual art. It was hypothesised that external attention would activate the medial rPFC whereas emotional introspection would activate the lateral rPFC. However, results showed no effect of condition or an interaction between condition and rPFC activation. Instead, it was found that medial rPFC showed greater activation during positive images only. This may have been in response to the experience of pleasantness of these images.

8. Study VI – *Self*-Focus vs. *Other*-Focus[4]

8.1 Abstract

The medial area of the rostral prefrontal cortex (rPFC) has been implicated in *self*-relevant processing, autobiographical memory and emotional processing. Furthermore, the rPFC has been associated with the experience of pleasant emotions such as liking during aesthetic experiences. The aim of this study was to investigate rPFC activity in an aesthetic context in response to affective stimuli that were viewed in either a *self*-relevant or *other*-relevant context. Eighteen positive and negative images were shown to 20 participants under two viewing conditions: (1) *self*, (2) *other*. In (1) participants were asked to think of their own emotions whereas participants in (2) were asked to think about the emotions of the artist. Results showed greater oxygenation in the rPFC when participants were asked to think about the emotions of the artist. An interaction between affect and *self*/*other* condition revealed greater oxygenation for positive images in condition (1) and greater oxygenation for negative images in condition (2). These findings may be indicative of threat detection in others and a positive *self*-bias towards the *self*.

[4] Part of the research presented in this chapter was presented at: Ignite 2014, AHRC Science in Culture Event, London, UK. "Processing art in the rostral prefrontal cortex of the brain." https://vimeo.com/92814284

8.2 Introduction

Understanding visual art involves the processing of the artwork in relation to one's own life experiences. A scene of a harbour (e.g. Figure 8.1) may, for example, be experienced as positive because of a general liking of the seaside or because of a memory of a particular pleasant holiday to a harbour town in Italy. Viewers who are unfamiliar with artistic styles or artist's background will be likely to draw from personal experiences to extract meaning from an artwork (Leder et al., 2004; Leder, 2013). Vessel et al. (2012) reported increased medial rostral prefrontal cortex (rPFC) activation during the processing of artworks that were experienced as most intense by art naïve viewers and attributed this effect to *self*-referential processing occurring within the default mode network (DMN; see Introduction for a detailed review). Vessel (2013) argued that highly moving artworks 'strike a chord' with the viewer and this resonance results in medial rPFC activation.

Activation of the rPFC has been associated with the processing of information about close others such as family members or close friends (Benoit et al., 2010), but not strangers (Krienen, Tu, & Buckner, 2010). Krienen et al. (2010) suggested that the rPFC is part of an area that evaluates social relations, i.e. identifying who is friendly/known and who is not. This hypothesis suggests that rPFC activation is not particular to *self*-relevant processing but is also relevant to theory of mind (ToM). Theory of Mind is the ability to understand that the behaviour of others is motivated by internal states such as thoughts, emotions and feelings and is a key aspect of the ability to navigate the social world (Blakemore & Decety, 2001; Carruthers & Smith, 1996; Mahy, Moses, & Pfeifer, 2014; Spreng et al., 2013). ToM is an important aspect of sociality and is usually acquired at the age of four or five and performed successfully by most adults (Astington, 1993). ToM research suggests that others are understood via an ability to use *self*-processing to simulate the experience of others (i.e. putting oneself into another person's shoes). The *self* is therefore employed to imagine scenes of potential actions and outcomes that are subsequently projected onto others.

Two neural systems have been implicated in ToM (see Mahy et al., 2014 for a review). The first system includes the cortical midline structures that consist of the rPFC, adjacent rostral anterior cingulate and medial posterior parietal cortices including posterior cingulate and precuneus. Recruitment of these structures could be indicative of simulation processes because they are involved both in *self*-perception and perspective taking (i.e. understanding others' by putting the *self* into their 'shoes') and are also implicated within the DMN (Mahy et al., 2014; Spreng et al., 2009; 2013). The second neural system for simulation processes is the mirror neuron system (MNS), which co-activates to the actions, intention and emotions of both the *self* and others (Mahy et al., 2014; Molnar-Szakacs & Uddin, 2013; Spreng et al., 2013). The areas of the brain involved in the MNS are the inferior frontal gyrus, premotor cortex, the anterior insula, primary sensory and primary motor cortices, the superior temporal sulcus and the rostral part of the inferior parietal lobule that are recruited during the perception and execution of identical actions. This network may help to simulate the mental states of others by enabling a direct mapping of the actions, goals and intentions of others to the *self*. Empathising with artworks, or understanding the properties of an artwork through empathy with physical properties, such as the movements visible in the brush strokes of the artist, has also been related to the processing of art (Freedberg & Gallese, 2007).

Molnar-Szakacs and Uddin (2013) suggested that the DMN and MNS work together to provide a coherent representation of the *self* and by extension of others. The DMN may be more activated when understanding another's mental states (i.e. during cognitive empathy or simulation) whereas the MNS is more activated in relation to embodiment (i.e. feeling or empathising with another's physical state). The interactions of both systems serve to produce appropriate mappings to meet social-cognitive demands. Spreng et al. (2013) identified an overlap of activation in the rPFC for autobiographical memories, ToM, prospection and *self*-related processing. These authors suggested that it is advantageous from an evolutionary perspective to have awareness of the relation between knowledge source and present knowledge state. Knowledge of the past-*self* in relation to the present-*self* facilitates future thinking and goal attainment. Furthermore, these authors argue that theory of mind is necessary to distinguish between the present, past and future *self* and relating to others may be therefore be an extension of *self*-knowledge.

The rPFC may play a more general role with respect to the integration of cognitive and emotional processes that are *self*-relevant and related to memory (Lee & Siegle, 2012). A number of spatial differentiations have been proposed within the rPFC. The lateral area of the rPFC has been related to meta-cognitive awareness of one's own thought whereas medial rPFC has been related to emotional awareness (Mccaig et al., 2011; McRae et al., 2011; Ochsner & Gross, 2005; Olsson & Ochsner, 2008) Gilbert et al. (2006) suggested that the medial rPFC is involved in perspective taking whereas lateral areas of the rPFC are implicated in tasks such as working memory or episodic memory. A recent meta-analysis revealed a ventral-dorsal gradient for simulation in the PFC (Denny et al., 2012). *Self*-related processing was associated with activity in the medial, ventral and rostral PFC, whereas *other*-related processing activated the dorsal/medial area of the PFC. However, other studies have found large overlaps between *self* and *other*-related processing in the rPFC (Araujo et al., 2013; Lee & Siegle, 2012; Spreng et al., 2013). It may be hypothesised that the rPFC plays an important role in the processing of *self*-relevant information and understanding of bodily and mental states of others. One part of the process of understanding others is a successful assessment and interpretation of emotional states (Amting, 2010). Dorsal areas of the PFC have been found to be sensitive to arousal whereas ventral and rostral areas (including BA10) were sensitive to valence in a study that compared the influence of valence and arousal on PFC activation (Dolcos, LaBar, & Cabeza, 2004). These authors suggested that this differentiation possibly reflects the involvement of dorsal regions in general processing of emotional information and ventral and rostral medial areas in *self*-awareness or appetitive behaviour. Afferent connections between medial rPFC and the amygdala support the sensitivity of this area to valence (Mitchell, 2011). Accordingly, activation in the medial rPFC has been reported during modulation of positive and negative emotions (Mitchell, 2011), decreasing of negative emotions (Kompus, Hugdahl, Ohman, Marklund, & Nyberg, 2009) and the experience of positive emotions (Dolcos et al., 2004; Viviani et al., 2010).

Although Vessel et al. (2012) demonstrated that rPFC is related to the processing of *self*-relevant properties of art (i.e. I find this image pleasant because I like its colours), it was unclear whether this sensitivity was unique to *self*-relevant properties, or 'striking a cord' in the viewer or related to more general *self*- as well as *other*-related processing. Furthermore, it was unclear whether *self*-related processing during the evaluation of visual art was confined to medial rPFC and whether this process was mediated by the emotional valence of the stimuli. This study aimed therefore to investigate rPFC activation during the experience of positive and negative emotions related to the processing of artworks in two conditions; condition (1) involved the processing of artworks in relation the *self*, and condition (2) involved the processing of the artworks in relation to another (the artist). It was predicted that medial rPFC would show greater activation when artwork was processed in relation to the *self*. Furthermore it was predicted that processing artwork that elicit positive emotions would result in greater activation of rPFC than those artworks associated with negative emotions.

8.3 Methods

8.3.1 Participants

Twenty right handed art naïve participants (10 female) with a mean age of 25.05 yrs. (s.d. 7) were recruited from the student population.

8.3.2 Experimental Task

The experimental stimuli were projected onto a white wall in front of the participants using E-prime 2.0 (PST Inc.); the image dimensions were 2040 x 786 pixels. The viewing distance to the screen was approx. 1.90m. Each stimulus was presented for 30 sec and preceded by a 60 sec baseline consisting of a light grey screen with a fixation * (Figure 8.2). Following image presentation, participants were asked to provide ratings for valence and complexity on the scales used in the survey; ratings were recorded in e-prime via a keypad. Following the ratings participants were asked to write down keywords about the emotions they had experienced using pen and paper. No time limit was set for the ratings; the writing task was limited to 30 seconds, a beep alerted participants to proceed to the next image. The tasks were designed to induce different emotional processing strategies by asking participants to contemplate the emotional content of the image from their own point of view (*self*) or from the artist's point of view (*other*). The prompt displayed before each image in the *self*-condition was:

"*SELF*: Think about how the image makes YOU feel. Does it make you feel sad/happy/angry? Does it make you think of a situation where you felt sad/happy/angry?"

The prompt for the *other*-condition was:

"ARTIST: Think about the ARTIST. What feelings or emotions did they want to show in the picture? What type of person painted this picture, e.g. their age, gender, personality (i.e. where they a happy/sad/angry person)?"

Each image was only displayed ones with half of the participants seeing half of the images in the *self*-condition, and the other half seeing the same images in the *other* condition. Each image was therefore seen equally often in the *self*- and *other*-condition.

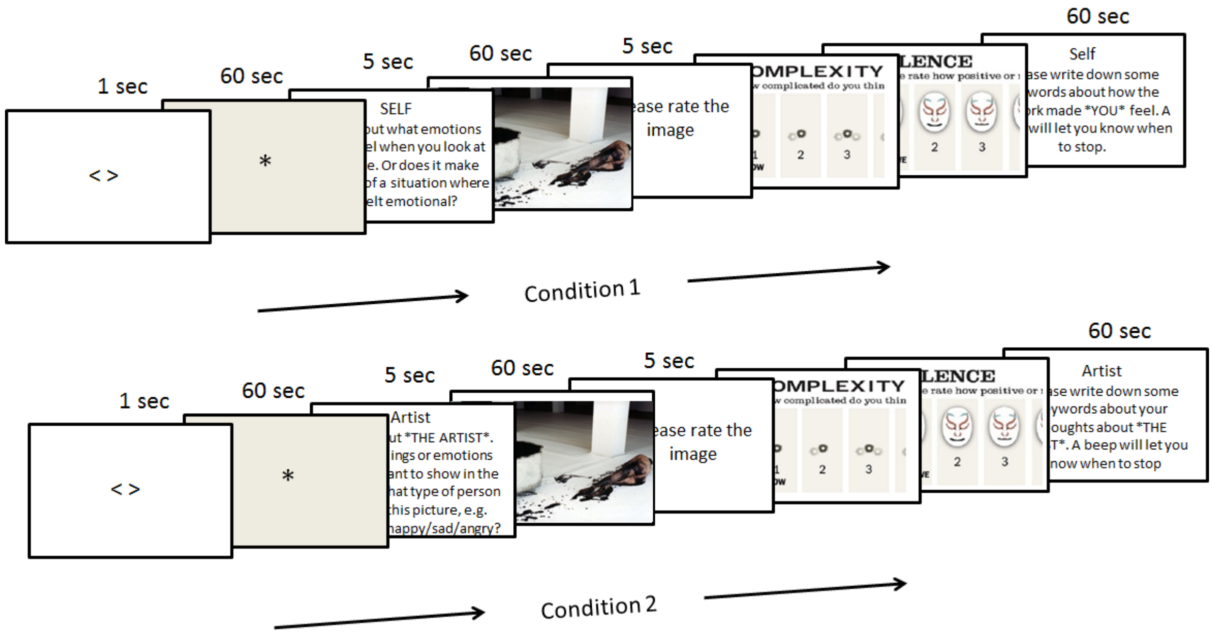


Figure 8.1 Experimental procedure and time-line for condition one (*self*) and condition two (*other*).

8.3.3 Stimuli

Eighteen images (six in a positive valence category, six in a negative valence category and six in a neutral category) were selected according to ratings of valence and complexity obtained during the survey (see chapter 3). The mean valence ratings for positive images was 3.33 (s.d. 1.75), for the neutral images 4.85 (s.d 1.64) and negative images 6.32 (s.d. 1.92), whilst subjective ratings of image complexity were constant between positive (mean 3.97, s.d. 2.06), neutral (mean 4, s.d. 1.79) and negative (mean 4.29, s.d. 1.97) images. The images were viewed under two conditions making a total of six categories (positive *self* (PS), negative *self* (NS), neutral *self* (NeuS), positive *other* (PO), negative *other* (NO) and neutral *other* (NeutO)).

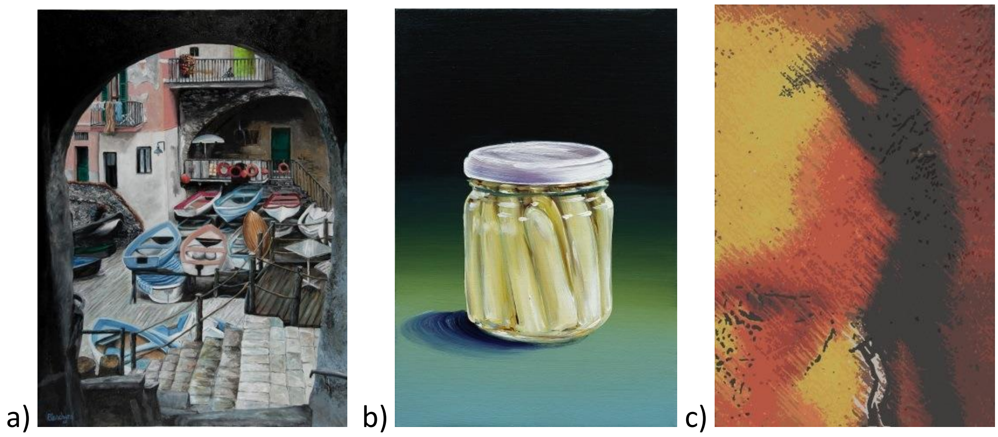


Figure 8.2 Examples of the stimuli assigned to the three valence categories (a) positive, (b) neutral and (c) negative

8.3.4 Procedure

Participants were informed about the nature of the study upon arrival and provided written consent before the fNIRS device was fitted. Participants were subsequently told about the study tasks through written instructions projected onto the wall. Participants had the opportunity to ask questions before and during four practice trials (two images per *self*/*other* task) that were presented after the instructions. The experimental protocol began after the experimenter was satisfied that the participant understood the experimental tasks. Participants were thanked for their participation following the experiment and compensated with a £15 voucher for their time.

8.3.5 Behavioural Data

Individual difference during the evaluation of visual art has been highlighted as a methodological problem in past studies (Cupchik et al., 2009; Vessel et al., 2012; General Methods and chapter 3). We selected two images that best represented each of the three categories (negative, neutral, positive) with respect to ratings of valence, which were subsequently split into *self*/*other* categories to deliver six categories in total (Figure 8.3).

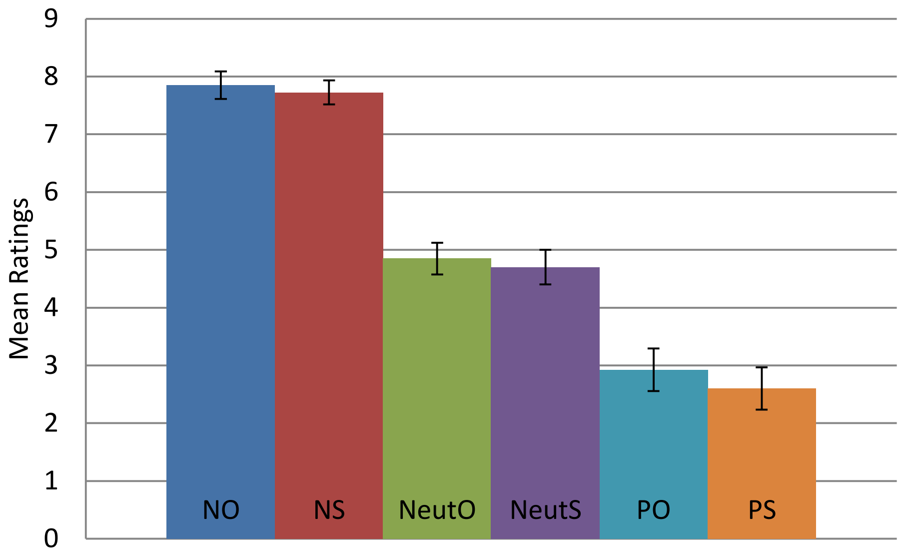


Figure 8.3 Mean ratings with standard error for the two conditions and three valence categories (NO = Negative/*Other*, NS = Negative/*Self*, NeutO = Neutral/*Other*, NeutS = Neutral/*Self*, PO = Positive/*Other* and PS = Positive/*Self*).

However, a detailed inspection of ratings obtained for images in the neutral category demonstrated considerable overlap with both positive and negative categories (Figure 8.4). It was therefore decided that the extreme ratings of the neutral category would be reassigned to the positive and negative categories to form a 2 (valence) x 2 (condition) model for further analysis. Each of the four groups of images (PS, PO, NS, NO) used in the final analysis was composed of three images; two from the original positive/negative category and one from the original neutral category.

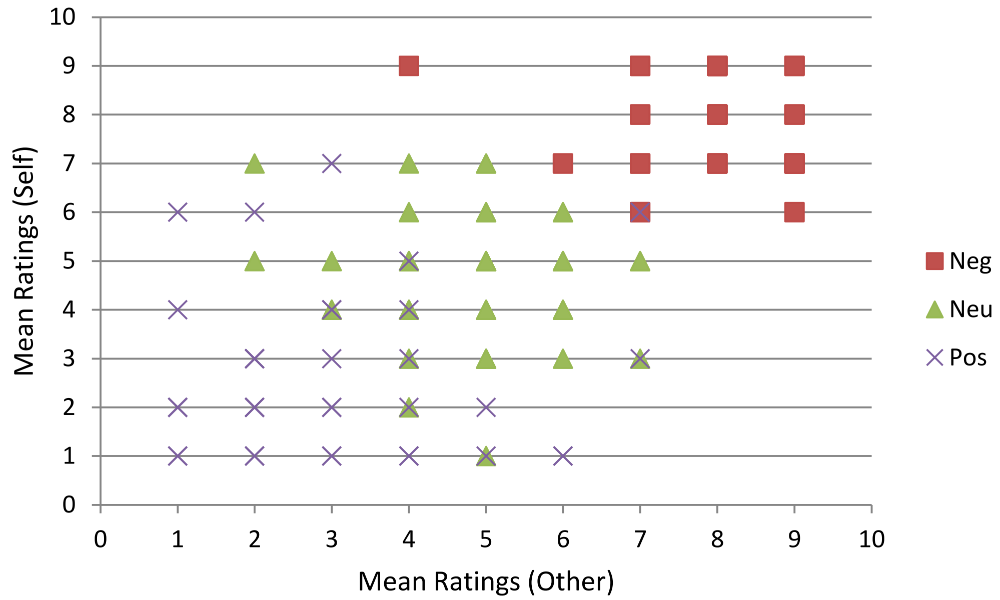


Figure 8.4 Distribution of mean valence ratings for the three categories Negative, Neutral and Positive.

8.3.6 fNIRS Data Collection

Functional near-infrared spectroscopy used to record haemoglobin changes using fNIR Imager1000 and COBI data collection suit (Biopac System Inc) (see General Methods for details). Eighteen segments with durations of 30 seconds were extracted using synchronization markers. For each 30 seconds of data HbO and HHB were calculated relative to the baseline of 20 seconds collected during the rest period immediately before each stimulus onset using the modified Beer-Lambert law. Oxygenation (oxy), a compound score that was calculated by subtracting HHb from HbO, was used for the remainder of the analysis (see General Methods for details). The 30 seconds segments were averaged according to category (PO, PS, NO, NS) and extracted to Excel for further analysis.

8.4 Results

8.4.1 Region of Interest (ROI) Analysis

A ROI analysis was performed to analyse the relationship between *self*-relevant and *other*-relevant processing further. ROIs were defined as right lateral, medial and left lateral areas. Each region consisted of four voxels. Voxel 3, 4, 5 and 6 formed the left lateral area; voxel 7, 8, 9 and 10 the medial area and voxel 11, 12, 13 and 14 the right lateral area (Figure 8.5). Research has shown that results from the marginal voxel (i.e. voxel 1, 2, 15 and 16) are most likely to be affected by movement artefacts as well as saturation due to incorrect reading that may have been caused by underlying hair (Ayaz, 2010; Scholkmann et al., 2014; General Methods for a further discussion). Voxels 1 and 2, and 15 and 16 were excluded from the ROI analysis to create three ROIs consisting of four voxels each.

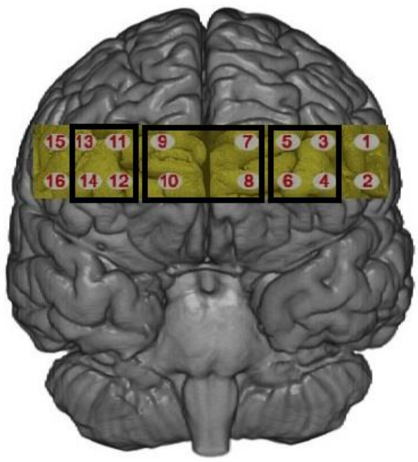


Figure 8.5 Lateral/Right, Medial and Lateral/Left Region of interest consisting of four voxels each.

A 3 (region) x 2 (condition) x 2 (valence) ANOVA was computed. The results revealed a main effect of condition ($F(1,16) = 10.46$, $p<0.005$, $\eta = .39$) and a region*condition*valence interaction ($F(2,32) = 4.39$, $p<0.02$, $\eta = .21$). The main effect of condition showed overall more activation for the *other*-condition (Figure 8.6).

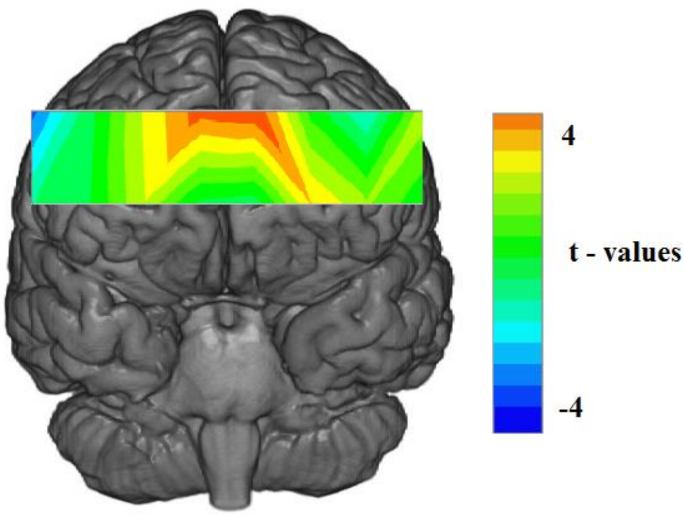


Figure 8.6 Heat map displaying t-values for main effect for condition (*Other – Self*). Higher t-values indicate greater activation in the '*other*' condition.

Post-hoc comparison of the interaction showed greater activation for PS compared to NS at the right lateral (PS mean = -0.08, s.d. = 0.24; NS mean = -0.25, s.d. = 0.32, $t(1,16) = 2.48$, $p<0.02$) and at the medial area (PS mean = -0.11, s.d. = 0.23; NS mean = -0.37, s.d. = 0.38; $t(1,16) = 3.54$, $p<0.003$). Further, a significant difference between NS and NO was found at the medial sight (NS mean = -0.37, s.d. = 0.38; NO mean = 0.08, s.d. = 0.47; $t(1,16) = 4.01$, $p<0.001$). Results are displayed in Figure 8.7.

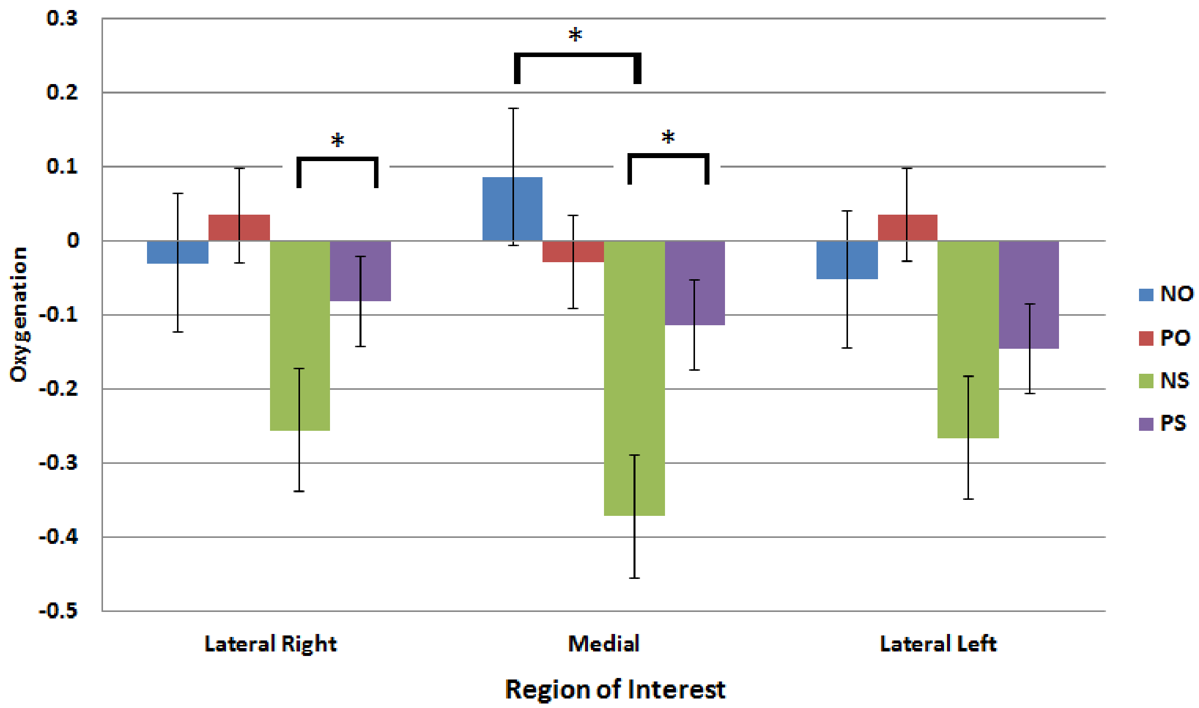


Figure 8.7 Mean oxygenation of the ROI analysis for valence and the two conditions (*self*/*other*).

A compound score was calculated to explore the interaction between *self* vs *other* across each category of valence further, by subtracting negative-*self* from positive-*self* (PosS), and negative-*other* from positive-*other* (PosO). A 3 (region) x 2 (condition) ANOVA showed a region*condition interaction ($F(2,32) = 4.39$, $p<0.02$, $\eta = .21$); no main effect was significant. Paired-sample t-test showed that PosS resulted in greater activation at the medial ROI compared to PosO (PosS mean 0.25, s.d. 0.29; PosO mean -0.11, s.d. 0.52; $t(1,16) = 2.72$, $p<0.01$) (Figure 8.8).

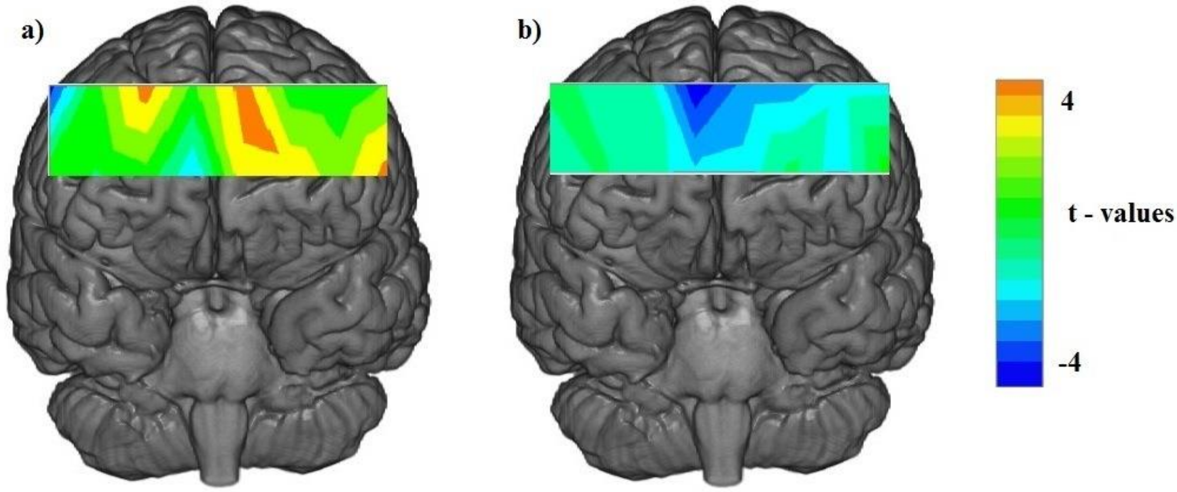


Figure 8.8 heat maps showing t-values for (a) Positive *self* (PosS – NegS) and (b) Positive *Other* (PosO – NegO).

8.5 Discussion

It was predicted that medial rPFC would show greater activation when artwork was processed in relation to the *self*. The results indicated the opposite effect – greater activation of rPFC when participants were asked to think about the artwork from another person's perspective (Figure 8.6). The second hypothesis stated that artworks that elicit positive emotions would result in greater activation of rPFC than those artworks associated with negative emotions. There was some evidence to support this position as greater activation for positive images was found during the *self*-condition (Figure 8.8). A number of significant interactions between *self*/*other* and positive/negative images revealed greater activation for positive images viewed from the perspective of the *self* at right lateral and medial areas of the rPFC. This pattern was reversed for the negative images where greater medial rPFC activation was observed when participants viewed images from the perspective of the artist (Figure 8.8). In addition and contrary to the main effect for condition, there was greater activation at the medial rPFC when viewing positive images from the perspective of the *self* vs. the *other* (Figure 8.8).

In line with previous research (Araujo et al., 2013; Lee & Siegel, 2012; Spreng et al., 2013) predominantly medial, but not lateral activation during *self*- and *other* referential processing was found (Figure 8.6). Gilbert et al. (2006) in particular showed that medial rPFC was engaged in *self*-referential processing whereas lateral areas were related to more general memory processes. Other research suggested that *self*-related processing activates ventral areas including rPFC (BA10) compared to *other*-related processing that activated dorsal areas (BA8/9) (Denny et al., 2012). The results of the current study indicated a spatial overlap of activation for *self*- and *other*-related processing along the dorsal-ventral gradient of the rPFC. Due to the spatial limitations of this device we were unable to verify if activation for *other* processing increased towards dorsal areas and decreased towards ventral areas.

Thinking about another's emotional state is an important process of social interaction which has been highlighted in ToM research (Blakemore & Decety, 2001; Carruthers & Smith, 1996; Mahy et al., 2014; Spreng et al., 2013). ToM is functionally equivalent to second order intentionality (I believe that you suppose…) (Dunbar, 2012; Lewis, Rezaie, Brown, Roberts, & Dunbar, 2011), which has been used in the *other*-condition to introspect on the artiste's emotion. The results of this study showed a large difference in activation between *self* and *other* relevant thinking, with greater oxygenation during *other* processing. Second order intentionality (i.e. thinking about the emotions of another) requires greater processing power than, for example, first order intentionality (i.e. thinking about one's own intentions and emotions) because an extra level of complexity is added. The main effect of condition (Figure 8.6) suggested that greater oxygenation in the *other* condition was indicative of second order intentionality that was used to understand the artists' emotional states. This difference may have been intensified during the processing of negative stimuli because of additional uncertainty towards these images (i.e. do these images pose threat to me?) resulting in a large difference in oxygenation between *self* and *other* relevant thoughts. Processing of *other* related information, particularly in relation to images with negative valence, may have been more challenging to participants than other forms of tasks (e.g. only processing emotional valence as reported in chapter 7) which resulted in a greater increase in oxygenation during the *other*-condition in the rPFC.

Asymmetric processing of emotions has been reported in previous studies that showed left hemispheric activation during the processing of positive or approach emotions and right hemispheric activation during the processing of negative avoidance emotions (Davidson, 2004; Ernst et al., 2012; Harmon-Jones et al., 2006; Sutton & Davidson, 2000). The results from this study did not support this finding; conversely, medial rPFC showed activation in response to positive and negative images. It was therefore concluded that asymmetrical processing of emotions in the rPFC during the contemplation of visual art is of limited relevance due to the interaction between valence and condition which may be a result of the complexity of aesthetic experiences.

Past research has suggested that the rPFC is sensitive to emotional valence (Amting, 2010; Dolcos et al., 2004; Viviani et al., 2010); with some studies finding activation for positive emotions (Dolcos et al., 2004; Viviani et al., 2010), negative emotions (Kompus et al., 2010) or both (Mitchelle, 2011). The ROI analysis enabled the identification of spatial differentiations between *self*- and *other*-related processing and how these are mediated by valence. The findings from this study supported earlier research, but there are some caveats as viewing condition interacted with emotional content. What was surprising was the interaction between valence and condition that showed greater oxygenation at the medial area for negative emotions when participants thought about the artist (*other*) and greater oxygenation for positive images when they thought about themselves (*self*) (Figure 8.8). Vessel (2013) suggested that medial rPFC is activated when an artwork 'strikes a chord' in the viewer signifying intense personal meaning. According to this view medial rPFC would only be relevant to first-order intentionality, in this case, thoughts about the importance of the image to the *self*. Results from this study suggest that activation in the medial rPFC is sensitive to both first (thinking about one's own emotion) and second (thinking about another's emotions) order intentionality, but that this relationship is mediated by valence. Results showed that medial rPFC activation was higher for *other*- compared to *self*-relevant processing for images that evoked negative emotions. This implies greater reactivity to negative stimuli when participants considered the emotions of others which may have been related to the resolution of ambiguity or imagined threat. However, it may also be a reflection of greater processing required to perform second-order introspection and that this effect is simply enhanced for negative stimuli. The sensitivity of the medial rPFC to negative emotions and first (*self*) and second (*other*) order intentionality may indicate an interactive role between cognitive and emotional processing streams deeper in the brain. Future research may expand this finding through the exploration of interactions between rPFC activation and activation of deeper brain structures such as the amygdala during the experience of first and second order processing of negative emotions. Activation of the amygdala may for example provide insights into the intensity of the experienced threat between *self*- and *other*-relevant processing because of its relevance to the experience of fearful stimuli (Delgado et al., 2008).

Introspecting about *self*-relevant positive emotions resulted in greater medial and right lateral rPFC activation in comparison to negative images that were *self*-relevant as well as positive images that were *other* relevant. This effect may be the results of a positivity bias when reflecting on positive emotional stimuli that are associated with the *self* and because this type of reflection may be experienced as rewarding. The positivity bias in relation to the spontaneous processing of emotional stimuli and its relation to rPFC activation has been demonstrated by Viviani et al. (2010). These authors found that participants were more likely to create positive sentences when asked to unscramble emotional words that could be *self*-relevant (e.g. “bright the very dismal looks future” was more likely to be transformed into “the future looks very bright” than a negative alternative). This occurred even if negative words (e.g. dismal) were emotionally more salient that positive words, showing that a mechanism must actively steer thoughts towards a positive bias during spontaneous thoughts. Activation in the rPFC was only found during the generation of spontaneous positive sentences compared to negative sentences or during a control condition in which participant were explicitly instructed to form positive or negative sentences. These authors attributed their findings to a naturally occurring *self*-serving bias that occurs during undirected emotional processing. Participants in this study had no knowledge of prior valence ratings attached to the images indicating that they engaged in spontaneous emotional introspection. It may be that processing of positive images that are *self*-relevant during the contemplation of visual art subscribe to the same *self*-serving bias. The interaction between emotion and *self*/*other* focus may therefore be an indication of the experience of pleasure in relation to the contemplation of positive images that are *self*-relevant and the resolution of ambiguity or threat if the images are negative and *other*-relevant. Thinking positively about the *self*- and detecting negative emotions in others may be advantageous during social interactions.

8.6 Limitations

The lack of a neutral category is a limitation to this study. Although a neutral category was included at the outset it soon became apparent that this was unusable. It may be possible to include stimuli that are more neutral by using non-art images such as black and white geometrical patterns. However, it is questionable if these patterns than match the ecological validity of the stimuli used in the current experiment, which were genuine artistic works.

The experimental design did not include a metric that enabled us to test if participants were able to perform the task and if there were individual differences in participants' performance in the task. Some participants may have been more engaged or more efficient at introspecting about their own as well as other emotional states which may have introduced additional variance into the data. However, an extensive training phase was included at the beginning of the experiment in which each participant was trained on the task. Answers during the training session were discussed in detail until the experimenter was satisfied that the participant understood and was able to perform the task. Further individual difference may have been introduced through differences in prior exposure by the participant to art through, for example, gallery visits. This study controlled for greater differences in art knowledge by only asking participants who had no formal training in an art related subject, but individual differences due to a layperson's interest in art was not controlled for, i.e. participants could have been asked how often they have visited a gallery in a given time period.

8.7 Future Research

The medial rPFC may play an important role in the interaction between emotion and social cognition. The results of this study suggest that valence and *self*-relevance interact in the rPFC during the contemplation of visual art. This is a novel finding because previous research has either focused on differential processing of *self/other* related information or emotional appraisal such as paying attention to the emotions a visual stimulus invokes. These findings may therefore pose future research questions for a number of areas. Viviani et al.'s (2010) study may, for example be repeated with the addition of instructions to form sentences that are *self*- or *other* relevant to explore the interaction between the positivity bias and *self/other* processing found in this study in other contexts.

Future research conducted to understand the main findings of this study better could investigate the interaction between emotions and *self*-focus in different participant groups such as art experts compared to art naïve participants or participants scoring high or low on depression. Particularly the latter group may be of interest to disambiguate the interaction between emotional stimuli and *self/other* processing, because it has been shown that individual affected by depression lack the positivity bias (Rude, Valrey, Odom, & Ebrahim, 2003; Rude, Wenzlaff, Gibbs, Vane, & Whitney, 2002) found in this study and described by Viviani et al. (2010). It may be hypothesised that rPFC activation in relation to the positivity bias is eliminated between *self/other* processing, and that images that are *self*-relevant and negative result in greater rPFC oxygenation compared to *self*-relevant positive images reversing the findings reported here (Figure 8.8). Furthermore, it may be of interest to investigate rPFC activation using the setting described in this study with populations differing in personality traits (for example extroverts vs. introverts) or those scoring high on social desirability scales or trait anxiety scales.

8.8 Conclusion

This study aimed to investigate rPFC activation during the experience of positive and negative artwork under two viewing conditions: (1) *self*-focus and (2) *other*-focus. Results from this study showed an interaction between emotion and condition in the medial rPFC; participants engaged more with positive images in the *self*-relevant condition and more with negative images in the *other*-relevant condition. The results suggest that rPFC plays an important role in mediating *self/other*-focus and emotional valence during aesthetic experiences.

9. Discussion

The general discussion consists of five sections; section 9.1 is a summary of the main findings. In section 9.2 the cognitive components (complexity and comprehension) that were manipulated in study III (chapter 5) and study IV (chapter 6) will be discussed. Section 9.3 will discuss the implications of the manipulation of the emotional component throughout all experimental studies; particularly positive emotions have been relevant to the experience of art. Section 9.4 discusses the implications of the findings in relation to the rPFC and aesthetic experience, and the implications to neuroaesthetics are outlined in section 9.5. The limitations of this research are described in section 9.6, followed by suggestions for future research (9.7).

9.1 Summary of Main Findings

This thesis reports the result of i) a survey exercise, ii) a pilot study and iii) four experimental studies. The survey generated a database of images with quantifiable psychological properties that were used as stimuli during the experimental studies. The first formal experimental study (Study III) manipulated complexity and valence and found no effect at the rPFC due to the manipulation of image complexity but a significant interaction between valence and time, i.e. greater oxygenation in the rPFC during the early period (the first 20 sec following stimulus onset) for positive images and during the late period (the last 20 sec following stimulus onset) for negative images. This finding highlighted the importance of using long exposure times to stimuli in order to fully capture the rPFC response to the emotional properties of the images because of a relatively slow haemodynamic response. The second formal experimental study (Study IV) manipulated comprehension (whether the image was easy to understand or not) as a cognitive component alongside positive/negative valence. There were no significant main effects for comprehension or valence but a significant interaction was found. Negative images resulted in greater rPFC oxygenation when images were difficult to comprehend and for positive images in combination with high comprehension (easy to understand) images. The interaction may indicate an experience of pleasure to positive images and the resolution of uncertainty in negative images. A final two studies manipulated viewing conditions using different sets of instructions whilst participants viewed positive and negative images. The third study (Study V) instructed participant to introspect about their emotions or direct their attention towards features, such as lines or colours in the external environment to assess the relevance of the gateway hypothesis to the aesthetic experience. The results from the third study did not support the Gateway Hypothesis, greater medial activation of the rPFC was found for positive images regardless of viewing condition. The final study (Study VI) manipulated the emotional experience of the viewer by asking participants to appraise the emotions evoked by an image from the perspective of themselves or of the artist. This study demonstrated that oxygenation of the rPFC increased when participants appraised the image from the perspective of the artist, indicating that participants found this condition more challenging than making an emotional appraisal from their own perspective. Moreover, there was a significant interaction between appraisal condition and valence with greater medial rPFC oxygenation for positive images when participants thought about their own emotions and greater medial rPFC oxygenation for negative images when participants thought about the emotions experienced by the artist during the creation of the image.

In summary, the rPFC was sensitive to positive and negative emotions during aesthetic experience. Oxygenation in the rPFC increased when the image was positive, *self*-relevant and easy to understand. On the other hand, activation of the rPFC was also enhanced when negative images were viewed under conditions of increased cognitive demand (i.e. when images were hard to understand or assessed from the perspective of another person).

9.2 The Cognitive Components

The first two experimental studies (Study III and Study IV) manipulated a cognitive dimension (complexity or comprehension) alongside an emotional component (valence) associated with the image. The findings from the first study showed no differentiation in activiy for images with high or low complexity suggesting that complexity may be processed in areas outside the rPFC such as visual cortex, parietal cortex, sensory cortices or thalamus. For example, Jacobsen et al. (2006) found greater activation in the parietal and premotor cortex during complexity judgements of symmetrical shapes. Judging the complexity of geometrical shapes (and perhaps also of visual art) may not require a deeper understanding of the image that is generated through complex cognitive activity within the rPFC but impacts on areas associated with basic sensory processing. Assessment of the complexity of visual art may be more representative of earlier stages of aesthetic appraisal, such as the perceptual analysis stage in Leder et al.'s (2004) model or of early visual processing in Chatterjee's (2004) model.

The second study indicated that activation of the rPFC to positive or negative valence was mediated by the ease of comprehension associated with the image. Understanding an image involves higher-order cognition such as memory and problem solving ability that are associated with rPFC function (Nee et al., 2013; Pessoa, Kastner, & Ungerleider, 2002; Vessel & Rubin, 2010). However, the results from the second study revealed that the impact of high/low comprehension in the rPFC was dependent upon positive or negative valence. The rPFC may be involved in the integration of autobiographical memory, *self*-relevance and emotional processing that are part of the later cognitive mastering stage and are important to obtain an aesthetic judgement or an aesthetic emotion in Leder et al.'s (2004) model. It has been argued that art naïve participants rely heavily on personal experiences in order to draw meaning from art (Leder et al., 2004; Leder, 2013). Participants in this study were art naïve and may have relied upon personal memories and feelings instead of technical knowledge to intuitively understand the images. The interaction between comprehension and valence may therefore reflect a convergence between complex cognitive processes in the rPFC that are guided by continuously updating affective states in the art naïve individual. This interaction may be unique to those participants and experts in art may be guided by factual knowledge and not be as strongly influenced affective states (Leder et al., 2004), resulting in differing patterns of rPFC activation compared to one reported in this experiment. This finding would indicate the importance of affective states during the evaluation of art for art naïve participants and may be explored in future research.

9.3 The Emotional Component

The results from the first experiment (chapter 5 – Complexity and Valence) showed a differential time course of emotional processing. León-Carrión et al. (2007) demonstrated that processing (as assessed by fNIRS) of 20 second emotional video clips resulted in an overshoot of activation into the baseline period. These authors argued that it was important to consider long exposure times and baselines following image presentation to capture the full emotional response to a stimulus. The first experimental study (Chapter 5) consisted therefore of 60 second stimulus presentation. Greater rPFC activation was found in response to positive valence in the early period and negative valence in the late period, a finding that highlights the importance of long exposure time during the contemplation of visual art as assessed by fNIRS. The importance of prolonged exposure time may be a reflection of a relatively slow haemodynamic response coupled with a relatively slow sensor (about 2 Hz). However, this effect was not replicated in the further experimental programme which may have been the result of increasing task demands resulting from instructions to appraise an image from one's own or another person's perspective.

Aesthetic emotions, such as preference or beauty have been studied in a number of ways (Cupchik et al., 2009; Ishizu & Zeki, 2011; Jacobsen et al., 2006; Zeki, 1999b), but the experience of beauty or aesthetic pleasure are not the only emotional states that may be experienced during the viewing of visual art. A continuous process of updating affective states that lead to the overall experience of an aesthetic emotion was described by Leder et al. (2004) that includes the possibility of negative as well as positive emotional states during aesthetic experiences. In addition, Leder et al.'s (2004) generation of 'affective states' highlight the influence of positive and negative affective states in the formation of an aesthetic evaluation or emotion. This model stands in contrast to research that views aesthetic emotions as an outcome of purely cognitive processing of art (Reber, 2012;

Reber et al., 2004) or those approaches where aesthetic emotions are studied without consideration of the process that leads to the formation of this emotion (e.g. Ishizu & Zeki, 2011; Kawabata & Zeki, 2004; Zeki, 1999). The research performed in the current thesis indicated that continuous affective processing, particularly of positive emotions, was highly relevant to activation in the rPFC. Greater oxygenation of the rPFC was found in free-viewing tasks for positive emotions during emotional introspection even when attention was directed to external features of the images (chapter 7). Negative emotions tended to incite greater oxygenation of the rPFC when introspection was mediated by comprehension or *self*/*other*-focused processing. This indicates that both cognitive demand (i.e. greater attention to identification of threat in relation to negative images) and aesthetic pleasure (i.e. the pleasure experienced in relation to positive images) both activate the rPFC, but under different circumstances.

It was found in Study IV that affective processing in the rPFC during the contemplation of visual art was mediated by comprehension. Participants showed greater rPFC activation in response to positive easy to understand images compared to negative easy to understand images. Contemplating landscapes or portraits (Di Dio & Gallese, 2009) that are experienced as evoking positive emotion, has been linked to rPFC activation and attributed to the experience of pleasure during contemplation of visual art (Jacobsen et al., 2006; Kirk et al., 2009; Thakral et al., 2012; Vessel et al., 2012). Therefore, it is postulated that greater rPFC activation during the contemplation of positive images that are easy to understand is associated with an experience of pleasantness (Jacobsen et al., 2006; Kirk et al., 2009; Thakral et al., 2012; Vessel et al., 2012). However, images that were difficult to understand and negative in emotional tone also resulted in greater oxygenation of the rPFC; in this case, increased rPFC activation may have resulted from a combination of heightened cognitive demand (because the image was hard to understand) and feelings of a possible threat (because the image had a negative emotional tone).

The resolution of uncertainty when viewing art has been described as an important part of the aesthetic experience (Berlyne, 1960; Silvia, 2008; 2010) and rPFC activation may represent a locally generated uncertainty signal or an attempt to resolve uncertainty signals generated by other regions (e.g. amygdala or anterior cingulate cortex) (Campbell-Sillls et al., 2011; Shackman, McMenamin, Maxwell, Greischar, & Davidson, 2009). The rPFC may therefore have an integrative role between cognitive and emotional processes that goes beyond the detection of pleasantness. Previous studies probably failed to detect this relationship because they did not control directly for the positivity or negativity of their stimuli or their participants' levels of comprehension of the artworks (e.g. Cela-Conde et al., 2004; Cela-Conde, Agnati, Huston, Mora, & Nadal, 2011; Di Dio, Canessa, Cappa, & Rizzolatti, 2011; Jacobsen et al., 2006; Thakral et al., 2012).

It has been proposed that internal processing (i.e. thinking about) art stimuli is related to the Gateway Hypothesis (Cupchik et al., 2009). The Gateway Hypothesis (Burgess et al., 2005) states that external stimuli feature such as lines or colours are processed by the medial rPFC whereas processes related to internal cognition such as emotional introspection are associated with lateral rPFC activation. In Study V the relevance of the gateway hypothesis during the experience of art was assessed by manipulating viewing conditions in order to emphasis external vs. internal processing. There was an increase of medial rPFC activation during the viewing of positive images but no effect of viewing condition was found. These results contradict the gateway hypothesis that posits an increase of lateral rPFC activation during internal cognitive processing. The results were therefore interpreted as an indicator for the experience of pleasantness as described previously by Jacobsen et al. (2006), Kirk et al. (2009b), Thakral et al. (2012) and Vessel et al. (2012). Those studies that originally supported the gateway hypothesis (Gilbert, Gonen-Yaacovi, Benoit, Volle, & Burgess, 2010; Henseler et al., 2011) used stimuli, such as geometric shapes or that had neither the emotional salience nor complexity of the visual art used in the current thesis and this difference may account for the differences in results.

An alternative theory involving rPFC activation is proposed by the Default Mode Network (DMN) (Buckner et al., 2008). The DMN was first associated with undirected thought such as mind wandering or when no active task has to be performed, but has since been implicated in the processing of *self*-relevant thought (Buckner et al., 2008; Molnar-Szakacs & Uddin, 2013). Particularly activation of the medial rPFC of the DMN has been associated with *self*-referential processing, mentalising (thinking about the intentions, emotions and actions of others) and autobiographical memories (Andrews-Hanna et al., 2010; Andrews-Hanna, 2012; Moran, Kelley, & Heatherton, 2013; Spreng et al., 2009, 2013). The DMN has been linked to aesthetic processing by Vessel et al. (2012; 2013) who proposed that those artworks that provoke strong emotional responses tend to activate rPFC because they are perceived to be highly relevant for the viewer. We investigated the relationship of emotional processing and *self*/*other*-focus by asking participants think about how positive and negative images made them feel or how the artist might have felt when painting the picture (chapter 8 – *Self*-Focus vs. *Other*-Focus). Our results indicated an increase of rPFC activation when participants were asked to consider the image from the perspective of another person (the artist). This finding may be a product of the additional cognitive demand/challenge associated with second order processing when an individual attempts to imagine the thoughts, feeling and intentions of another person (Dunbar, 2012).

Although this thesis focused on activation in the rPFC, connections from other brain areas will influence this activation. Bludau et al (2013) showed differential connectivity between lateral and medial rPFC and areas outside of the rPFC. Lateral areas were connected with inferior frontal as well as parietal regions which were preferentially activated by autobiographical and working memory tasks. Medial areas on the other hand were mainly involved in emotional as well as social cognition tasks and functionally connected to the lateral temporal lobe, the right laterobasal group of the amygdala and the right hippocampus. Bludau et al (2013) suggested that the lateral rPFC and connected areas form an important substrate for organising behaviour, planning of actions and managing multiple goals whereas medial rPFC and connected areas are important to assign emotional value to sensory stimuli. Similarly, Gilbert et al (2010) showed a differentiation between medial and lateral rPFC connections. Here, activation in lateral rPFC was particularly associated with co-activation in dorsal cingulate, dorsal PFC, anterior insula and lateral parietal cortex whereas medial areas were associated with co-activation in posterior cingulate, posterior superior temporal sulcus and temporal pole. Further, these authors showed that rPFC connectivity can be influenced by the type of task participants are asked to perform. For example, Gilbert et al (2010) showed that dlPFC, anterior cingulate and lateral parietal cortex tend to co-activate with lateral rPFC in most tasks but with medial rPFC in tasks involving mentalising. These findings provide further support of the importance of medial areas during the processing of *self/other* relevance and emotional value in an aesthetic context.

9.4 Implications for rPFC and the Aesthetic Experience

Activation of the medial rPFC was found throughout the experimental studies and was interpreted as supporting evidence for the involvement of the DMN in the aesthetic experience. Others (Cupchik et al., 2009) have linked rPFC activation during aesthetic experiences to the Gateway Hypothesis, but the results found in chapter 7 rejected this interpretation. The DMN has continually shown activation in medial rPFC during the processing of *self*-relevant information (Buckner et al., 2008; Christoff & Gabrieli, 2000; Mason et al., 2007; Qin & Northoff, 2011; Whitfield-Gabrieli et al., 2011) which may be directly connected to *self*-related interpretations of art. The Gateway Hypothesis on the other hand suggests activation of lateral rPFC during internally generated processing, such as emotional introspection. Vessel (2013) argued that only images that are highly moving ‘strike a chord’ (i.e. resonate with the viewer’s sense of identity and provide an intense feeling of pleasure as a side-effect) in the viewer which results in medial rPFC activation. Our findings expanded this position by showing that rPFC activation extends beyond ‘striking a chord’ in an individual. We argue instead that medial rPFC is an important hub of the DNM (Andrews-Hanna et al., 2010; Andrews-Hanna, 2012) where autobiographical memories, emotional processing and *self*/*other*-relevance are combined in order to assess the impact of visual art. The interaction of updating affective states, autobiographical memories and *self*-relevant processing enabled art naïve individuals who participated in the experiments to make an aesthetic judgement and experience an aesthetic emotion.

Neuroaesthetics has been criticised for studying aesthetic experience without considering the personal background and previous experience of art across individuals (de Smedt & de Cruz, 2011). The study of beauty often examines aesthetic emotions as the outcome of an aesthetic experience (Leder et al., 2004) but does not consider the origins or contributing variables to this judgement. However, the idiosyncratic background of a person (i.e. autobiographical memories) will influence or interact with continuously updating affective states in order to form an aesthetic judgement. Furthermore, autobiographical memories are *self*-relevant by definition and have been found to activate medial rPFC in addition to other areas that are relevant to emotional processing (e.g. amygdala) and memory processing (e.g. hippocampus) (Andrews-Hanna et al., 2010; Mars et al., 2012; Molnar-Szakacs & Uddin, 2013; Qin & Northoff, 2011). The experimental studies reported here required art naïve participants to connect with the artwork on a personal level (how does this image make you feel?) and this process of appraisal resulted in greater attentional demand and rPFC activation. These findings suggest that an area of the brain related to autobiographical memories is also activated during the contemplation of art. It could be further argued that the *self*-relevance of a stimulus cannot be assessed without considering autobiographical memories and vice versa

The assessment of *self*-relevance in the light of one's own personal background i.e. autobiographical memories (AMs) has important implications to how the social world is navigated. Processes, AMs as well as *self*/*other*-processing, are important aspects of social cognition, or more specifically to Theory of Mind (ToM). Theory of Mind is the ability to understand the intentions, thoughts and feelings of others by putting oneself into their 'shoes' (Benoit et al., 2012; Lombardo et al., 2010; Mahy et al., 2014). One stage to understanding art is also to understand the intentions of the artist (i.e. what did the artist want to say with this artwork?) (Bullot & Reber, 2013), and therefore incorporates a processes of putting oneself into the artist's 'shoes' in order to understand what information the artists wished to convey. Molnar-Szakacs and Uddin (2013) argued that the DMN is particularly activated when mental states (i.e. understanding someone's thoughts, feelings and intentions) are assessed because ToM acts as an extension of the *self*; i.e., by knowing our own feelings and emotions we can imagine what another person's feelings and emotions might be. The association between the medial rPFC and DMN, ToM and AM suggests that the former mediates the *self*-*other* relevance (how do I feel/ how does someone else feel) and emotional tone which is connected to the person's own experiences during aesthetic encounters. The interactions between valence and comprehension as well as *self*/*other*-relevant processing would support this hypothesis.

The process of continuously updating affective states underlies the evaluative process of visual art (Leder et al., 2004) and is therefore important to aesthetic evaluation. The results from these studies suggest that emotional responses to images are mediated in the rPFC because this area reflects *self*-relevant and autobiographical memory processes that are mediated by the affective tune of the stimulus. These processes aids aesthetic evaluations, particularly in art naïve individual, because the evaluations are *self*-relevant (i.e. what does this picture mean to me? Do I understand its meaning?).

9.5 Implications for Neuroaesthetics

This thesis demonstrated that neuroaesthetics would benefit from expanding the role of emotional processing during aesthetic experience to incorporate other facets besides aesthetic emotions such as beauty. This expansion would lead to a more inclusive approach and adoption of a reductive methodology in order to understand how aesthetic judgements and emotions are derived in the brain. Neuroaesthetics would benefit by consideration of detailed models of aesthetic experience such as Leder et al.'s (2004) processing model. The work reported in this thesis focused on the role of rPFC activation during the contemplation of static visual art. Our results suggested that rPFC is particularly sensitive to processes related to the fourth stage (cognitive mastering) of Leder et al.'s (2004) model (Figure 1.3) or late visual processing in Chatterjee's (2004) model (Figure 1.2). We would argue that ToM and AMs are mediated by continuously updating affective states during *self*-related interpretations, or rather that affective states are continuously updated based on *self*-relevant processing via ToM and AMs during the cognitive mastering stage (Figure 9.1). This process forms an important step during the understanding of one's own feelings as well as the artist's intentions of an artwork and contributes towards the formation of aesthetic judgements and/or aesthetic emotions.

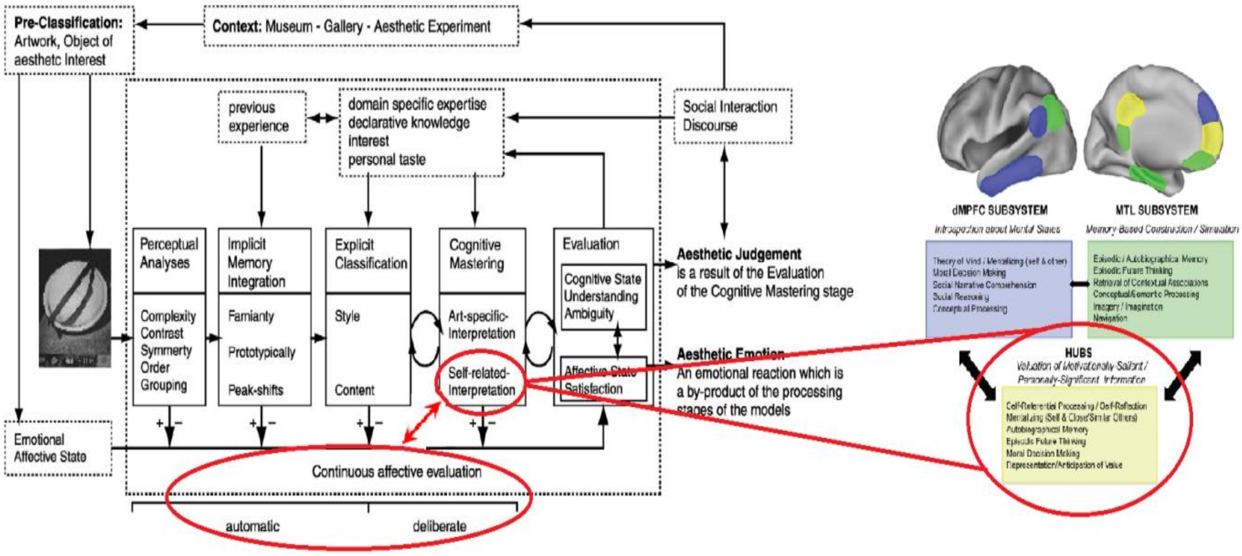


Figure 9.1 The functional-anatomic organisation of the hub of DMN network may form an important part of *self*-related interpretations during the cognitive mastering stage proposed by Leder et al. (2004).

9.6 Limitations

9.6.1 Individual Differences

An individual's personal experience and knowledge of art can influence their understanding of a painting to a great degree (Bullot & Reber, 2013; de Smedt & de Cruz, 2012). Above all, differences in the understanding of art between art experts and art naïve individuals have been highlighted (Batt et al., 2010; Bhattacharya & Petsche, 2002; Kirk et al., 2009; Leder et al., 2004; Vessel et al., 2012). To avoid prior knowledge of the stimuli in the current work, artworks were chosen from little known artist. This step was taken to inhibit historical or personal association participants may have had with more famous works, e.g. Mona Lisa by Leonardo da Vinci. Additionally, only participants who had no formal education in an art related subjects were invited to take part in the experimental studies. However, participants were not asked about their personal interest in art. Subsequently, some participants may have had greater familiarity with visual art than others through, for example, voluntary gallery visits. Future research may control for this source of individual differences by asking participants about the frequency they visit a gallery or environments where they are exposed to art.

9.6.2 The Stimuli

Selecting suitable stimuli for the study of neuroaesthetics poses a number of methodological challenges. Research within neuroaesthetics has highlighted two equally important aspects of stimulus selection, one is the importance of consistent use of stimuli to ease comparison between studies (Di Dio & Gallese, 2009), the other the importance of accounting for individual differences in the experience of art (Vessel & Rubin, 2010). Consistent use of stimuli can be achieved by using artificial simple stimuli such as geometric shapes, but these stimuli do not accurately reflect the richness of aesthetic experience. The use of realistic complex artworks provides ecological valid stimuli but poorer experimental control. This thesis used pre-rated images to increase experimental control and to create coherent sets of stimuli that allow the comparison of results across studies; nevertheless addressing individual differences in the experience of these sets remained a challenge. Vessel and Rubin (2010) argued that previous research focused on the manipulation of objective features of the stimulus, an approach that relies on large group averages to provide meaningful data, rather than considering individual differences in art appreciation. Berlyne’s psychobiological approach, for example, emphasised the role of measurable stimulus variables such as novelty or complexity (Berlyne, 1960), rather than individual differences in the experience of these variables. Vessel and Rubin (2010) suggested that consensus about stimuli can only be reached through shared experiences with a stimulus. Participants agree upon aesthetic judgements or emotions because of a shared cultural framework and not because of individual features of an image. A painting of flowers, for example, is experienced as beautiful because of a shared reference to the experience of flowers as beautiful. Their findings suggested that a common preference can be found for representative images, but not for abstract images because participants lack a common reference frame for abstract art.

Although, this approach allows the study of image categories for which participants have a shared reference frame, it would limit neuroaesthetics research to the study of representational paintings. It would also be impractical to assess each participant's experience with art to assure that there is a common framework. However, an emphasis on the internal aspects of preference formation needs to be considered and requires the use of methods that allow the experimenter to relate individuals' preferences to objective image properties. The images for the database used in this thesis were selected according to the psychological properties described in research by Berlyne (1960) and Silvia (2008) to provide ratings that allowed the coherent and controlled selection of stimuli sets (e.g. high complexity vs. low complexity). This approach provided experimental control in the selection of stimuli, but it did not account for individual differences with respect to the conceptual basis of subjective assessment, e.g. did high complexity mean the same thing to all participants? It was concluded that the survey provided a population based distinction between images that had to be supplemented by calibration to the individual. The approach taken was therefore to use the survey data (chapter 3 - The Survey) to select images that conformed on average to the chosen experimental categories but to use only a subset of the images where participants agreed with the norm were in the final analysis. This approach accounted for the use of coherent stimulus sets as well as individual differences in experiencing these sets.

A further limitation to the stimuli is the absence of a neutral category. All emotional comparisons in this work were between negative and positive images and efforts to include a neutral category were not successful. This limitation raises the question of whether it is possible to have a neutral category of art. Neutral was defined here as half way point between negative and positive or in other words a rating around five, the midpoint of the valence scale. However, the first problem is caused by using a rating of five as a midpoint. Not all participants used the full breadth of the scales as a result the midpoint between the two most extreme ratings for one participant may have been different to that of another. There was also greater variability across individuals for items in the neutral category than for positive or negative categories. The greater disagreement for the neutral category may have originated in greater uncertainty about these images and not because they were seen as neutral, i.e. positive ratings from some individuals were offset by negative ratings obtained from others. For example, Figure 9.2 was seen as positive by a number of participants and equally as negative by others. This image was one of the training set during the study reported in Study VI and verbal reports by participants indicated that they were often unsure of where to place this image and it was therefore assigned a 'neutral' score of five. It may be argued that the neutral category consisted of images where participants did not have a common frame of interpretation which would be necessary to form a consensus (Vessel and Rubin, 2010). A further option to introduce a neutral category would be to use geometrical shapes or abstract black and white images. However, this would introduce other difference to the art images used as stimuli. Geometric shapes, for example, lack aesthetic status and represent therefore a different category of images compared to aesthetic artworks which brings the suitability of these patterns as neutral category into doubt.

Figure 9.2 Image Tremblay, © Julie Tremblay

9.6.3 The Co-dependency of the Psychological Properties

The psychological properties chosen for the survey were selected because they had been associated in previous research as important and independent parts of the aesthetic experience (Berlyne, 1960; Russell, 1980; Silvia, 2001, 2008). However the survey results suggested co-dependency between some of the six properties. Novelty, for example, showed high correlations with all other properties (Table 3.1) and was therefore not used to manipulate the viewer’s experience. Only variables that demonstrated a high tolerance threshold in the multiple regression analysis, namely complexity, comprehension and valence, were used as independent variables in the experimental studies. The aim of the first two experimental studies was to manipulate the viewer’s experience through the change of stimuli properties. Complexity and valence, and comprehension and valence were chosen. However, complexity, comprehension and valence were still subject to low co-dependency, which became particularly apparent in the manipulation of comprehension and valence. The result of this co-dependency was that the low comprehension negative valence category was less comprehensible than the low comprehension positive valence category. In other words, positive images were easier to understand in a general sense compared to negative images (Figure 6.3) which may have confounded the results. Vessel and Rubin (2010) argued that the manipulation of stimulus properties during aesthetic experiences poses a problem due to individual differences in taste. This thesis found that the manipulation of image properties also poses a problem because of co-dependency between different properties or dimensions of each image. It was therefore decided that a further two experiments would focus on changing the viewer's experience by changing their attentional focus to different aspect of the experience (e.g. *self* vs. *other* focus). This methodology enabled us to investigate underlying processes of the aesthetic experience that were independent of fixed properties such as complexity or comprehension.

9.6.4 Limitations of the Neuroimaging Technique

The CW fNIRS device measures relatively slow changing haemodynamic responses in relation to a specific event. The findings in this thesis are therefore limited in their contribution to the aesthetic literature insofar as that they are not assessing the temporal properties of the aesthetic experience. Other imaging modalities, e.g. EEG or MEG, would be more suitable to investigate the time course, and possibly differentiations between early and late visual processing (Chatterjee, 2004; Figure 1.2) of the aesthetic experience.

Only rPFC activation was assessed in this thesis as a result of the size of the fNIRS device used in this thesis (Figure 2.5). Furthermore, fNIRS technology is limited to a depth of three cm making it unsuitable to assess activation in deeper brain structures such as the amygdala. Other imaging modalities, e.g. fMRI may be suitable to assess the relevance of deeper brain structures to the aesthetic experience.

9.7 Future Research

Neuroaesthetics as an independent research field is still in its early stages and many avenues are worthy of exploring to gain a fuller understanding of the aesthetic experience. Future research evolving from the findings of the experimental studies can be grouped into different categories. Each category could provide its own strand of research that focuses on different aspect of the aesthetic experience.

9.7.1 Alternative Manipulations

Future work may benefit from collaborations with artist to create custom made stimuli for experimentation. This would enable the use of stimuli that is identical in complexity but may only vary in relation to colour (for example, dark colours for negative moods and bright colours for positive moods). Creating specific stimuli for the use of an experimental design would add a further level of control to the stimulus and the experience of the viewer. Collaborations with artists would also allow the presentation of original paintings, compared to images projected onto a computer screen or a wall, providing the viewer with a more authentic aesthetic experience.

Further avenues that may be explored are the manipulation of the viewer through written descriptions of relatively neutral artwork to induce positive and negative emotions in participants rather than relying on stimulus properties. For example, emotions may be manipulated by providing autobiographical details of the artist that are positive (e.g. this image was painted to celebrate the birth of the artist’s child), negative (e.g. this image was painted after the death of the artist’s mother) or neutral (e.g. this image was painted whilst the artist listened to music). This approach allows the introduction of a neutral category in which participants focus is directed to other stimuli properties, such as stylistic features. Furthermore, it increases experimental control because the images can be kept constant across categories.

9.7.2 Alternative Participant Groups

Research has shown that art experts and art naïve participants process visual art differently (Batt et al., 2010; Bhattacharya & Petsche, 2002; Leder, 2013). Future research may investigate differences in emotional and cognitive factors in art experts vs. art naïve participants in the rPFC. Differences in emotional processing between these two populations may be of interest as it has been suggested that art naïve participants rely to a greater extend on *self*-relevant processing whereas art experts rely more on categorical knowledge to form an aesthetic judgement or an aesthetic emotion (Leder et al., 2004). Study IV (Comprehension and Valence) may be replicated to compare rPFC activation in art experts and art naïve participants. It may be predicted that art naïve participants show greater rPFC activation because they show a greater reliance on emotional and *self*-referential information to form aesthetic judgements. Further, it may be predicted that art experts do not show the interaction between valence and comprehension because this participant group is more likely to rely on factual, rather than emotional knowledge to comprehend art.

Emotion regulation during aesthetic experiences may also differ in populations affected with depression. Previous research has shown that PFC, including rPFC activation is impaired in clinical populations (Jollant et al., 2010; Kim, Gee, Loucks, Davis, & Whalen, 2011). Future research may explore if the interactions found between comprehension and valence or *self*/*other* focus and valence differ in clinical populations. Considering the findings reported here, a number of predictions can be formulated about rPFC activation during aesthetic experiences in populations affected by depression. Study VI (*Self*-Focus vs. *Other*-Focus) showed that rPFC activation was lowest during the viewing of negative images in condition 1 (*self*) and highest during the viewing of positive images (Figure 8.5) in healthy participants used in this thesis. Individuals affected by depression have been shown to have a tendency to attribute negative events to themselves and positive events to outside sources, i.e. a reversal of the positivity bias (Jollant et al., 2010; Seligman, 1998). Activation of the rPFC may therefore be (1) increased during the viewing of negative images and (2) decreased during the viewing of positive images that are *self*-

relevant in a population affected by depression. Further, heightened rPFC activation could be expected during negative/low comprehension images because the threat that these images pose may become more relevant to a population affected by depression or anxiety.

9.7.3 Alternative Brain Areas

The research reported here was limited to the investigation of emotional processes in the rPFC because of the limited spatial resolution of the fNIRS device. Future research may use other technology such as fMRI to perform a whole brain analysis that may highlight connections between the rPFC and deeper brain structures such as the amygdala. It has also been proposed that dorsal medial PFC responds more to *other* related processing whereas medial rPFC or medial VPFC respond more to *self*-relevant processing. The use of fMRI would be able to uncover this relationship during aesthetic experiences.

A further avenue to be explored may be the connection between OFC and rPFC during aesthetic experiences. This thesis argued that the experience of beauty is equivalent to Leder et al.'s (2004) aesthetic emotion, rather than continuously updating affective states. Results reported here indicate that continuous affective evaluations are processed in the rPFC. These affective states lead to the experience of aesthetic emotions and activation in the OFC, an area that has been related to the experience of beauty (Zeki, 1999b; Zeki, 1999). Investigating the relationship between OFC and rPFC can therefore provide important insights into aesthetic evaluations and the experience of beauty.

9.8 Conclusion

This thesis investigated the role of the rPFC during the processing of cognitive and emotional components of static visual art. The findings indicated that the rPFC is particularly sensitive to continuously updating affective states which are mediated by the individual's understanding of the artwork and the *self*/*other* focus of the observed level of emotional processing. These results show that a person's prior experience with art needs to be taken into consideration if the process of how an aesthetic judgement is formed is to be understood fully. It has been shown that frameworks of the aesthetic experience, as proposed by Leder et al. (2004), can be successfully applied as a framework to understand the aesthetic experience. It has also been demonstrated that emotional processing plays an important part during the appreciation of art in art naïve participants.

10. Bibliography

Allen, J., Harmon-Jones, E., & Cavender, J. (2001). Manipulation of frontal EEG asymmetry through biofeedback alters self-reported emotional responses and facial EMG. *Psychophysiology*.

Amting, J. (2010). Multiple Mechanisms of Consciousness: The Neural Correlates of Emotional Awareness. *The Journal of Neuroscience*, *30*(30), 10039–10047. doi:10.1523/JNEUROSCI.6434-09.2010

Andrews-Hanna, J. R., Reidler, J. S., Sepulcre, J., Poulin, R., & Buckner, R. L. (2010). Functional-anatomic fractionation of the brain's default network. *Neuron*, *65*(4), 550–62. doi:10.1016/j.neuron.2010.02.005

Araujo, H. F., Kaplan, J., & Damasio, A. (2013). Cortical Midline Structures and Autobiographical-Self Processes: An Activation-Likelihood Estimation Meta-Analysis. *Frontiers in Human Neuroscience*, *7*(September), 548. doi:10.3389/fnhum.2013.00548

Augustin, M. D., Defranceschi, B., Fuchs, H. K., Carbon, C.-C., & Hutzler, F. (2011). The neural time course of art perception: An ERP study on the processing of style versus content in art. *Neuropsychologia*, 1–11. doi:10.1016/j.neuropsychologia.2011.03.038

Ayaz, H. (2010). *Functional Near Infrared Spectropscopy based Brain Computer Interface*. Drexel University Philadelphia, PA.

Ayaz, H., Izzetoglu, M., Shewokis, P. A., & Onaral, B. (2010). Sliding-window motion artifact rejection for Functional Near-Infrared Spectroscopy. *Conference Proceedings : ... Annual International Conference of the IEEE Engineering in Medicine and Biology Society. IEEE Engineering in Medicine and Biology Society. Conference*, *2010*, 6567–70. doi:10.1109/IEMBS.2010.5627113

Ayaz, H., Shewokis, P. A., Bunce, S., Izzetoglu, K., Willems, B., & Onaral, B. (2012). Optical brain monitoring for operator training and mental workload assessment. *NeuroImage*, *59*(1), 36–47. doi:10.1016/j.neuroimage.2011.06.023

Ayaz, H., Shewokis, P. A., Curtin, A., Izzetoglu, M., Izzetoglu, K., & Onaral, B. (2011). Using MazeSuite and functional near infrared spectroscopy to study learning in spatial navigation. *Journal of Visualized Experiments : JoVE*, (56). doi:10.3791/3443

Banks, S. J., Eddy, K. T., Angstadt, M., Nathan, P. J., & Phan, K. L. (2007). Amygdala-frontal connectivity during emotion regulation. *Social Cognitive and Affective Neuroscience*, *2*(4), 303–12. doi:10.1093/scan/nsm029

Batt, R., Palmiero, M., Nakatani, C., & van Leeuwen, C. (2010). Style and spectral power: Processing of abstract and representational art in artists and non-artists. *Perception*, *39*(12), 1659–1671. doi:10.1068/p6747

Belke, B., Leder, H., Strobach, T., & Carbon, C. C. (2010). Cognitive fluency: High-level processing dynamics in art appreciation. *Psychology of Aesthetics, Creativity, and the Arts*, *4*(4), 214–222. doi:10.1037/a0019648

Benoit, R. G., Gilbert, S. J., Volle, E., & Burgess, P. W. (2010). When I think about me and simulate you: medial rostral prefrontal cortex and self-referential processes. *NeuroImage*, *50*(3), 1340–9. doi:10.1016/j.neuroimage.2009.12.091

Benoit, R., Gilbert, S., Frith, C., & Burgess, P. (2012). Rostral Prefrontal Cortex and the Focus of Attention in Prospective Memory. *Cerebral Cortex*, *22*(August), 1876–1886. doi:10.1093/cercor/bhr264

Berlyne, D. E. (1960). *Conflict, Arousal, and Curiosity*. London: McGraw-Hill Book Company.

Berridge, K. C., & Kringelbach, M. L. (2008). Affective neuroscience of pleasure: reward in humans and animals. *Psychopharmacology*, *199*(3), 457–80. doi:10.1007/s00213-008-1099-6

Bhattacharya, J., & Petsche, H. (2002). Shadows of artistry: cortical synchrony during perception and imagery of visual art. *Brain Research. Cognitive Brain Research*, *13*(2), 179–86.

Blakemore, S. J., & Decety, J. (2001). From the perception of action to the understanding of intention. *Nature Reviews Neuroscience*, *2*, 561 – 567.

Bludau, S., Eickhoff, S. B., Mohlberg, H., Caspers, S., Laird, a R., Fox, P. T., … Amunts, K. (2014). Cytoarchitecture, probability maps and functions of the human frontal pole. *NeuroImage*, *93 Pt 2*, 260–75. doi:10.1016/j.neuroimage.2013.05.052

Boas, D. A., Elwell, C. E., Ferrari, M., & Taga, G. (2014). Twenty years of functional near-infrared spectroscopy: introduction for the special issue. *NeuroImage*, *85 Pt 1*, 1–5. doi:10.1016/j.neuroimage.2013.11.033

Boxtel, A. Van. (2010). Facial EMG as a Tool for Inferring Affective States. *Proceedings of Measuring Behaviour*, *Eindhoven,*(August), 104–108.

Brown, S., Gao, X., Tisdelle, L., Eickhoff, S. B., & Liotti, M. (2011). Naturalizing aesthetics: brain areas for aesthetic appraisal across sensory modalities. *NeuroImage*, *58*(1), 250–8. doi:10.1016/j.neuroimage.2011.06.012

Buckner, R. L., Andrews-Hanna, J. R., & Schacter, D. L. (2008). The brain’s default network: anatomy, function, and relevance to disease. *Annals of the New York Academy of Sciences*, *1124*, 1–38. doi:10.1196/annals.1440.011

Bullot, N. J., & Reber, R. (2013). The artful mind meets art history: toward a psycho-historical framework for the science of art appreciation. *The Behavioral and Brain Sciences*, *36*(2), 123–37. doi:10.1017/S0140525X12000489

Burgess, P. W., Dumontheil, I., & Gilbert, S. J. (2005). The gateway hypothesis of rostral prefrontal cortex (area 10) function. *Measuring the Mind: Speed, Control, and Age*, *11*(7), 290–8. doi:10.1016/j.tics.2007.05.004

Burgess, P. W., Quayle, A., & Frith, C. D. (2001). Brain regions involved in prospective memory as determined by positron emission tomography. *Neuropsychologia*, *39*, 545 – 555.

Burgess, P. W., Scott, S. K., & Frith, C. D. (2003). The role of the rostral frontal cortex (area 10) in prospective memory: a lateral versus medial dissociation. *Neuropsychologia*, *41*(8), 906–918. doi:10.1016/S0028-3932(02)00327-5

Cabeza, R., & St Jacques, P. (2007). Functional neuroimaging of autobiographical memory. *Trends in Cognitive Sciences*, *11*(5), 219–27. doi:10.1016/j.tics.2007.02.005

Campbell-Sillls, L., Simmons, A. N., Lovero, K. L., Rochlin, A. A., Paulus, M. P., & Stein, M. B. (2011). NeuroImage Functioning of neural systems supporting emotion regulation in anxiety-prone individuals. *NeuroImage*, *54*(1), 689–696. doi:10.1016/j.neuroimage.2010.07.041

Carruthers, P., & Smith, P. K. (1996). *Theories of theories of mind*. Cambridge: Cambridge University Press.

Causse, M., Péran, P., Dehais, F., Caravasso, C. F., Zeffiro, T., Sabatini, U., & Pastor, J. (2013). Affective decision making under uncertainty during a plausible aviation task: an fMRI study. *NeuroImage*, *71*, 19–29. doi:10.1016/j.neuroimage.2012.12.060

Cela-Conde, C. J., Agnati, L., Huston, J. P., Mora, F., & Nadal, M. (2011). The neural foundations of aesthetic appreciation. *Progress in Neurobiology*, *94*(1), 39–48. doi:10.1016/j.pneurobio.2011.03.003

Cela-Conde, C. J., Marty, G., Maestú, F., Ortiz, T., Munar, E., Fernández, A., … Quesney, F. (2004). Activation of the prefrontal cortex in the human visual aesthetic perception. *Proceedings of the National Academy of Sciences of the United States of America*, *101*(16), 6321–5. doi:10.1073/pnas.0401427101

Chance, B., Zhuang, Z., UnAh, C., Alter, C., & Lipton, L. (1993). Cognition-activated low-frequency modulation of light absorption in human brain. *Proceedings of the National Academy of Sciences of the United States of America*, *90*(8), 3770–4.

Chatterjee, A. (2004). Prospects for a Cognitive Neuroscience of Visual Aesthetics. *Bulletin of Psychology and the Arts*, *4*(2), 55 – 60.

Chatterjee, A. (2006). The neuropsychology of visual art: conferring capacity. *International Review of Neurobiology*, *74*(06), 39–49. doi:10.1016/S0074-7742(06)74003-X

Christie, I. (2004). Autonomic specificity of discrete emotion and dimensions of affective space: a multivariate approach. *International Journal of Psychophysiology*, *51*(2), 143–153. doi:10.1016/j.ijpsycho.2003.08.002

Christoff, K., & Gabrieli, J. (2000). The frontopolar cortex and human cognition: Evidence for a rostrocaudal hierarchical organization within the human prefrontal cortex. *Psychobiology*, *28*(2), 168–186.

Christoff, K., Keramatian, K., Gordon, A. M., Smith, R., & Mädler, B. (2009). Prefrontal organization of cognitive control according to levels of abstraction. *Brain Research*, *1286*, 94–105. doi:10.1016/j.brainres.2009.05.096

Coan, J. A., & Allen, J. J. B. (2004). Frontal EEG asymmetry as a moderator and mediator of emotion. *Biological Psychology*, *67*(1-2), 7–49. doi:10.1016/j.biopsycho.2004.03.002

Craig, a D. B. (2005). Forebrain emotional asymmetry: a neuroanatomical basis? *Trends in Cognitive Sciences*, *9*(12), 566–71. doi:10.1016/j.tics.2005.10.005

Cupchik, G. C., Vartanian, O., Crawley, A., & Mikulis, D. J. (2009). Viewing artworks: contributions of cognitive control and perceptual facilitation to aesthetic experience. *Brain and Cognition*, *70*(1), 84–91. doi:10.1016/j.bandc.2009.01.003

Damasio, A. (1999). *The feeling of what happens: Body and emotion int he making of consciouness*. New York: Harvest Books.

Damasio, A., Everitt, B. J., & Bishop, D. (1996). The somatic marker hypothesis and the possible functions of the prefrontal cortex. *Philosophical Transactions: Biological Science*, *351*(1346), 1413–1420.

Davidson, R. J. (2004). What does the prefrontal cortex “do” in affect: perspectives on frontal EEG asymmetry research. *Biological Psychology*, *67*(1-2), 219–33. doi:10.1016/j.biopsycho.2004.03.008

De Smedt, J., & de Cruz, H. (2011). A Cognitive Approach to the Earliest Art. *The Journal of Aesthetics and Art …*, *64*(4), 379 – 389.

De Smedt, J., & de Cruz, H. (2012). Human Artistic Behaviour: Adaptation, Byproduct, or Cultural Group Selection? In K. S. Plaisance & T. A. C. Reydon (Eds.), *Philosophy of Behavioral Biology* (Vol. 282, pp. 167 – 187). Dordrecht: Springer Netherlands. doi:10.1007/978-94-007-1951-4

Delgado, M. R., Nearing, K. I., Ledoux, J. E., & Phelps, E. A. (2008). Neural circuitry underlying the regulation of conditioned fear and its relation to extinction. *Neuron*, *59*(5), 829–38. doi:10.1016/j.neuron.2008.06.029

Denkova, E., Dolcos, S., & Dolcos, F. (2013). The Effect of Retrieval Focus and Emotional Valence on the Medial Temporal Lobe Activity during Autobiographical Recollection. *Frontiers in Behavioral Neuroscience*, *7*(August), 109. doi:10.3389/fnbeh.2013.00109

Denny, B. T., Kober, H., Wager, T. D., & Ochsner, K. N. (2012). A Meta-analysis of Functional Neuroimaging Studies of Self- and Other Judgments Reveals a Spatial Gradient for Mentalizing in Medial Prefrontal Cortex. *Journal of Cognitive Neuroscience*, *24*(8), 1742–1752.

Di Dio, C., Canessa, N., Cappa, S. F., & Rizzolatti, G. (2011). Specificity of esthetic experience for artworks: an FMRI study. *Frontiers in Human Neuroscience*, *5*(November), 139. doi:10.3389/fnhum.2011.00139

Di Dio, C., & Gallese, V. (2009). Neuroaesthetics: a review. *Current Opinion in Neurobiology*, *19*(6), 682–7. doi:10.1016/j.conb.2009.09.001

Di Dio, C., Macaluso, E., & Rizzolatti, G. (2007). The golden beauty: brain response to classical and renaissance sculptures. *PloS One*, *2*(11), e1201. doi:10.1371/journal.pone.0001201

Dolcos, F., LaBar, K. S., & Cabeza, R. (2004). Dissociable effects of arousal and valence on prefrontal activity indexing emotional evaluation and subsequent memory: an event-related fMRI study. *NeuroImage*, *23*(1), 64–74. doi:10.1016/j.neuroimage.2004.05.015

Dunbar, R. I. M. (2012). The social brain meets neuroimaging. *Trends in Cognitive Sciences*, *16*(2), 101–2. doi:10.1016/j.tics.2011.11.013

Duncan, A., Meek, J. H., Clemence, M., Elwell, C. E., Tyszczuk, L., Cope, M., & Delpy, D. T. (1995). Optical pathlegth measurements on adult head, calf and forearm and the head fo the newborn infant using phase resolved optical spectroscopy. *Physics in Medicine and Biology*, *40*(2), 295 – 304.

Duncan, J., & Owen, a M. (2000). Common regions of the human frontal lobe recruited by diverse cognitive demands. *Trends in Neurosciences*, *23*(10), 475–83.

Elwell, C. E., & Cooper, C. E. (2011). Making light work: illuminating the future of biomedical optics. *Philosophical Transactions. Series A, Mathematical, Physical, and Engineering Sciences*, *369*(1955), 4358–79. doi:10.1098/rsta.2011.0302

Ernst, L. H., Weidner, A., Ehlis, A., & Fallgatter, A. J. (2012). Controlled attention allocation mediates the relation between goal-oriented pursuit and approach – avoidance reactions to negative stimuli. *Biological Psychology*, *91*(2), 312–320. doi:10.1016/j.biopsycho.2012.08.004

Ertl, M., Hildebrandt, M., Ourina, K., Leicht, G., & Mulert, C. (2013). Emotion regulation by cognitive reappraisal - the role of frontal theta oscillations. *NeuroImage*, *81*, 412–21. doi:10.1016/j.neuroimage.2013.05.044

Etkin, A., Egner, T., & Kalisch, R. (2011). Emotional processing in anterior cingulate and medial prefrontal cortex. *Trends in Cognitive Sciences*, *15*(2), 85–93. doi:10.1016/j.tics.2010.11.004

Euston, D. R., Gruber, A. J., & Mcnaughton, B. L. (2012). Review The Role of Medial Prefrontal Cortex in Memory and Decision Making. *Neuron Review*, *76*(6), 1057–1070. doi:10.1016/j.neuron.2012.12.002

Fairhall, S. L., & Ishai, A. (2008). Neural correlates of object indeterminacy in art compositions. *Consciousness and Cognition*, *17*(3), 923–32. doi:10.1016/j.concog.2007.07.005

Faw, B. (2003). Pre-frontal executive committee for perception, working memory, attention, long-term memory, motor control, and thinking: A tutorial review. *Consciousness and Cognition*, *12*(1), 83–139. doi:10.1016/S1053-8100(02)00030-2

Fechner, G. T. (1876). *Vorschule der Aesthetik*. Leipzig: Breitkopf & Haertel.

Ferrari, M., & Quaresima, V. (2012). A brief review on the history of human functional near-infrared spectroscopy (fNIRS) development and fields of application. *NeuroImage*, *63*(2), 921–35. doi:10.1016/j.neuroimage.2012.03.049

Fridlund, A., & Cacioppo, J. (1986). Guidelines for human electromyographic research. *Psychophysiology*, *23*(5), 567 – 589.

Fuster, J. (2008). *The Prefrontal Cortex* (4th ed.). London: Elsevier.

Gervain, J., Mehler, J., Werker, J. F., Nelson, C. A., Csibra, G., Lloyd-Fox, S., … Aslin, R. N. (2011). Near-infrared spectroscopy: a report from the McDonnell infant methodology consortium. *Developmental Cognitive Neuroscience*, *1*(1), 22–46. doi:10.1016/j.dcn.2010.07.004

Giannini, A. M., Tizzani, E., Baralla, F., & Gurrieri, G. (2013). What I like is How I Am: Impact of Alexithymia on Aesthetic Preference. *Creativity Research Journal*, *25*(3), 312–316. doi:10.1080/10400419.2013.813796

Gilbert, S. J., Frith, C. D., & Burgess, P. W. (2005). Involvement of rostral prefrontal cortex in selection between stimulus-oriented and stimulus-independent thought. *The European Journal of Neuroscience*, *21*(5), 1423–31. doi:10.1111/j.1460-9568.2005.03981.x

Gilbert, S. J., Gonen-Yaacovi, G., Benoit, R. G., Volle, E., & Burgess, P. W. (2010). Distinct functional connectivity associated with lateral versus medial rostral prefrontal cortex: a meta-analysis. *NeuroImage*, *53*(4), 1359–67. doi:10.1016/j.neuroimage.2010.07.032

Glotzbach, E., Muehlberger, A., Gschwendtner, K., Fallgatter, A. J., Pauli, P., & Herrmann, M. J. (2010). Prefrontal Brain Activation During Emotional Processing: A Functional Near Infrared Spectroscopy Study (fNIRS). *The Open Neuroimaging Journal*, *5*, 33–39.

Goldin, P. R., McRae, K., Ramel, W., & Gross, J. J. (2008). The neural bases of emotion regulation: reappraisal and suppression of negative emotion. *Biological Psychiatry*, *63*(6), 577–86. doi:10.1016/j.biopsych.2007.05.031

Gray, J., Braver, T., & Raichle, M. (2002). Integration of emotion and cognition in the lateral prefrontal cortex. *Proceedings of the National Academy of Sciences*, *99*(6), 4115 – 4120.

Gusnard, D. A., & Raichle, M. E. (2001). Searching for a baseline: functional imaging and the resting human brain. *Nature Reviews Neuroscience*, *2*, 685 – 694.

Gyurak, A., Gross, J., & Etkin, A. (2011). Explicit and Implicit Emotion Regulation: A Dual-Process Framework. *Cognition and Emotion*, *25*(3), 400–412. doi:10.1080/02699931.2010.544160.Explicit

Hagtvedt, H., Hagtvedt, R., & Patrick, V. M. (2008). The perception and evaluation of visual art. *Empirical Studies of the Arts*, *26*, 107 – 218.

Harmon-Jones, E., Lueck, L., Fearn, M., & Harmon-Jones, C. (2006). The effect of personal relevance and approach-related action expectation on relative left frontal cortical activity. *Psychological Science*, *17*(5), 434–40. doi:10.1111/j.1467-9280.2006.01724.x

Harmon-Jones, E., & Sigelman, J. (2003). Anger, coping, and frontal cortical activity: The effect of coping potential on anger-induced left frontal activity. *Cognition and Emotion*, *17*(1), 1–24. doi:10.1080/02699930143000635

Henseler, I., Krüger, S., Dechent, P., & Gruber, O. (2011). A gateway system in rostral PFC? Evidence from biasing attention to perceptual information and internal representations. *NeuroImage*, *56*(3), 1666–76. doi:10.1016/j.neuroimage.2011.02.056

Herrmann, M., Ehlis, A., & Fallgatter, A. (2003). Prefrontal activation through task requirements of emotional induction measured with NIRS. *Biological Psychology*, *64*, 255–263. doi:10.1016/S0301-0511(03)00095-4

Höfel, L., & Jacobsen, T. (2007). Electrophysiological indices of processing aesthetics: Spontaneous or intentional processes? *International Journal of Psychophysiology : Official Journal of the International Organization of Psychophysiology*, *65*(1), 20–31. doi:10.1016/j.ijpsycho.2007.02.007

Holland, A. C., & Kensinger, E. A. (2013). The neural correlates of cognitive reappraisal during emotional autobiographical memory recall. *Journal of Cognitive Neuroscience*, *25*(1), 87–108. doi:10.1162/jocn_a_00289

Holroyd, C. B., & Yeung, N. (2012). Motivation of extended behaviors by anterior cingulate cortex. *Trends in Cognitive Sciences*, *16*(2), 122–8. doi:10.1016/j.tics.2011.12.008

Hoshi, Y. (2005). Functional near-infrared spectroscopy: potential and limitations in neuroimaging studies. *International Review of Neurobiology*, *66*(05), 237–66. doi:10.1016/S0074-7742(05)66008-4

Hoshi, Y., Huang, J., Kohri, S., Iguchi, Y., Naya, M., Okamoto, T., & Ono, S. (2011). Recognition of human emotions from cerebral blood flow changes in the frontal region: a study with event-related near-infrared spectroscopy. *Journal of Neuroimaging : Official Journal of the American Society of Neuroimaging*, *21*(2), e94–101. doi:10.1111/j.1552-6569.2009.00454.x

Irani, F., Platek, S. M., Bunce, S., Ruocco, A. C., & Chute, D. (2007). Functional near infrared spectroscopy (fNIRS): an emerging neuroimaging technology with important applications for the study of brain disorders. *The Clinical Neuropsychologist*, *21*(1), 9–37. doi:10.1080/13854040600910018

Ishai, A., Fairhall, S., & Pepperell, R. (2007). Perception, memory and aesthetics of indeterminate art. *Brain Research Bulletin*, *73*, 319–324. doi:10.1016/j.brainresbull.2007.04.009

Ishizu, T., & Zeki, S. (2011). Toward a brain-based theory of beauty. *PLoS One*, *6*(7). doi:10.1371/journal.pone.0021852

Ishizu, T., & Zeki, S. (2013). The brain's specialized systems for aesthetic and perceptual judgment. *The European Journal of Neuroscience*, *37*(9), 1413–20. doi:10.1111/ejn.12135

Ito, T. A., Cacioppo, J. T., & Lang, P. J. (1998). Eliciting affect using the International Affective Picture System: Trajectories through evaluative space. *Personality and Social Psychology Bulletin*, *24*(8), 855–879.

Izzetoglu, K., Bunce, S., Onaral, B., Pourrezaei, K., & Chance, B. (2004). Functional Optical Brain Imaging Using Near-Infrared During Cognitive Tasks. *International Journal of Human-Computer Interaction*, *17*(2), 211 – 227.

Izzetoglu, M., Bunce, S. C., Izzetoglu, K., Onaral, B., & Pourrezaei, K. (2007). Functional brain imaging using near-infrared technology. *IEEE Engineering in Medicine and Biology Magazine : The Quarterly Magazine of the Engineering in Medicine & Biology Society*, *26*(4), 38–46.

Jacobsen, T. (2006). Bridging the Arts and Sciences: A Framework for the Psychology of Aesthetics. *LEONARDO*, *39*(2), 155 – 162.

Jacobsen, T., Schubotz, R. I., Hofel, L., Höfel, L., & Cramon, D. Y. V. (2006). Brain correlates of aesthetic judgment of beauty. *NeuroImage*, *29*(1), 276–85. doi:10.1016/j.neuroimage.2005.07.010

Jollant, F., Lawrence, N. S., Olie, E., O'Daly, O., Malafosse, A., Courtet, P., & Phillips, M. L. (2010). Decreased activation of lateral orbitofrontal cortex during risky choices under uncertainty is associated with disadvantageous decision-making and suicidal behavior. *NeuroImage*, *51*(3), 1275–81. doi:10.1016/j.neuroimage.2010.03.027

Kalisch, R., Wiech, K., Herrmann, K., & Dolan, R. J. (2006). Neural correlates of self-distraction from anxiety and a process model of cognitive emotion regulation. *Journal of Cognitive Neuroscience*, *18*(8), 1266–76. doi:10.1162/jocn.2006.18.8.1266

Kawabata, H., & Zeki, S. (2004). Neural correlates of beauty. *Journal of Neurophysiology*, *91*(4), 1699–705. doi:10.1152/jn.00696.2003

Kim, M. J., Gee, D. G., Loucks, R. a, Davis, F. C., & Whalen, P. J. (2011). Anxiety dissociates dorsal and ventral medial prefrontal cortex functional connectivity with the amygdala at rest. *Cerebral Cortex (New York, N.Y. : 1991)*, *21*(7), 1667–73. doi:10.1093/cercor/bhq237

Kirk, U. (2008). The neural basis of object-context relationships on aesthetic judgment. *PloS One*, *3*(11), e3754. doi:10.1371/journal.pone.0003754

Kirk, U., Skov, M., Christensen, M. M. S., & Nygaard, N. (2009). Brain correlates of aesthetic expertise: a parametric fMRI study. *Brain and Cognition*, *69*(2), 306–15. doi:10.1016/j.bandc.2008.08.004

Klumpers, F. (2012). Fear not–neurobiological mechanisms oF Fear and anxiety.

Kompus, K., Hugdahl, K., Ohman, A., Marklund, P., & Nyberg, L. (2009). Distinct control networks for cognition and emotion in the prefrontal cortex. *Neuroscience Letters*, *467*(2), 76–80. doi:10.1016/j.neulet.2009.10.005

Krienen, F. M., Tu, P.-C., & Buckner, R. L. (2010). Clan mentality: evidence that the medial prefrontal cortex responds to close others. *The Journal of Neuroscience : The Official Journal of the Society for Neuroscience*, *30*(41), 13906–15. doi:10.1523/JNEUROSCI.2180-10.2010

Kuchinke, L., Trapp, S., Jacobs, A. M., & Leder, H. (2009). Pupillary Responses in Art Appreciation : Effects of Aesthetic Emotions. *Psychology of Aesthetics, Creativity, and the Arts*, *3*(3), 156–163. doi:10.1037/a0014464

Lacey, S., Hagtvedt, H., Patrick, V. M., Anderson, A., Stilla, R., Deshpande, G., … Sathian, K. (2011). Art for reward's sake: visual art recruits the ventral striatum. *NeuroImage*, *55*(1), 420–33. doi:10.1016/j.neuroimage.2010.11.027

Lang, P. J., Greenwald, M. K., Bradley, M. M., & Hamm, a O. (1993). Looking at pictures: affective, facial, visceral, and behavioral reactions. *Psychophysiology*, *30*(3), 261–73.

Larsen, J. T., Norris, C. J., & Cacioppo, J. T. (2003). Effects of positive and negative affect on electromyographic activity over zygomaticus major and corrugator supercilii. *Psychophysiology*, *40*(5), 776–85.

Leder, H. (2013). Next steps in neuroaesthetics: Which processes and processing stages to study? *Psychology of Aesthetics, Creativity, and the Arts*, *7*(1), 27–37. doi:10.1037/a0031585

Leder, H., Belke, B., Oeberst, A., & Augustin, D. (2004). A model of aesthetic appreciation and aesthetic judgments. *British Journal of Psychology (London, England : 1953)*, *95*(Pt 4), 489–508. doi:10.1348/0007126042369811

Lee, K. H., & Siegle, G. J. (2012). Common and distinct brain networks underlying explicit emotional evaluation: a meta-analytic study. *Social Cognitive and Affective Neuroscience*, *7*(5), 521–34. doi:10.1093/scan/nsp001

Leff, D. R., Orihuela-Espina, F., Elwell, C. E., Athanasiou, T., Delpy, D. T., Darzi, A. W., & Yang, G.-Z. (2011). Assessment of the cerebral cortex during motor task behaviours in adults: a systematic review of functional near infrared spectroscopy (fNIRS) studies. *NeuroImage*, *54*(4), 2922–36. doi:10.1016/j.neuroimage.2010.10.058

Leon-Carrion, J., Damas, J., Izzetoglu, K., Pourrezai, K., Martín-Rodríguez, J. F., Barroso y Martin, J. M., & Dominguez-Morales, M. R. (2006). Differential time course and intensity of PFC activation for men and women in response to emotional stimuli: a functional near-infrared spectroscopy (fNIRS) study. *Neuroscience Letters*, *403*(1-2), 90–5. doi:10.1016/j.neulet.2006.04.050

Leon-Carrion, J., Izzetoglu, M., Izzetoglu, K., & Martin-Rodrigues, M. R. (2010). Efficient learning produces spontaneous neural repetition supression in prefrontal cortex. *Behavioural Brain Research*, *208*(2), 502 – 508.

León-Carrión, J., & León-Domínguez, U. (2012). Functional Near-Infrared Spectroscopy (fNIRS): Principles and Neuroscientific Applications. *Intechopen.com*.

León-Carrión, J., Martín-Rodríguez, J. F., Damas-López, J., Pourrezai, K., Izzetoglu, K., Barroso y Martin, J. M., & Domínguez-Morales, M. R. (2007). A lasting post-stimulus activation on dorsolateral prefrontal cortex is produced when processing valence and arousal in visual affective stimuli. *Neuroscience Letters*, *422*(3), 147–52. doi:10.1016/j.neulet.2007.04.087

Leopold, A., Krueger, F., dal Monte, O., Pardini, M., Pulaski, S. J., Solomon, J., & Grafman, J. (2012). Damage to the left ventromedial prefrontal cortex impacts affective theory of mind. *Social Cognitive and Affective Neuroscience*, *7*(8), 871–80. doi:10.1093/scan/nsr071

Levine, B., Freedman, M., Dawson, D., Black, D., & Studd, D. T. (1999). Ventral frontal contribution to self-regulation: Convergence of episodic memory and inhibition. *Neurocase*, *5*, 263 – 275.

Lewis, P. A., Rezaie, R., Brown, R., Roberts, N., & Dunbar, R. I. M. (2011). Ventromedial prefrontal volume predicts understanding of others and social network size. *NeuroImage*, *57*(4), 1624–9. doi:10.1016/j.neuroimage.2011.05.030

Lindquist, K. A., & Barrett, L. F. (2012). A functional architecture of the human brain: emerging insights from the science of emotion. *Trends in Cognitive Sciences*, *16*(11), 533–40. doi:10.1016/j.tics.2012.09.005

Lloyd-Fox, S., Blasi, a, & Elwell, C. E. (2010). Illuminating the developing brain: the past, present and future of functional near infrared spectroscopy. *Neuroscience and Biobehavioral Reviews*, *34*(3), 269–84. doi:10.1016/j.neubiorev.2009.07.008

Mackert, B.-M., Leistner, S., Sander, T., Liebert, A., Wabnitz, H., Burghoff, M., … Curio, G. (2008). Dynamics of cortical neurovascular coupling analyzed by simultaneous DC-magnetoencephalography and time-resolved near-infrared spectroscopy. *NeuroImage*, *39*(3), 979–86. doi:10.1016/j.neuroimage.2007.09.037

Mahy, C. E. V, Moses, L. J., & Pfeifer, J. H. (2014). How and where: Theory-of-mind in the brain. *Developmental Cognitive Neuroscience*, *9C*, 68–81. doi:10.1016/j.dcn.2014.01.002

Maier, M., & di Pellegrino, G. (2012). Impaired Conflict Adaptation in an Emotional Task Context following Rostral Anterior Cingulate Cortex Lesions in Humans. *Journal of Cognitive Neuroscience. Oct2012*, *24*(10), 2070–2079. 10p. 2 Color Photographs.

Maier, S., Szalkowski, A., Kamphausen, S., Perlov, E., Feige, B., Blechert, J., … Tüscher, O. (2012). Clarifying the role of the rostral dmPFC/dACC in fear/anxiety: learning, appraisal or expression? *PloS One*, *7*(11), e50120. doi:10.1371/journal.pone.0050120

Mak, A. K. Y., Hu, Z.-G., Zhang, J. X., Xiao, Z.-W., & Lee, T. M. C. (2009). Neural correlates of regulation of positive and negative emotions: an fmri study. *Neuroscience Letters*, *457*(2), 101–6. doi:10.1016/j.neulet.2009.03.094

Mars, R. B., Neubert, F.-X., Noonan, M. P., Sallet, J., Toni, I., & Rushworth, M. F. S. (2012). On the relationship between the “default mode network” and the “social brain”. *Frontiers in Human Neuroscience*, *6*(June), 189. doi:10.3389/fnhum.2012.00189

Mastandrea, S., Bartoli, G., & Carrus, G. (2011). The automatic aesthetic evaluation of different art and architectural styles. *Psychology of Aesthetics, Creativity, and the Arts*, *5*(2), 126–134. doi:10.1037/a0021126

Mccaig, R. G., Dixon, M., Keramatian, K., Liu, I., & Christoff, K. (2011). Improved modulation of rostrolateral prefrontal cortex using real-time fMRI training and meta-cognitive awareness. *NeuroImage*, *55*(3), 1298–1305. doi:10.1016/j.neuroimage.2010.12.016

McDaniel, M. A., LaMontagne, P., Beck, S. M., Scullin, M. K., & Braver, T. S. (2013). Dissociable Neural Routes to Successful Prospective Memory. (J. Duncan, L. Phillips, & P. McLeod, Eds.)*Psychological Science*, (August), 1 – 10. doi:10.1177/0956797613481233

McNaughton, N., & Corr, P. J. (2004). A two-dimensional neuropsychology of defense: fear/anxiety and defensive distance. *Neuroscience and Biobehavioral Reviews*, *28*(3), 285–305. doi:10.1016/j.neubiorev.2004.03.005

McRae, K., Hughes, B., Chopra, S., Gabrieli, J. D. E., Gross, J. J., & Ochsner, K. N. (2010). The neural bases of distraction and reappraisal. *Journal of Cognitive Neuroscience*, *22*(2), 248–62. doi:10.1162/jocn.2009.21243

McRae, K., Ochsner, K. N., & Gross, J. J. (2011). The Reason in Passion: A Social Cognitive Neuroscience Approach to Emotion Regulation. In K. D. Vohs & R. F. Baumeister (Eds.), *Handbook of Self-Regulation: Research, Theory, and Applications* (2nd ed., pp. 186 – 203). London: The Guildford Press.

Mitchell, D. G. V. (2011). The nexus between decision making and emotion regulation: a review of convergent neurocognitive substrates. *Behavioural Brain Research*, *217*(1), 215–31. doi:10.1016/j.bbr.2010.10.030

Molnar-Szakacs, I., & Uddin, L. Q. (2013). Self-Processing and the Default Mode Network: Interactions with the Mirror Neuron System. *Frontiers in Human Neuroscience*, *7*(September), 571. doi:10.3389/fnhum.2013.00571

Moran, J. M., Kelley, W. M., & Heatherton, T. F. (2013). What Can the Organization of the Brain's Default Mode Network Tell us About Self-Knowledge? *Frontiers in Human Neuroscience*, *7*(July), 391. doi:10.3389/fnhum.2013.00391

Munar, E., Nadal, M., Castellanos, N. P., Flexas, A., Maestú, F., Mirasso, C., & Cela-Conde, C. J. (2011). Aesthetic appreciation: event-related field and time-frequency analyses. *Frontiers in Human Neuroscience*, *5*(January), 185. doi:10.3389/fnhum.2011.00185

Nadal, M., & Pearce, M. T. (2011). Brain and Cognition The Copenhagen Neuroaesthetics conference : Prospects and pitfalls for an emerging field. *Brain and Cognition*, *76*(1), 172–183. doi:10.1016/j.bandc.2011.01.009

Nee, D. E., Brown, J. W., Askren, M. K., Berman, M. G., Demiralp, E., Krawitz, A., & Jonides, J. (2013). A meta-analysis of executive components of working memory. *Cerebral Cortex*, *23*(2), 264–82. doi:10.1093/cercor/bhs007

Norris, C. J., Gollan, J., Berntson, G. G., & Cacioppo, J. T. (2010). The current status of research on the structure of evaluative space. *Biological Psychology*, *84*(3), 42–56. doi:10.1016/j.biopsycho.2010.03.011

Ochsner, K. N., & Gross, J. J. (2004). Thinking Makes It So: A Social Cognitive Neuroscience Approach to Emotion Regulation. In K. D. Vohs & R. F. Baumeiseter (Eds.), *Handbook of Self-Regulation: Research, Theory, and Applications* (1st ed., pp. 229 – 255). London: Guilford Press.

Ochsner, K. N., & Gross, J. J. (2005). The cognitive control of emotion. *Trends in Cognitive Sciences*, *9*(5), 242–9. doi:10.1016/j.tics.2005.03.010

Ochsner, K. N., Ray, R. D., Cooper, J. C., Robertson, E. R., Chopra, S., Gabrieli, J. D. E., & Gross, J. J. (2004). For better or for worse: neural systems supporting the cognitive down- and up-regulation of negative emotion. *NeuroImage*, *23*(2), 483–99. doi:10.1016/j.neuroimage.2004.06.030

Olsson, A., & Ochsner, K. N. (2008). The role of social cognition in emotion. *Trends in Cognitive Sciences*, *12*(2), 65–71. doi:10.1016/j.tics.2007.11.010

Owen, A. M., McMillan, K. M., Laird, A. R., & Bukkmore, E. (2005). N-back working memory paradigm: a meta-analysis of normative functional neuroimaging studies. *Human Brain Mapping*, *25*(1), 46 – 59.

Palmer, S. E., Schloss, K. B., & Sammartino, J. (2012). Hidden Knowledge in Aesthetic Judgements: Preferences for Color and Spatial Composition. In A. P. Shimamura & S. Palmer (Eds.), *Aesthetic Science: Connecting Monds, Brains, and Experience* (pp. 189 – 222). Oxford: Oxford University Press. Inc.

Pessoa, L., Kastner, S., & Ungerleider, L. (2002). Attentional control of the processing of neutral and emotional stimuli. *Cognitive Brain Research*, *15*, 31–45.

Phan, K., Wager, T., Taylor, S., & Liberzon, I. (2002). Functional neuroanatomy of emotion: a meta-analysis of emotion activation studies in PET and fMRI. *Neuroimage*, *348*, 331–348. doi:10.1006/nimg.2002.1087

Plichta, M. M., Herrmann, M. J., Baehne, C. G., Ehlis, A.-C., Richter, M. M., Pauli, P., & Fallgatter, A. J. (2006). Event-related functional near-infrared spectroscopy (fNIRS): are the measurements reliable? *NeuroImage*, *31*(1), 116–24. doi:10.1016/j.neuroimage.2005.12.008

Qin, P., & Northoff, G. (2011). How is our self related to midline regions and the default-mode network? *NeuroImage*, *57*(3), 1221–33. doi:10.1016/j.neuroimage.2011.05.028

Raichle, M. E., MacLeod, A. M., Snyder, A. Z., Powers, W. J., & Gusnard, D. A. (2001). A default mode of brain function. *Proceedings of the National Academy of Sciences of the United States of America*, *98*, 676 – 682.

Ramnani, N., & Owen, A. (2004). Anterior prefrontal cortex: insights into function from anatomy and neuroimaging. *Nature Reviews Neuroscience*, *5*(March), 184–194. doi:10.1038/nrn1343

Rea, M., Kullmann, S., Veit, R., Casile, A., Braun, C., Belardinelli, M. O., … Caria, A. (2011). Effects of aversive stimuli on prospective memory. An event-related fMRI study. *PloS One*, *6*(10), e26290. doi:10.1371/journal.pone.0026290

Reber, R. (2012). Processing Fluency, Aesthetic Pleasure, and Culturally Shared Taste. In A. P. Shimamura & S. E. Palmer (Eds.), *Aesthetic Science: Connecting Monds, Brains, and Experience* (pp. 223 – 249). Oxford: Oxford University Press. Inc.

Reber, R., Schwarz, N., & Winkielman, P. (2004). Processing fluency and aesthetic pleasure: is beauty in the perceiver's processing experience? *Personality and Social Psychology Review : An Official Journal of the Society for Personality and Social Psychology, Inc*, *8*(4), 364–82. doi:10.1207/s15327957pspr0804_3

Rude, S. S., Valrey, C. R., Odom, S., & Ebrahim, A. (2003). Negative cognitive biases predict subsequent depression. *Cognitive Therapy Research*, *27*, 415 – 429.

Rude, S. S., Wenzlaff, R. M., Gibbs, B., Vane, J., & Whitney, T. (2002). Negative processing bias predicte subsequent depressive symptoms. *Cognition and Emotion*, *16*(423 - 440).

Rueda, M. R., Posner, M. I., & Rothbart, K. M. (2011). Attentional Control and Self-Regulation. In K. D. Vohs & R. F. Baumeiseter (Eds.), *Handbook of Self-Regulation: Research, Theory, and Applications* (2nd ed., pp. 284 –299). London: Guilford Press.

Russell, J. A. (1980). A circumplex model fo affect. *Journal of Personality and Social Psychology*, *39*, 1161 – 1178.

Scherer, K. (2001). Appraisal considered as a process of multilevel sequential checkin. In K. R. Scherer, A. Schorr, & T. Johnstone (Eds.), *Apprasial processes in emotion: Theory, methods, research* (pp. 92 –120). New York: Oxford University Press.

Scholkmann, F., Kleiser, S., Metz, A. J., Zimmermann, R., Mata Pavia, J., Wolf, U., & Wolf, M. (2014). A review on continuous wave functional near-infrared spectroscopy and imaging instrumentation and methodology. *NeuroImage*, *85 Pt 1*, 6–27. doi:10.1016/j.neuroimage.2013.05.004

Schroeter, M. L., Kupka, T., Mildner, T., Uludağ, K., & von Cramon, D. Y. (2006). Investigating the post-stimulus undershoot of the BOLD signal--a simultaneous fMRI and fNIRS study. *NeuroImage*, *30*(2), 349–58. doi:10.1016/j.neuroimage.2005.09.048

Seitz, R. J., Franz, M., & Azari, N. P. (2009). Value judgments and self-control of action: the role of the medial frontal cortex. *Brain Research Reviews*, *60*(2), 368–78. doi:10.1016/j.brainresrev.2009.02.003

Seligman, M. E. P. (1998). *Learned optimism*. New York: Pocket Books.

Shackman, A. J., McMenamin, B. W., Maxwell, J. S., Greischar, L. L., & Davidson, R. J. (2009). Right dorsolateral prefrontal cortical activity and behavioral inhibition. *Psychological Science*, *20*(12), 1500–6. doi:10.1111/j.1467-9280.2009.02476.x

Shimamura, A. P. (2012). Toward a Science of Aesthetics: Issues and Idea. In A. P. Shimamura & S. Palmer (Eds.), *Aesthetic Science: Connecting Monds, Brains, and Experience* (pp. 3 – 32). Oxford: Oxford University Press. Inc.

Silvia, P. J. (2001). Interest and interests: The psychology of constructive capriciousness. *Review of General Psychology*, *5*(3), 270–290. doi:10.1037//1089-2680.5.3.270

Silvia, P. J. (2007). Knowledge-based assessment of expertise in the arts: Exploring aesthetic fluency. *Psychology of Aesthetics, Creativity, and the Arts*, *1*(4), 247–249. doi:10.1037/1931-3896.1.4.247

Silvia, P. J. (2008). Interest—The Curious Emotion. *Current Directions in Psychological Science*, *17*(1), 57–60. doi:10.1111/j.1467-8721.2008.00548.x

Silvia, P. J. (2010). Confusion and interest: The role of knowledge emotions in aesthetic experience. *Psychology of Aesthetics, Creativity, and the Arts*, *4*(2), 75–80. doi:10.1037/a0017081

Singer, T. (2006). The neuronal basis and ontogeny of empathy and mind reading: review of literature and implications for future research. *Neuroscience and Biobehavioral Reviews*, *30*, 855 – 863.

Sloman, A. (2004). What are emotion theories about? *Architectures for Modeling Emotions: Cross- …*.

Spreng, R. N., Mar, R. A., & Kim, A. S. N. (2009). The common neural basis of autobiographical memory, prospection, navigation, theory of mind, and the default mode: a quantitative meta-analysis. *Journal of Cognitive Neuroscience*, *21*(3), 489–510. doi:10.1162/jocn.2008.21029

Spreng, R. N., Sepulcre, J., Turner, G. R., Stevens, W. D., & Schacter, D. L. (2013). Intrinsic architecture underlying the relations among the default, dorsal attention, and frontoparietal control networks of the human brain. *Journal of Cognitive Neuroscience*, *25*(1), 74–86. doi:10.1162/jocn_a_00281

Squire, R., & Noudoost, B. (2013). Prefrontal contributions to visual selective attention. *Annual Review of …*, *36*, 451–66. doi:10.1146/annurev-neuro-062111-150439

Stern, R. M., Ray, W. J., & Quigley, K. S. (2001). *Psychophysiological Recording* (2nd ed., p. 282). Oxford: Oxford University Press.

Sutton, S. K., & Davidson, R. J. (2000). Prefrontal brain electrical asymmetry predicts the evaluation of affective stimuli. *Neuropsychologia*, *38*(13), 1723–33.

Svoboda, E., McKinnon, M. C., & Levine, B. (2006). The functional neuroanatomy of autobiographical memory: a meta-analysis. *Neuropsychologia*, *44*(12), 2189–208. doi:10.1016/j.neuropsychologia.2006.05.023

Tai, K., & Chau, T. (2009). Single-trial classification of NIRS signals during emotional induction tasks: towards a corporeal machine interface. *Journal of Neuroengineering and Rehabilitation*, *6*, 39. doi:10.1186/1743-0003-6-39

Thakral, P. P., Moo, L. R., & Slotnick, S. D. (2012). A neural mechanism for aesthetic experience. *Neuroreport*, *23*(5), 310–3. doi:10.1097/WNR.0b013e328351759f

Thayer, J. F., Ahs, F., Fredrikson, M., Sollers, J. J., & Wager, T. D. (2012). A meta-analysis of heart rate variability and neuroimaging studies: implications for heart rate variability as a marker of stress and health. *Neuroscience and Biobehavioral Reviews*, *36*(2), 747–56. doi:10.1016/j.neubiorev.2011.11.009

Tupak, S. V, Dresler, T., Guhn, A., Ehlis, A.-C., Fallgatter, A. J., Pauli, P., & Herrmann, M. J. (2014). Implicit emotion regulation in the presence of threat: neural and autonomic correlates. *NeuroImage*, *85 Pt 1*, 372–9. doi:10.1016/j.neuroimage.2013.09.066

Van Honk, J., & Schutter, D. J. L. G. (2006). From affective valence to motivational direction: the frontal asymmetry of emotion revised. *Psychological Science*, *17*(11), 963–5. doi:10.1111/j.1467-9280.2006.01813.x

Vartanian, O., & Goel, V. (2004a). Emotion pathways in the brain mediate aesthetic preference. *Bulletin of Psychology and the Arts*.

Vartanian, O., & Goel, V. (2004b). Neuroanatomical correlates of aesthetic preference for paintings. *Neuroreport*, *15*(5). doi:10.1097/01.wnr.00001

Veen, V. Van, & Carter, C. S. (2006). Conflict and Cognitive Control in the Brain. *Current Directions in Psychological Science*, *15*(5), 237–240. doi:10.1111/j.1467-8721.2006.00443.x

Vessel, E. A., Starr, G. G., & Rubin, N. (2013). Art reaches within: aesthetic experience, the self and the default mode network. *Frontiers in Neuroscience*, *7*(December), 258. doi:10.3389/fnins.2013.00258

Vessel, E., & Rubin, N. (2010). Beauty and the beholder: highly individual taste for abstract, but not real-world images. *Journal of Vision*, *10*, 1–14. doi:10.1167/10.2.18.Introduction

Vessel, E., Starr, G. G., & Rubin, N. (2012). The brain on art: intense aesthetic experience activates the default mode network. *Frontiers in Human Neuroscience*, *6*(April), 66. doi:10.3389/fnhum.2012.00066

Viviani, R., Lo, H., Sim, E., & Beschoner, P. (2010). The neural substrate of positive bias in spontaneous emotional processing. *PLoS One*, *5*(11), 1–9. doi:10.1371/journal.pone.0015454

Volle, E., Gilbert, S., Benoit, R., & Burgess, P. (2010). Specialization of the rostral prefrontal cortex for distinct analogy processes. *Cerebral Cortex*. doi:10.1093/cercor/bhq012

Vul, E., Harris, C., Winkielman, P., & Pashler, H. (2009). Puzzlingly High Correlations in fMRI Studies of Emotion, Personality, and Social Cognition. *Perspectives on Psychological Science*, *4*(3), 274–290. doi:10.1111/j.1745-6924.2009.01125.x

Whitfield-Gabrieli, S., Moran, J. M., Nieto-Castañón, A., Triantafyllou, C., Saxe, R., & Gabrieli, J. D. E. (2011). Associations and dissociations between default and self-reference networks in the human brain. *NeuroImage*, *55*(1), 225–32. doi:10.1016/j.neuroimage.2010.11.048

Wiesmann, M., & Ishai, A. (2008). Recollection- and familiarity-based decisions reflect memory strength. *Frontiers in Systems Neuroscience*, *2*(May), 1. doi:10.3389/neuro.06.001.2008

Wobst, P., Wenzel, R., Kohl, M., Obrig, H., & Villringer, a. (2001). Linear aspects of changes in deoxygenated hemoglobin concentration and cytochrome oxidase oxidation during brain activation. *NeuroImage*, *13*(3), 520–30. doi:10.1006/nimg.2000.0706

Yue, X., Vessel, E. A., & Biederman, I. (2007). The neural basis of scene preferences. *Neuroreport*, *18*(6), 525–9. doi:10.1097/WNR.0b013e328091c1f9

Zaidel, D. W., Nadal, M., Flexas, A., & Munar, E. (2013). An evolutionary approach to art and aesthetic experience. *Psychology of Aesthetics, Creativity, and the Arts*, *7*(1), 100–109. doi:10.1037/a0028797

Zeki, S. (1999a). Art and the brain. *Journal of Consciousness Studies, 6*, *6*(7), 76–96.

Zeki, S. (1999b). *Inner Vision: An Exploration of Art and the Brain*. Oxford: Oxford University Press.

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11. Appendices

11.1 Appendix 1 – Mean and Standard Deviation for all Images

Table 11.1 Mean ratings and standard deviations for the sixty images used in Study I - The Survey.

		VT		Activation		Attraction		Complexity		Comprehension		Novelty		Valence		
ID	Image Name	Mean	s.d.	Mean	s.d.	Mean	s.d.	Mean	s.d.	Mean	s.d.	Mean	s.d.	Mean	s.d.	N
1.01	afremove	11948.86	9037.51	6.08	2.24	2.25	1.64	4.58	2.09	2.47	1.68	3.51	1.98	2.41	1.55	371
1.02	armchair	9760.22	6361.24	3.19	2.03	4.66	1.92	3.60	2.37	2.77	2.12	2.60	1.69	4.52	1.69	371
1.03	artistinlove	16790.34	12059.56	5.30	2.14	4.50	1.95	6.84	1.51	5.58	2.03	5.93	2.00	4.92	1.87	371
1.04	blood	11985.67	8473.50	5.49	2.19	4.74	2.16	4.70	1.95	5.08	2.19	5.41	2.15	5.91	2.06	371

1.05	catinwindow	9761.24	7419.22	4.02	2.27	3.75	2.05	2.24	1.43	2.30	1.77	2.41	1.71	3.22	1.96	371
1.06	earthsky	9546.78	8765.68	3.48	2.20	3.02	1.82	2.21	1.58	2.07	1.71	1.97	1.58	2.85	1.70	371
1.07	feelings	12115.09	8494.16	4.95	2.38	6.48	2.01	4.66	2.05	3.55	2.17	5.57	2.22	6.85	1.87	371
1.08	girlmoon	11446.85	8695.92	4.65	2.26	3.32	1.91	3.55	1.71	2.80	1.78	3.65	1.94	3.16	1.93	371
1.09	lavoisier	12433.4	9064.71	3.85	2.23	4.68	1.80	5.35	2.11	5.41	2.31	5.04	2.29	4.53	1.43	371
1.10	lightafterstorm	10392.21	8555.60	3.29	2.05	3.96	1.85	2.61	1.67	2.16	1.63	2.07	1.52	3.81	1.70	371
1.11	magicrealism	14689.32	9474.83	5.26	2.13	3.90	1.88	5.20	1.77	4.59	2.23	5.42	2.06	4.26	1.92	371
1.12	morningwalk	10300.86	7652.09	4.14	2.12	3.82	1.97	2.90	1.63	2.80	1.85	2.76	1.75	3.39	1.96	371
1.13	pursuithappiness	17210.45	11893.53	5.42	2.23	5.74	2.21	6.18	1.82	5.31	2.24	5.98	2.08	6.24	2.04	371

1.14	realmofsense	13152.78	9013.06	5.24	2.08	5.48	2.13	5.47	1.78	4.61	2.26	5.56	2.18	6.26	1.91	371
1.15	riomaggiore	11754.42	9528.86	4.02	2.04	3.44	1.68	3.72	2.07	2.43	1.68	2.39	1.55	3.52	1.68	371
1.16	sunsetrees	10267.43	7424.70	4.63	2.14	3.35	1.80	3.57	1.84	3.05	2.01	3.32	1.87	3.61	1.80	371
1.17	swansong	13609.18	10779.26	5.12	2.15	4.56	1.77	6.28	1.60	5.91	2.09	6.03	2.13	5.05	1.83	371
1.18	timedrelease	11513.32	8880.09	4.89	2.15	4.17	1.86	6.19	1.78	5.68	2.13	5.59	2.03	4.26	1.75	371
1.19	tincan	10010.09	8103.33	2.71	1.99	4.80	1.84	2.50	1.89	3.32	2.47	2.52	1.83	4.78	1.43	371
1.20	vangabot	11085.52	8880.60	4.17	2.14	5.18	1.75	4.42	1.88	4.75	2.26	5.11	1.98	5.66	1.80	371
2.21	abfluss	9641.53	7339.77	4.02	2.09	4.72	1.82	3.21	1.88	3.46	2.14	3.86	2.01	5.60	1.74	333
2.22	abstract	9886.75	7435.77	4.56	2.03	3.51	1.71	3.98	1.87	4.44	2.28	4.24	2.02	3.54	1.69	333

2.23	animalfarm	11742.63	10030.94	4.30	2.00	4.68	1.73	3.91	1.84	3.61	2.11	4.44	2.04	4.92	1.80	333
2.24	clockwork	24019.34	24019.34	4.30	1.98	4.68	1.73	4.71	1.71	4.65	2.36	5.03	1.95	4.72	1.61	333
2.25	donquijote	13176.91	9011.76	4.56	2.15	5.32	1.74	6.01	1.77	6.19	2.15	5.99	2.02	6.02	1.70	333
2.26	elytron	12199.32	8573.11	5.16	2.17	5.76	2.14	4.80	2.05	5.08	2.41	5.81	2.15	6.48	2.08	333
2.27	eveningstroll	11731.89	8160.82	4.27	1.96	5.16	1.68	5.24	1.94	5.89	2.16	5.52	2.21	5.25	1.64	333
2.28	expressionalthoughts	10228.01	6782.28	4.86	2.27	3.74	2.02	4.96	2.10	5.07	2.38	4.91	2.14	4.18	1.87	333
2.29	igiveyoumyheart	14565.87	10099.44	4.91	2.00	4.71	1.89	4.93	1.83	4.31	2.11	5.02	2.03	5.43	2.04	333
2.30	judgmentday	14345.31	10098.04	4.83	2.13	5.77	1.77	6.22	1.95	5.13	2.33	5.59	2.15	6.36	1.66	333
2.31	maccarthy	15043.77	9626.94	4.75	2.35	6.89	2.10	4.81	2.08	4.44	2.46	6.40	2.22	7.05	1.87	333

2.32	masquelavoisier	10012.88	7181.86	3.88	1.95	5.25	1.71	3.74	1.97	4.75	2.29	4.69	2.10	5.56	1.56	333
2.33	nastysurprise	10167.66	7707.72	4.31	2.22	6.40	2.27	3.87	1.92	4.13	2.48	5.73	2.27	6.31	2.16	333
2.34	sadart	11309.84	7606.89	4.51	2.02	4.74	1.69	4.42	1.89	5.14	2.27	5.22	2.00	5.79	1.83	333
2.35	spargel	9807.44	7977.92	2.84	1.87	4.89	1.67	2.86	1.95	3.79	2.59	3.32	2.19	4.71	1.50	333
2.36	suit	10681.19	8503.84	4.50	2.23	5.96	2.07	4.08	2.00	4.88	2.30	6.07	2.12	5.65	1.85	333
2.37	summerwine	13301.94	9287.17	5.55	2.04	3.89	1.98	4.85	1.88	3.52	1.95	4.47	2.03	5.09	1.98	333
2.38	swimmer	10088.22	8794.34	3.69	1.93	4.84	1.70	3.73	1.80	3.80	2.11	3.94	1.98	4.93	1.69	333
2.39	thenett	15923.73	10529.68	5.06	2.18	5.82	2.17	5.85	1.86	4.85	2.29	5.79	2.10	6.32	1.86	333
2.40	watertrap	12860.29	9279.25	5.34	2.19	4.89	1.90	5.65	1.97	5.19	2.18	5.92	2.05	5.84	1.85	333

3.41	ablaze	9500.94	7555.03	4.71	2.19	3.41	1.79	4.39	2.06	4.55	2.34	4.15	2.15	3.63	1.71	324
3.42	battle	11861.36	8721.85	5.11	2.27	5.95	2.12	4.90	1.95	4.61	2.35	5.94	2.14	6.59	2.00	324
3.43	bestabstract	12886.74	11386.82	4.01	2.25	3.46	1.74	3.68	2.38	2.61	2.21	2.40	2.16	3.52	1.79	324
3.44	candle	10136.37	7460.44	3.89	1.96	4.36	1.73	3.21	1.93	3.42	2.30	3.34	2.18	4.20	1.72	324
3.45	elegance	10085.82	7448.42	4.16	2.17	3.25	1.71	2.79	1.80	2.24	1.63	2.18	1.55	3.22	1.75	324
3.46	forbiddenspark	21014.26	14028.20	5.75	2.15	4.63	2.08	7.27	1.65	6.14	2.14	6.37	2.09	5.02	1.92	324
3.47	gonzoid	13840.49	9380.50	4.81	2.26	4.88	2.13	6.32	2.16	6.56	2.39	6.59	2.23	5.13	1.95	324
3.48	izzi	9725.88	6300.21	4.46	2.18	3.92	1.99	4.32	2.06	3.58	2.22	3.88	2.08	3.84	1.90	324
3.49	lullaby	14168.50	9714.77	5.09	2.05	4.54	1.84	5.86	1.86	5.00	2.18	5.75	2.02	5.01	1.87	324

3.50	pentzagram	16111.42	10913.11	4.98	2.11	4.84	1.96	4.46	1.98	4.67	2.22	4.58	2.23	5.12	1.99	324
3.51	planetsmos	12952.42	10215.59	3.95	1.98	5.52	1.76	5.03	1.97	6.28	2.20	6.23	2.03	5.41	1.62	324
3.52	prarie	9163.76	7129.66	4.25	2.32	3.41	2.11	3.15	2.10	2.78	2.06	2.85	2.14	3.60	2.06	324
3.53	prevenit	12904.49	10475.71	5.96	2.14	4.75	2.45	5.61	1.97	4.99	2.25	6.13	2.09	6.22	2.19	324
3.54	rantII	10741.91	8528.66	5.13	2.35	6.40	2.06	6.09	1.83	5.82	2.11	6.40	1.80	6.58	1.83	324
3.55	repetition	14318.77	11161.17	5.26	2.23	5.76	2.04	6.58	1.71	5.24	2.27	6.08	1.95	6.42	1.87	324
3.56	rootsarmchair	10141.91	7889.96	3.85	2.02	5.40	2.14	5.44	2.11	5.79	2.43	5.76	2.06	5.24	1.83	324
3.57	sidestreet	9975.42	7709.58	3.85	2.17	3.20	1.73	2.98	1.90	1.93	1.42	1.88	1.36	3.04	1.76	324
3.58	spaceman	14141.95	10433.00	4.92	2.18	5.68	1.97	6.31	1.80	5.81	2.24	6.67	1.74	5.58	1.80	324

3.59	squattercity	11179.90	8502.45	4.59	1.98	5.05	1.90	5.24	1.99	5.17	2.44	5.43	2.30	5.40	1.96	324
3.60	tremblay	10926.55	7808.43	4.80	1.94	4.03	1.75	4.86	2.09	4.23	2.28	4.95	2.19	4.07	1.76	324

Note: VT = viewing time, VT given in seconds, N = number of participants, s.d. = standard deviation

11.2 Appendix 2 – The Artworks

Table 11.2 Images with Artist Information.

ID	Image	Image Name	Artist	Additional Information
1.01		afremove	Leonid Afremov.	Afremov. www.afremov.com
1.02		armchair	Museo Nacional de Artes Decorativas. Madrid	Armchair and footstool for a sculpture of the Virgin. Valencia (Spain). Courtesy of: Museo Nacional de Artes Decorativas. Madrid

1.03		artistinlove	Adrian Borda	Artist in Love. www.adrianborda.com
1.04		blood	Ryohei Hase	Blood © 2008. www.ryoheihase.com
1.05		catinwindow	Donna Master Kriebel	Cat in Window. www.dmasterskriebel.com

1.06		earthsky	Adrian Borda	Where the Earth Kiss the Skye. www.adrianborda.com
1.07		feelings	Ryohei Hase	Their Feelings © 2006. www.ryoheihase.com
1.08		girlmoon	Adrian Borda	Girl Moon. www.adrianborda.com

1.09		lavoisier	Musée des Arts et Métiers	Laboratoire de Lavoisier M. Favareille_11. Courtesy of: Musée des arts et métiers. http://arts-et-metiers.net
1.10		lightafterstorm	Charlotte Blanchard	Light After the Storm. http://wishfultravelergallery.com/
1.11		magicrealism	Michael Parkes	Magic Realism. www.theworldofmichaelparkes.com

1.12		morningwalk	Maria Hathway Spencer	Once upon a Morning Walk. www.fineartamerica.com/profiles/maria-hathaway.html
1.13		pursuithappiness	Adrian Borda	The Pursuit of Happiness. www.adrianborda.com
1.14		realmofsense	Adrian Borda	Realm of Senses. www.adrianborda.com

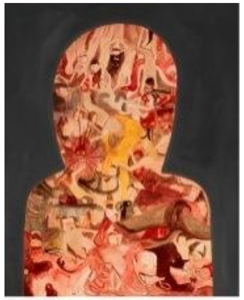
1.15		riomaggiore	Charlotte Blanchard	Harbours Egde in Riomaggiore. http://wishfultravelergallery.com/
1.16		sunsetrees	Carol Nelson	Sunsetrees. http://carolnelsonfineart.com/
1.17		swansong	Adrian Borda	The Swansong Hunters. www.adrianborda.com

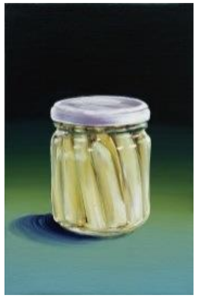
1.18		timedrelease	Demon Soul	Timed Release. Demon Soul
1.19		tincan	Mark ShaSha	Tincan © 2011. www.MarkShaSha.com
1.20		vangabot	Vangobot	Vangabot. http://popartmachine.com/vangobot.php

2.21		abfluss	Cornelius Voelker	Abfluss. www.cornelius-voelker.de
2.22		abstract	Tom Zamorin aka TomYoda	Abstract. http://tomyoda.deviantart.com/gallery/
2.23		animalfarm	Gabriel Wyse	Animalfarm. http://gabrielwyseillustration.com/

2.24		clockwork	Domen Lombergar	A Clockwork Orange. www.domelo.com
2.25		donquijote	Domen Lombergar	Don Quijote. www.domelo.com
2.26		elytron	Monika Weiss	Elytron © 2003 Self-shot photography, single channel video, performance, sound, paper, ink, cement. Courtesy of Chelsea Art Museum, New York and Monika Weiss.

2.27		eveningstroll	Domen Lombergar	Eveningstroll. www.domelo.com
2.28		expressionalthoughts	Tom Zamorin aka TomYoda	Expressional Thoughts. http://tomyoda.deviantart.com/gallery/
2.29		igiveyoumyheart	Adrian Borda	I Give You My Heart. www.adrianborda.com

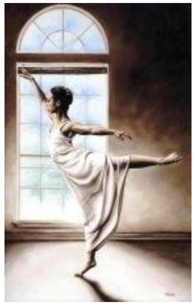
2.30		judgmentday	Andrew Pommier	Judgementday. www.andrewpommier.com
2.31		maccarthy	Jason Kaufman	McCarthy. Photo by Jason Kaufman, Los Angeles, 2010 (Paul McCarthy) © 2011. www.jasonkaufman.info/INVIEWBlog.htm
2.32		mask lavoisier	Musée des arts et métiers	Masque de Lavoisier Philippe Hurlin. Courtesy of: Musée des arts et métiers. http://arts-et-metiers.net

2.33		nastysurprise	Gabriel Wyse	A Nasty Surprise. http://gabrielwyseillustration.com/
2.34		sadart	Tom Zamorin aka TomYoda	Sad Art. http://tomyoda.deviantart.com/gallery/
2.35		spargel	Cornelius Voelker	Spargel. www.cornelius-voelker.de

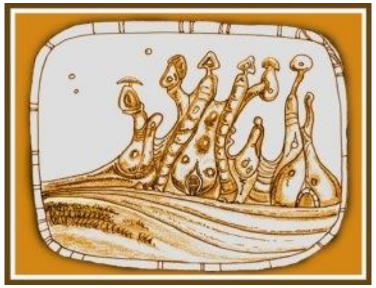
2.36		suit	Markus Leitsch	Suit. http://markus.leitsch.at/
2.37		summerwine	Adrian Borda	My Summer Wine. www.adrianborda.com
2.38		swimmer	Cornelius Voelker	Schwimmer. www.cornelius-voelker.de

2.39		thenett	HR Giger	The Nett II, © 1988, 140x100 cm, acrylic on paper on wood. Courtesy of: www.hrgigermuseum.com
2.40		watertrap	Ryohei Hase	Water Trap © 2008. www.ryoheihase.com
3.41		ablaze	Patrick Gunderson	Ablaze. Patrick Gunderson

3.42		battle	Ryohei Hase	Battle ©2008. www.ryoheihase.com
3.43		bestabstract	Adrian Borda	The Best Abstract You'll Ever See. www.adrianborda.com
3.44		candle	Barbara Fox	Candle. www. BarbaraFoxArtStudio.com

3.45		elegance	Richard Young	Light Elegance. www.ryoung-art.com
3.46		forbiddenspark	Adrian Borda	The Forbbiden Spark. www.adrianborda.com
3.47		gonzoid	Peewee Gonzoid	Untitled. http://peeweegonzoid.tumblr.com/

3.48		izzi	Michel Keck	Izzi Shi Tzu. http://www.michelkeck.com/
3.49		lullaby	Adrian Borda	Lullaby for a Last Song. www.adrianborda.com
3.50		pentzagram	Michael Gaughan	Pentzagram. http://www.michael-gaughan.com/

3.51		planetsmos	Peewee Gonzoid	Small Village on Planet Smos. http://peeweegonzoid.tumblr.com/
3.52		prarie	Maria Hathway Spencer	Prarie. www.fineartamerica.com/profiles/maria-hathaway.html
3.53		prevenit	Ryohei Hase	Cannot prevent it ©2006. www.ryoheihase.com

3.54		rantII	Peewee Gonzoid	Rant II. http://peeweegonzoid.tumblr.com/
3.55		repetition	Ryohei Hase	Repetition © 2009. www.ryoheihase.com
3.56		rootsarmchair	Museo Nacional de Artes Decorativas. Madrid	Armchair made of roots, Asiatic Art. Courtesy of: Museo Nacional de Artes Decorativas. Madrid

3.57		sidestreet	Charlotte Blanchard	Side Streets in Annecy. http://wishfultravelergallery.com/
3.58		spaceman	Peewee Gonzoid	Spaceman. http://peeweegonzoid.tumblr.com/
3.59		squattercity	Demon Soul	Squattercity. Demon Soul

3.60		tremblay	Julie Tremblay	Tremblay. http://www.julietremblay.net/
		Rating Scales	All rating scales were designed by Megan Abel.	http://www.meganabel.co.uk/