Emotional processing of natural visual images in brief exposures and compound stimuli: fMRI and behavioural studies.

A thesis submitted for the degree of Doctor of Philosophy

by

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Abstract

Can the brain register the emotional valence of brief exposures of complex natural stimuli under conditions of forward and backward masking, and under conditions of attentional competition between foveal and peripheral stimuli? To address this question, three experiments were conducted. The first, a behavioural experiment, measured subjective valence of response (pleasant vs unpleasant) to test the perception of the valence of natural images in brief, masked exposures in a forward and backward masking paradigm. Images were chosen from the International Affective Picture System (IAPS) series. After correction for response bias, responses to the majority of target stimuli were concordant with the IAPS ratings at better than chance, even when the presence of the target was undetected. Using functional magnetic resonance imaging (fMRI), the effects of IAPS valence and stimulus category were objectively measured on nine regions of interest (ROIs) using the same strict temporal restrictions in a similar masking design. Evidence of affective processing close to or below conscious threshold was apparent in some of the ROIs. To further this line of enquiry, a second fMRI experiment mapping the same ROIs and using the same stimuli were presented in a foveal ('attended') peripheral ('to-be-ignored') paradigm (small image superimposed in the centre of a large image of the same category, but opposite valence) to investigate spatial parameters and limitations of attention. Results are interpreted as showing both valence and category specific effects of 'to-be-ignored' images in the periphery. These results are discussed in light of theories of the limitations of attentional capacity and the speed in which we process natural images, providing new evidence of the breadth of variety in the types of affective visual stimuli we are able to process close to the threshold of conscious perception.

Keywords: Amygdala; Anterior Cingulate Cortex; medial Prefrontal Cortex; Dorsolateral Prefrontal Cortex; Orbitofrontal Cortex; Parahippocampus; Fusiform Gyrus; Insula; Superior Temporal Gyrus; consciousness; attention; masking; fMRI.

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Would I have started a PhD programme if I had known how many avenues I needed to travel: those that end with a brick wall, those that go around in a circle, those that entice me into 'interesting' directions only to discover I am miles away from where I need to be? The answer is yes. I have experienced extreme frustration, bewilderment, uncertainty and doubt in my ability when presenting at conferences to audiences whose combined academic experience probably adds up to 1000s of years compared to my meagre few. Had I not experienced all of this, I would not have met so many inspiring people nor would I have learnt so much.

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Glossary of Working Definitions

Attended condition – instructed to voluntarily attend to a small image presented in the fovea superimposed on a large image of the same category, but opposite valence (Section 5:2).

Awareness – perception allowing identification of content, and accompanied by a distinctive sensory impression.

Backward masking – method to reduce detectability of a target stimulus by presenting a second stimulus (mask) immediately after the target.

Concordant – participant's impression of the stimuli in agreement with IAPS ratings.

Coni – *abbr. valence impression confidence.* In chapter 3 participants rated how confident they were in their overall judgement of valence for each trial as a whole.

Cons – *abbr. seen confidence.* In chapter 3 the participants recorded how confident they were in their answer to how many pictures they saw. This measure is termed 'seen confidence'.

Consciousness – in this thesis, the term consciousness is used in the sense of Damasio's 'core consciousness' to refer to perception with awareness in the awake state (Damasio, 1999).

Detection threshold – operationally defined as identical to the subjective threshold.

Discordant – participant's impression of the stimuli not in agreement with IAPS ratings.

Discrimination threshold – operationally defined as identical with the objective threshold.

Dual image – compound image consisting of the attended condition superimposed on the 'to-be-ignored' condition of opposite valence (Section 5:1).

Explicit perception – perception with awareness allowing self-report and further cognitive operations including discrimination naming and description of stimuli.

Feelings – subjective private mental portrait, composite perceptions of the physiological reactions of emotions.

Forward masking – detectability of target stimulus is reduced when following a longer duration stimulus (mask).

Gist – a very sparse, coarse impression.

Implicit perception – perception without awareness: input influences cognitive operations but is not available to self-report.

Perception of emotion – objective response, chemically and neurologically produced by the brain when presented with the appropriate stimuli.

Subliminal processing – defined in the behavioural experiment as below detection threshold, but above discrimination threshold.

Supraliminal – above the threshold of conscious awareness.

To-be-ignored condition – instructed to ignore large image, surrounding foveal image of the same category, but opposite valence (Section 5:1).

Unconsciousness perception – perception without awareness.

Chapter 1 Introduction

1:1 Backgound

It has been argued that our perception of natural images is not limited by the capacity of visual attention as severely as is the perception of artificial, simpler visual stimuli. Li and colleagues used natural images of animals and vehicles and concluded that "some visual tasks associated with 'high-level' cortical areas may proceed in the near absence of attention" (Li et al., 2002, p 9596), challenging previous theories of visual limitations of attention (Li et al., 2002).

The use of artificial stimuli such as simple geometric shapes or actors' faces has formed the bulk of the evidential basis for theories of visual processing below conscious threshold. This has happened for a good reason, as valid experiments need to be controlled for all possible variables, so controlling for colour, orientation, luminance and salience enable quantification of those visual properties that determine detection and discrimination. However, these stimuli are not ecologically valid. Employing natural images moves some way towards ecological validity, but it is more difficult to achieve tight experimental control of all the variables in such complex stimuli.

With this in mind, however, there are noteworthy contributors investigating the brain mechanisms behind the rapid visual processing of everyday images, demonstrating that certain natural objects can be detected within natural scenes remarkably quickly (Rousselet et al., 2002, Thorpe et al., 2001b, Thorpe et al., 2006) . Thorpe and colleagues, for instance, continue to consider rapid categorisation/detections tasks using response timings (RTs) and event-related potentials (ERPs) and have concluded that animal and face detection in everyday images happen in as little as 150ms (Fabre-Thorpe et al., 2001, Thorpe et al., 1996). Note that these detections are not 'perception without awareness' since conscious categorisation of the images is possible.

In contrast with these demonstrations of the ability to categorise visual stimuli from brief presentations, evidence from change blindness and inattentional blindness studies demonstrates the poverty of information that can be recovered from visual stimuli in the absence of conscious perception and

attention. These compelling phenomena show that (provided the local motion signals that cue image changes are masked), large changes in an image or the presence of unexpected stimuli are rendered invisible, because the gist of the picture is unchanged (Beck et al., 2001, Mack and Rock, 1998).

This raises the question of how we process the emotional content of scenes and pictures. Is emotional valence a simple category (like 'animal', 'face' or 'building') that we can immediately categorise in a brief visual presentation, or does it depend (in complex scenes) upon conscious processing – 'beyond the gist'? Or is there, indeed, a special mechanism for identifying emotional content that does not require conscious awareness?

It has been argued that responses to visual emotional stimuli are automatic and can be processed without conscious awareness. The functionality of affective significance is one of survival in the detection of threat, or opportunity for procreation and sustenance, and early automatic processing is arguably of an evolutionary advantage. Research on emotional processing has supported this theoretical premise. Detection of threat-related faces, in one experiment, was faster than those of neutral expressions (Öhman et al., 2001b), as was the detection of animals compared with neutral images (Öhman et al., 2001a). Emotional scenes have also shown more rapid discrimination than neutral scenes (Cuthbert et al., 2000).

Rapid emotional processing has been demonstrated using skin conductance response (SCR) (Lane and Nadel, 2000), and electroencephalogram (EEG) (Schupp et al., 2000). Moreover, brain imaging research has revealed more detailed information on the brain structures mediating early processing. For instance, positron emission technology (PET) directly identifies activity in neurotransmitter systems by introducing positron-emitting radiolabelled tracers injected into healthy participants (Huettal et al., 2004). Some researchers favour the chemical specificity of PET when investigating emotional expressions and experience (e.g. Damasio et al., 2000), whilst others prefer the more accurate spatial resolution and better temporal resolution of functional magnetic resonance imaging (fMRI). These include experiments investigating conscious awareness of affect, with either natural images presented supraliminally, as in an expectancy and perception experiment reflecting dissociable emotion and cognitive networks (Bermpohl

et al., 2006), or subliminally presented images that are less complex such as pictures of faces (Etkin et al., 2004, Pessoa et al., 2005a). However, to date relatively few experiments have systematically used fMRI to analyse cortical activity in relation to a wide range of natural everyday images whilst presented below the level of conscious awareness.

1:2 Historical Context

1:2:1 Consciousness

Consciousness is a seductive conundrum. It has tantalised and perplexed some of the greatest minds in history.

For instance, "cogito ergo sum", famously translated as "I think therefore I am" (Je pense, donc je suis) is the best-known aphorism from the influential 17th Century philosopher Rene Descartes, illustrating the primacy of our own mental states as the foundation for what we can know (Descartes, 1637/1909). But how do our mental states relate to the matter of which we, and the rest of the universe, are composed? In a further attempt to understand the res extensa (extended substance, matter) and the res cogitans (thinking substance), constituting his dualistic theory of two separate substances, Descartes subsequently conceded that they were closely connected and indeed intertwined (Damasio, 1994). Whilst not producing definitive answers, the clarity of his analysis has challenged and stimulated many critics and thus shaped our entire thinking about consciousness and its relation to the body.

In 1890, William James published what is considered to be the most influential summary of nineteenth century psychology, *The Principles of Psychology* (James, 1890/1950). Exploring the biological function and physical basis of consciousness, which he called the scientific study of mind, this work covered aspects of psychology that included brain function, the self, attention, memory, perception and the 'stream of consciousness', which he believed was 'thought' that continuously changes and is never exactly repeated. 'Thought' involves attention in that it attends to certain objects whilst omitting others, which also involves short term memory (James, 1890/1950). His prolific contributions remain relevant and influential today as

evidenced by his ideas on fringe consciousness, “to designate the influence of a faint brain process upon our thought, as it makes it aware of relations and objects but dimly perceived” (James, 1890/1950, p 258). This has more recently been described as gist perception, a representation of a scene that may be outside of focal attention or without awareness of detail (Koch, 2004). James also deliberated upon the works of Dr Mosso, who discovered that changes in cerebral blood flow accompanied cerebral activation (James, 1890/1950). This work constituted the starting point for haemodynamics of brain imaging techniques such as MRI and PET (Baars and Gage, 2007).

Beginning his medical career in neurology, Freud anticipated the hypothesis that a neural network generates conscious experience by introducing the concept of three classes of neurons. According to Freud, ϕ neurons are responsible for perception, ψ neurons mediate memory expediated by contact barriers (Freud, 1895/2001), which were not discovered until 2 years later by Sherrington, whereby he adopted the name synapse which is Greek for clasp (Sherrington, 1897). Thirdly, ω neurons mediate consciousness including the subjective aspect of qualia (Freud, 1895/2001). This work was far ahead of neuroscience at that time and it is for this reason that it is speculated that Freud abandoned neurology and turned to developing psychoanalytic theories, although this supposition is challenged (Pribram, 1998, Solms, 1998).

As the turn of the 20th century began, consciousness studies started to lose momentum, partly because of the scientific impracticality of its indeterminate subjective nature, and partly because of the difficulty in validating experiments by repetition based on the experience of others. Therefore, psychology moved away from mental study and towards experiments that measured behaviour using stimulus and response techniques. Enter the behaviourist movement, and consciousness took a back seat in the scientific world and remained with religious scholars and philosophers (Crick, 1994).

In the late 1950s and 1960s, however, the behaviourist movement was running out of steam because many psychologists began to realise that the study of behaviour had become oversimplified. Computer science was gaining

momentum and human cognitive processes were soon looked upon in the light of computer programming and so the emergence of cognitive psychology once again legitimised the study of mental processes such as attention, perception, emotion, memory and language (Crick, 1994).

In fact, Crick (1994), in his book 'The Astonishing Hypothesis' gave a rallying-cry for a new science of consciousness, building on what we might call the *standard history* of consciousness studies (outlined above). According to Crick, in order to study consciousness we should only study the relationships between brain and behaviour scientifically through the application of neuroscience with one clear-cut question in mind – what are the neural correlates of consciousness (NCCs)? In collaboration with Koch, they chose to study the difference between conscious and nonconscious visual experiences, as research had already progressed extensively our knowledge of the visual system. They believed that aiming to understand NCCs by comparing conscious and non-conscious processing would lead the way to causal explanations. An example of the evidence they have offered so far is of an alliance of neurons responsible for perception which compete for awareness via saliency or selective attention through feedback mechanisms from the higher cortex (Koch, 2004).

Although this scientific programme has been criticised for extreme reductionism (Blackmore, 2003), it has contributed to enticing scientists to consider subjective experience as part of the experimental scientific mainstream. However, this whole new environment for consciousness studies has not been without its problems, for even defining consciousness is a challenge. Consciousness can exist in different states, as in dreaming compared with the waking state. Consciousness may be held to refer specifically to attention and perception, to self-consciousness, to the qualitative content of experience or most generally, to the possession of any mental state. 'Unconsciousness' can refer to inattention, implicit processing, repression, sleep, anaesthesia or death, but also may be due to brain damage. A useful distinction has been made by Damasio (1999) between core consciousness (immediate awareness) and extended consciousness (the integrated structure of knowledge of the external world and the self). Specific knowledge, including the capacity for language, is thus part of extended consciousness (Damasio,

1999). For the purposes of this thesis, however, the definition of consciousness is close to Damasio's concept of core consciousness: consciousness is being aware whilst in the awake state.

In an attempt to understand consciousness, vision studies have proven invaluable. There are several reasons for this. Firstly, one can study several brain structures that are dedicated to visual processing, underlining the importance of seeing; there is a wealth of information in images and it is possible to easily manipulate various aspects of stimuli using various computer graphics packages. Equally, visual illusions are abundant in variety and ambiguity (Koch, 2004), such as the Ames distorted room, whereby one corner of the rear wall is further away from the viewpoint than the other, and by applying learnt knowledge of a three dimensional figure, the two dimensional figure is misinterpreted (Eysenck and Keane, 2005). Lastly, animal studies using visual perception have contributed enormously to our knowledge of vision and attention (Koch, 2004). To add to the diversity of the efficacy of using visual stimuli, lesion studies have provided a wealth of information for consciousness studies, especially those that impair visual awareness. Cortical blindness, or blindsight, is a case in point whereby patients deny any visual sensation of a stimulus, but are able to point to it or guess basic visual properties such as orientation or colour (Baars and Gage, 2007).

All of these advantages render visual percepts ideal for measuring neuronal representations of conscious and unconscious visual processing. This leads to the question as to what is the difference between conscious and unconscious representations in the brain? Perhaps there is a difference between the two different processes? Or perhaps there is an additional quality to the same representation that renders a percept conscious? Quantity as in size or strength may determine if a representation becomes conscious or not. Or maybe the 'forty-hertz' hypothesis is correct, whereby cortical cells fire in synchrony at a 40 times per second oscillation for a visual conscious experience, which suggests that conscious experience arises from temporal rather than spatial aspects of neural processing (Gray and Singer, 1989). Equally, conscious processing may be a matter of degree rather than a sharp contrast of conscious processing occurring completely or not at all (Rose, 2006). These ideas will be further expanded upon as this discourse unfolds.

Working with one modality (vision) to measure unconscious processing enables further insight into a second aspect of unconscious processing, which is that of emotion, which will now be addressed.

1:2:2 Emotion and the Brain

Since the late nineteenth century, the role of biology and the brain in emotion has been contemplated. In *The Expression of Emotions in Man and Animals* (1872/1999) Charles Darwin argued that the existence of complex behaviours, including the expression of emotion, depends on natural selection (animal or human). Emotionally expressive behaviours develop from responses to stimuli and acquire additional survival value through their communicative functions. For example, an expression of emotion becomes habitual if it is serviceable, and develops out of associated reflexive responses (e.g. the action of withdrawing rapidly from danger due to the warning of pain), or voluntary behaviours. Other expressions of emotion have evolved from pre-emptive behaviour patterns, such as a low growl a dog makes as a warning which can be equated to a human voice lowering in tone and becoming a deliberate threatening signal. Darwin's ideas were supported by the observational notes he made on his children. He noted that from the moment they were born, their emotional outbursts and expressions were fully recognisable; therefore because they were evident so early in life, they could not have been learnt so must be innate. As such, according to Darwin, evolution has determined our emotional expressions and behaviour (Darwin, 1872/1999).

Consistent with this, in 1884 William James and Carl Lange proposed related ideas on the theory of emotion (James, 1884, Lange, 1885). The James-Lange theory, as it later became known, postulates that emotion is a response to perceived physiological changes, (e.g. one sees a spider and starts to tremble). The emotion or interpretation of the physical manifestation (trembling) takes place in the cerebral cortex, which is fed back to infer that if one is trembling then one must be afraid. However, the implication here may be that in the absence of awareness of physiological signs, one will not feel emotion. Nevertheless, there is a correlation between strong emotions and

certain physiological manifestations, but a causal relationship is not obvious (Cannon, 1927, Cannon, 1931).

When Walter Cannon and Philip Bard studied animals and humans after trans-section of the spinal cord, it was noted that even though body sensations were eliminated below the cut, signs of emotions were still exhibited and felt, thus the elimination of sensation in the body did not eliminate emotions, as the James-Lange theory predicted. The Cannon-Bard theory asserts that the experience of emotion is simultaneously influenced by a) physiological changes and b) processing of information in the cerebral cortex, (e.g. the sensory input is received by the cerebral cortex, which activates the skeletal muscles and autonomic nervous system and results in physiological changes in the body). When a particular pattern of signals reaches the thalamus, the type of emotion is determined resulting in physiological change (e.g. sweating for fear) (Bard, 1934, Cannon, 1927, Cannon, 1931).

One of the earliest contributors to propose a model of cerebral anatomic connections with the emotional system was Paul Broca (Broca, 1878), whose extensive work on the structure of the brain led him to rename the visceral brain the limbic system. Limbic means edge, which Broca used to describe the rim of the medial cortex. In 1937 Papez advanced a circuitry pathway (the Papez Circuit Theory, as it later became known) mediating the flow of emotional information involving the hypothalamus, the medial cortex – anterior thalamus, amygdala cortex and hippocampus – and back to the hypothalamus (Papez, 1937).

Considerable research into the architecture of the emotional system continued and in 1970 MacLean proposed the Triune Brain. Adding the structure of Broca's limbic system with Papez circuit theory, this functional model proposed three evolutionary hierarchical layered brains in one: the reptilian brain (brain stem and cerebellum); the paleomammalian or limbic brain; and the neomammalian or neocortex. Each phylogenetic area, according to MacLean, was autonomous but because of their high connectivity, one could dominate the other, (e.g. the limbic system underlying the emotion system can overrule the higher cognitive functions of the neocortex). His limbic system theory included regions such as the amygdala, prefrontal cortex (PFC) and septum (MacLean, 1970).

The evolutionary concept of the Triune Brain is still popular. However, Maclean's single unified limbic system theory, responsible for all our emotions, has been strongly challenged. In fact, it is now believed that there may be many different smaller emotional systems subserving different emotions, but this does not mean that certain areas in Maclean's model are not considered relevant to emotional processing (LeDoux, 1998).

LeDoux (1998), for instance, famously associates the amygdala and neocortex with fear conditioning (LeDoux, 1998). His quest in the neurobiology of emotions and animal experimentation has led him to assert that there are two sensory input pathways for processing strong emotions. The first is a subcortical short route ('low road') that rapidly sends sensory information from the thalamus directly to the amygdala: this facilitates an automatic emotional response, which is based on a rough coding of the stimuli. The second is a cortical route ('high road') which is longer and slower, whereby information is sent from the thalamus to the cortex and hippocampus and then projected onto the amygdala, thus involving cognitive evaluation. LeDoux used the analogy of a slender shape on a pathway that could be a snake. The information is sent to the thalamus and the amygdala via the subcortical route immediately alerting us into appropriate avoidance. Meanwhile, the cortex calculates that the shape is a curved stick and corrects one's behaviour (LeDoux, 2002).

Another major researcher in the study of the emotional brain is neurologist Antonio Damasio. Part of his work has involved studying patients with frontal lobe damage. Patient Elliot was one such study, who had a tumour removed, causing prefrontal lesions. The result was that Elliot lacked normal emotional responses and was unable to make decisions, especially those that were in the personal and social domain. It was evident that emotion disrupts reasoning, which was later confirmed by further studies by Damasio. However, different areas of cortical lesions also led to similar failures in judgement, which correlated with impairment in the same processes of reasoning, decision making, feelings and emotion which Damasio took as a further indication of an interaction between these systems (Damasio, 1994).

It is important to make the distinction between the neural correlates of sensory perception of emotional stimuli, and affective states (Damasio et al.,

2000, LeDoux, 2000). For instance, Damasio's interpretation of this distinction is that emotion is a response chemically and neurologically produced by the brain when presented with the appropriate stimuli, whilst feelings are the private mental portrait, the composite perceptions of the physiological reactions of emotions (Damasio, 2001). The distinction between cognition and feelings needs to be made clear, for this current research concentrates on perception of valence advanced by the invaluable availability of fMRI and not affective feelings.

Emotion and brain organisation has also been considered in terms of cerebral asymmetry. Lesion studies and patient studies with psychiatric disorders have been interpreted by some investigators as supporting a theory that the right hemisphere (RH) mediates all basic emotions (Tucker, 1981). A contrary hypothesis states that the brain is organised in terms of valence, and postulates that the RH mediates negative emotions and the left hemisphere (LH) positive emotions. This idea was developed from reports of patients with pathological emotion disorders, including gelastic epilepsy (a form of epilepsy where laughter is part of the seizure pattern) and from 19 patients following a hemispherectomy (Sackheim et al., 1982).

Using EEG recordings and observations of facial behaviour, a third model of hemispheric specialisation has been advanced. In the context of approach emotions (happy) and motor responses, activity was lateralised in the LH in the anterior temporal area, and in the case of withdrawal emotions (disgust), activity was lateralised in the RH in the frontal and anterior temporal regions (Davidson et al., 1990). The latter model discusses affective states in terms of their associated approach and withdrawal responses. These are the basic features of two motivational systems of emotional organisation: appetitive (reproduction, pleasure) and defensive (survival, unpleasant) (Lang, 2000). These systems are part of our evolutionary inheritance, and are associated with specific deep cortical and subcortical mechanisms; as evidenced by the association of the amygdala with our defensive motivational system, and of subcortical and deep cortical structures with appetitive motivation (i.e. limbic-striatal-pallidal circuitry) (Lang, 2000). These systems will be further discussed in context with the findings of the present research.

It should be noted at this point that it is now widely accepted that people can reliably discriminate between six different classes of facial expression: happy, sad, angry, surprised, afraid and disgusted. This ability is said to transcend cultural or linguistic barriers, therefore these facial expressions are not culturally specific, even when taking into account the differing social norms of emotional responses (Ekman, 1993). This supports the idea of the intrinsic phylogenetic, biological importance of facial expressions in human beings. The inherent ability in recognising and distinguishing different emotional expressions is necessary to read the emotional states of others and for effective social interaction (Darwin, 1872/1999). It has also been suggested that there may be an innate response in many species, including humans, to the typical visual forms, sounds and smells of certain biological hazards (e.g. predators, poisonous animals). Panksepp (1998) for instance, describes a basic 'hard-wired' network in the brain that has evolved in all mammals to facilitate primal situations. The labels Panksepp uses to correspond with innate emotional responses are: *seeking* – appetitive goals such as food, shelter and water; *rage* – a vigorous reaction arising from anger or frustration; *fear* – avoidance of threat or destruction through fight or flight; *panic* – reaction to separation from caregiver; *lust* – pursuit of sex; *play* – the need for social interaction through joy; and *nurturance* – the urge to care for infants (Panksepp, 1998, p 50). According to Panksepp, these behavioural measures would typically respond to motivational stimuli such as appetitive resources (sustenance, reproduction) or avoidance (odours, sounds, sightings of predators or aggressors) and each emotional response would map onto a neural system (e.g. a "*fear* circuit that courses between the central amygdala and the periaqueductal gray of the midbrain") (Panksepp, 1998, p 206). Although Panksepp's work is based on solid evidence from extensive animal research, there are nevertheless contenders to these ideas. One such criticism is that attributing affective states onto animal behaviours is inconclusive, as overt behavioural changes in animals may not correspond to apparent associated feelings (Posner et al., 2005). An alternative approach is the circumplex model of affect. This model proposes a two dimensional method with two orthogonal axes; the vertical axis arousal and the horizontal axis valence. Points around the circle illustrate a varying synthesis of valence and arousal. Therefore,

rather than considering discrete and independent neural circuits of affect, the circumplex model asserts that all affective states can be considered in terms of two (valence and arousal) neurophysiological systems (Russell, 1980).

In contrast to responses to human and animal faces and bodies, an emotional response to scenes or inanimate objects is not likely to be universal throughout our evolutionary history, and those reactions are likely to have been learned through experience or social teachings (Darwin, 1872/1999).

Two outcomes have derived from these ideas to inform the design of experiments described in this thesis. The first is that because of the uncontrollable complexities of natural images, investigating several distinct categories of emotion would have introduced too many variables to be tenable. Therefore, following the circumplex model, the stimuli used were IAPS pictures (International Affective Picture System) (Center for the Study of Emotion and Attention [CSEA-NIMH], 2001), which are calibrated dimensionally for high and low valence and for intensity (arousal). Secondly, the evolutionary significance of facial expressions and the apparent weaker significance of learnt emotional stimuli such as scenes were relevant when choosing the four a priori categories of stimuli for the present experiments – animals, faces, scenes and inanimate objects. Several authors have used subsets of visual emotional stimuli before (e.g.Gorno-Tempini and Price, 2001, Hariri et al., 2003, Kreiman et al., 2000, VanRullen and Thorpe, 2001a) and will be discussed further in sections 1:7:4 and 1:7:5.

1:2:3 Relationship between Consciousness and Emotion

How has the study of emotion contributed to the study of consciousness? According to neurological theorist Damasio "consciousness buys an enlarged protection policy" (Damasio, 1994, p 133). To illustrate, if a person knows that something causes fear, there are two ways of behaving. The first is a reaction that is out of our conscious control, it is innate. The innate feeling, Damasio argues, is a reactive primary emotion that depends on prime systems such as the amygdala and anterior cingulate cortex (ACC). As evidence, he cites a patient with bilateral damage to the amygdala (a major component of the limbic system) who became personally and socially inadequate, displaying

inappropriate emotions. The second way is to avoid the situation based on past experience. These reflective secondary emotions respond to thoughts controlled by the frontal cortices, which signals the limbic system to generate an emotional response, thus secondary emotions utilise the mechanisms of primary emotion. (Damasio, 1994).

In his view, the experience of emotion begins with conscious considerations that a person holds about someone or something. A cognitive evaluation takes place involving various sensory cortices**.** For secondary emotions and at a conscious level, automatic responses are activated from the retrieval of previously acquired representations (not innate), which involves areas in the PFC. This is then signalled to the amygdala, beginning the coordination of appropriate psychophysiological reactions. (Damasio, 1994).

Therefore, emotional processing in patients with prefrontal lesions is of the secondary type, as they cannot generate emotions or 'feelings' relative to images of a situation or stimuli. However, they can have primary emotion.

In the context of these observations, Damasio proffered the *somatic marker hypothesis.* Whether consciously or unconsciously, somatic markers are thought to be stored in the PFC and act as links between cognitive evaluation based on past experience and a 'feeling' based on emotional signals from the visceral regions, (e.g. amygdala and bodily states) which leads to appropriate decision making (Damasio, 1994). Damasio's work demonstrates how studies of emotion may be closely identified with studies of consciousness.

Consciousness and emotion are considered to be closely connected by many other contributors. There has been a profusion of evidence, for instance, demonstrating that emotional priming is preconscious (Kern et al., 2005) and mediates attention, as evidenced by rapidly presented emotionally arousing stimuli being detected more efficiently than less emotionally arousing stimuli (Phelps et al., 2006).

Bias of processing affective stimuli is said to be adaptive, reflecting the motivational significance of such stimuli. In this context, it is proposed that the evaluation of affective significance is automatic, preattentive and without awareness, to facilitate a rapid response and adaptive function. Studies briefly presenting visual affective images have supported theories of emotional stimuli

being processed quicker than neutral stimuli at a preconscious threshold (Cuthbert et al., 2000, Lang et al., 1997, Schupp et al., 2000, Vuilleumier et al., 2003a).

However, other researchers believe that effective emotional processing does need sufficient resources of attention and argue that any unconscious processing of affect is limited (Pessoa, 2005, Pessoa et al., 2002a). This debate will be further addressed later in this discourse.

Emotion is indeed central to human life and intimately connected to the experience of consciousness. After all, most of our experiences have an affective content. Is there any evidence that all of our experiences have an affective content? If asked to fill in a PANAS[1] self report, people report all sorts of moods and emotions, and even if they are doing nothing they are either contented, complacent, bored or slightly anxious. If none of Panksepp's motivational systems (Panksepp, 1998) are active, then it follows that people are either deeply unconscious or dead. The study of the neural correlates of emotion, therefore, affords important insights into the neural correlates of consciousness.

This project will follow the tenet that emotions are mental states with distinct neural correlates and further evaluate the relationship between consciousness and emotional response.

1:3 Cognition and Emotion

Animal and human studies have demonstrated interactions between neural circuits underlying cognition and emotion, and studies of these interactions are continually advancing our understanding of mental representations and human behaviour (Phelps, 2006).

Brain regions identified with emotional processing, such as the amygdala, show extensive connections with areas identified with cognition, (e.g. the PFC). The widely-researched amygdala was the focus of a recent review by Phelps (2006) in which different domains were highlighted as

[1] The Positive and Negative Affect Schedule is a self report measuring positive and negative affect. Twenty items, 10 positive and 10 negative are scored in a range of 1very slightly to 5 extremely. Developed by Watson, Clark and Tellegen (Watson et al., 1988).

examples of the interaction between cognition and emotion: emotional learning and memory; emotional effect on memory; the influence of emotion on perception and attention; and emotional processing in the context of social behaviour and emotional adjustment (Phelps, 2006). In context of the review by Phelps and in accord with the subject of the present thesis, emotional influence on perception and attention will now be addressed briefly.

By limiting attentional resources, studies show that emotion-laden stimuli will reach conscious awareness more effectively than neutral stimuli (Vuilleumier, 2002). In order to examine the effects of voluntary attention on auditory stimuli, Sander et al. (2005) conducted an fMRI dichotic listening task using meaningless words and an angry voice. They found significant amygdala response to anger regardless of whether the instruction was 'to-be-attended' or 'to-be-ignored' (Sander et al., 2005). Equally, Anderson and Phelps (2001) considered the role of the amygdala on the verbal perception of affect. Gaining evidence from a patient with bilateral damage to the amygdala revealed that, when presented with verbal aversive stimuli, there was a distinct absence of enhanced perception even though the patient understood the meaning of the words (Anderson and Phelps, 2001). These two examples serve to demonstrate the relationship of cognition with emotion and the pivotal role of the amygdala.

It is also hypothesised that the amygdala determines the significance of emotional input. This is achieved either automatically during direct encoding of input or in influencing the PFC which in turn modulates response by temporary inhibitory feedback (Baars and Gage, 2007).

Other workers have analysed the many afferent and efferent associations and the direct and indirect pathways involving projections from the early stages in sensory processing to the prefrontal cortices, suggesting feedforward and feedback mechanisms linking cognitive and emotional processes (Barbas, 2000).

The reciprocal effects of cognition and emotion discussed thus far, might seem to imply that different brain regions are associated with one or the other. However, there is a strong argument that these systems in terms of function cannot be separated as there is a dynamic integration of cognition and emotion that ultimately shapes behaviour. One example given by Pessoa (2008), is that the orbitofrontal cortex (OFC) is now associated with emotion

but once it was not, thus highlighting the difficulties in defining the emotional brain. Equally, as previously mentioned, the amygdala appears to determine what stimuli should be attended to, dependent upon significance. This role is juxtaposed with the role of the visual cortex in attentional effects (Pessoa, 2008).

One other aspect of the cognitive-emotion relationship needs to be addressed. The results from an fMRI experiment by Hariri et al. (2003) using natural and artificial fear-inducing visual stimuli, found that by introducing a cognitive evaluation task they witnessed attenuation of amygdala activations whilst at the same time there was an increase in activations in the right PFC (Hariri et al., 2003). Reciprocal modulation supports the hypothesis of a functional neural network between cognitive and emotional processing. Similar findings were also found by Taylor and colleagues (2003). Again using IAPS stimuli they found that when comparing passive viewing with active viewing employing a simple ratings task, there were correlated reductions as well as increases in activations, (e.g. less activation in the insula and right amygdala during the cognitive task correlated with greater activations in the dorsolateral prefrontal cortex (DLPFC) and ACC) (Taylor et al., 2003). This again is consistent with another study reporting an inhibitory effect on amygdala response when activations increase in the DLPFC and OFC (Öhman, 2005).

Considering all of this, one cannot deny that there are strong interactions between cognition and emotion.

1:4 Attention, Awareness and Perception

We are brought up to believe that it is common sense to ‘pay attention’ to something for it to ‘enter’ our conscious experience, as James famously said

“My experience is what I agree to attend to” (James, 1890/1950, p 402).

This follows the assumption that attention *causes* (or selects) a conscious experience. However, it can also be argued that attention is the *effect* of a conscious experience, for instance, an unexpected loud noise (unattended) makes us turn to see where it came from (conscious perception) (Koch, 2004).

It is hypothesised that there are two aspects of attention that can influence awareness. The first is location or salience of an object, the second is one of direction, we either voluntarily decide to attend to an object or our attention is involuntarily directed from an unexpected source (Kentridge et al., 1999).

Knowledge of object location, for instance, arises from attending to a spatial location, but this process does not necessarily entail awareness. The spatial characteristics of attention correlate with topographic activation in the visual and parietal cortex. Attention for the purposes of object identification, on the other hand, leads to awareness and perception of an object, which involves the primary visual cortex and inferior temporal cortex (Milner and Goodale, 2006).

A relationship between awareness (or lack of awareness) and attention is evidenced from lesion studies. For instance, hemineglect is a spatial disorder defined as a lack of awareness for stimuli located contralateral to the site of cerebral damage, which is invariably associated with the RH (Bisiach and Luzzatti, 1978). A related phenomenon is extinction, whereby isolated objects in the affected visual field can be seen, but when objects are presented simultaneously in both visual fields, only the stimulus in the opposite unaffected hemifield can be seen. The problem is not due to visual field defects, but to higher order attentional difficulty (Posner, 1994). A case in point was patient GK with right posterior inferior parietal damage. Using fearful or neutral faces and houses presented in either the left or right visual field or bilaterally, it was evident that emotional stimuli activated the amygdala and OFC regardless of neglect or extinction, indicating processing without conscious awareness (Vuilleumier et al., 2002).

Influential studies by Libet and colleagues have investigated the temporal distinction between conscious and unconscious processing. Libet et al. (1983) ran an EEG experiment recording activation in the primary motor cortex. The participants were asked to push a button ‘whenever they felt the urge to’, the timing of which was recorded from an electrical signal from the button press action, and to report when they wished to move. At around 350ms before the participants reported ‘an urge’, EEG activity (readiness potential) started, which was 550ms before their actual response. This led to the

supposition that an unconscious commitment for a voluntary action was made before intention became conscious (Libet et al., 1983). The controversy surrounding the interpretation of these experiments has been reviewed by Dennett (1991) who claims that Libet is confusing the time that a representation occurs (i.e. when a conscious or unconscious event happens), and the representation in consciousness of the timing of an event. Dennett's view is that there is no "fact of the matter about exactly when (in absolute time, as Libet would put it) a conscious experience happens" (Dennett, 1991, p 162) – there is simply a draft or narrative we construct about the sequence of events. Contrariwise, Libet's explanation, however paradoxical it seems, does make sense if we expect there to be a causal connection between neural events and behavioural or subjective correlates of those events.

Later, using electrodes implanted for treatment of pain, Libet and colleagues (1991) induced stimulation at various intervals to participants via the thalamus. The instruction to the participants was to indicate when the stimulus occurred via one of two button presses. The result suggested a linear progression from unconscious to conscious neuronal functions by demonstrating that detection occurred in the absence of awareness, and to reach a vague impression of awareness, a longer duration was needed. Thus by increasing duration ('time-on') of the same inputs, unconscious functions become conscious. Therefore, according to Libet et al., adequate neuronal activation is needed for unconscious processing to reach conscious processing, intimating that once a 'noise' happens, there is unconscious processing before the 'noise' becomes conscious (Libet et al., 1991).

Is there a difference between perception without attention and perception without awareness? Several investigators have made operational distinctions between these concepts.

One definition of studies of perception without awareness, involves stimuli that were unnoticed (i.e. not seen) and could not be identified, because the content was degraded, whereas perception without attention is perception of stimuli that are unnoticed because they are presented outside attention, (e.g. through masking or priming) (Merikle and Joordens, 1997). Both paradigms test implicit (also referred to as unconscious) perception. Blindsight is an excellent example of perception without 'seeing', (i.e. without visual

awareness). For instance, patient DB could perform visual tasks accurately although he could not 'see' (Weiskrantz et al., 1974). Table 1.1 briefly attempts to classify perceptual and behavioural aspects of visual awareness in various clinical (or experimental) conditions.

	Can stimulus be seen? (i.e. is the person aware that there is a stimulus present?)	Can stimulus be perceived? (e.g. identified)	Can stimulus control behaviour?
Blindsight (Weiskrantz et al., 1974)	No	To some extent	Yes
Neglect (Driver, 1996)	If no extinction	No	To some extent
Visual object agnosia (Milner and Goodale, 2006)	Yes	No	Yes
Optic ataxia (Milner and Goodale, 2006)	Yes	Yes	No
Subliminal perception (Enns, 2004)	No	To some extent	To some extent

Table 1.1 Summary of visual impairment

It is clear that there are careful distinctions to be made between attention, awareness and perception, and to discuss attention thoroughly and in context of this thesis, a separate section is now dedicated.

1:4:1 Attention

There is a profusion of stimuli competing for attentional resources at any one time and the selective processing of the emotional significance of stimuli is

said to have an evolutionary advantage (Pessoa et al., 2002a), in that positive and negative affect modulates appetitive and defensive behaviour, ultimately leading to reproduction and survival. As such, only a fleeting glimpse of an emotionally relevant cue is sufficient to reach awareness and perception (Lang et al., 1997). In addition, when the attentional resources directed to a stimulus are severely limited over time, as in experiments that render neutral target stimuli invisible by using visual masking paradigms, emotional stimuli are still detected, especially fear-related stimuli (Dolan, 2002). Therefore, perception of emotion can take place automatically in the absence of attention (Vuilleumier et al., 2001). This view is supported from studies investigating the rapid responses of the amygdala for fast detection of emotional stimuli without attention or reported conscious awareness. For example, during an emotional learning task two angry faces were presented either as a pair or one face paired with an unconditioned stimulus. The faces were then re-presented in a backward masked or unmasked paradigm whereby participants indicated the presence of an angry face by means of a button press. Using PET, it was found that a lateralised amygdala response was dependent upon level of awareness, in that the unmasked stimuli enhanced the left amygdala and the masked stimuli enhanced the right amygdala (Morris et al., 1998b). Another masking experiment using fMRI demonstrated greater activation in the amygdala in response to nonconscious processing of fearful faces as compared to happy faces (Whalen et al., 1998b).

However, Pessoa et al. (2002b) has argued that even emotion-laden faces need some level of attention. Using fearful, happy and neutral faces in an fMRI experiment, it was made evident that processing of emotional stimuli in the amygdala, fusiform gyrus, insula, ACC, superior temporal sulcus (STS) and prefrontal cortices would only occur when sufficient attentional resources were available. Examination of these results led Pessoa and colleagues to argue that previous experiments claiming unconscious processing of emotion did not fully engage attention by a competing task. As an example, Pessoa discusses an experiment conducted by Vuilleumier et al. (Vuilleumier et al., 2001), and argues that any indication of automatic processing of affect was evident because a less attentionally taxing paradigm was employed whilst measuring attention and valence. Therefore, Pessoa et al. concluded that emotion-laden

facial expressions are not automatically processed, but are under top-down control (Pessoa et al., 2002b).

In light of these divergent points of view concerning the role of attention in processing emotional stimuli, some main theories of attention will now be reviewed.

To prevent information overload from the immeasurable onslaught of sensory information, our brain has limited capacity to attend to every detail. In fact, if only two tasks that require attention are carried out simultaneously, one will interfere with the other (Koch, 2004). *Change blindness* (Grimes, 1996, Simons and Levin, 1997) is a powerful demonstration of the failure to detect what can sometimes be an enormous change between two previously indistinguishable scenes because attention was not on the specific point of detection, or the saliency of the target was not strong enough to draw attention to it (Beck et al., 2001, Wright, 2005). Correspondingly, by fixating on a cross and deciding which arm was longer, participants failed to detect an unannounced introduction of a small coloured geometric shape. This phenomenon is known as *inattentional blindness* (Mack and Rock, 1998), and is another example of needing attention to see (Noe and O'Regan, 2000).

The main purpose of attentional processing therefore, is to choose selected information for further processing and in so doing ignore other information. This has led to theories of competition between neuronal representations such as the biased competition model, that favours a bias towards relevant information for behaviour and motor responses (Desimone and Duncan, 1995).

To explain the selection process of attention, the majority of historically important theories have followed the 'pipeline' model. The original proposal for a pipeline model (Broadbent, 1958), and a revised version (Zeman, 2001) both state that preconscious sensory filters act as an 'attentional bottleneck' as if, metaphorically, on guard duty as to what may pass 'into' conscious processing (Broadbent, 1958, Zeman, 2001).

The Filter Theory originally proposed by Broadbent (1958) was based on experiments on selective listening, as inspired by the 'cocktail party problem' (Cherry, 1953) whereby many conversations are being conducted in parallel, but individuals are able to listen and understand only one.

Distinctiveness in the physical features of the different speech streams makes them easier to separate. In an early selection model two stages of processing occur. First, all incoming information would be filtered for physical properties (e.g. loudness, pitch of voice, ear of origin) and second, higher level psychological data would be processed (e.g. meaning). The cognitive processes involved in this higher level analysis would have limited capacity due to the possible multiple meanings available. Hence, the emergence of the hypothesis of a selective filter guarding against overload, meaning that unattended information would not filter through a 'bottle neck' (Broadbent, 1958).

As in the early selection model, late selection theory also proposes two levels of perceptual processing. The first unconscious level identifies and rejects non target stimuli in parallel. Non target stimuli, however, are identified and rejected on the basis of meaning, whereas the early selection model extracts simple characteristics only, such as colour. In order to preserve the most relevant information, the output passes into a limited capacity system into awareness. (Deutsch and Deutsch, 1963, Norman, 1969)

Research investigating visual attention has often used a visual search task whereby a target, such as a letter T, is detected amongst a number of distractors, such as a letter L. The success of detection is facilitated by the level of difference between the target and distractors in terms of colour, form, location and size of movement. According to feature integration theory, several object features such as orientation and colour are coded with separate feature maps. These are then integrated in parallel into a saliency map. If the target does not share the same features as the distractors, it 'pops-out'. A feature search for simple targets that are defined by elementary features is performed rapidly and pre-attentively, whereas a conjunction search combining these elementary features takes attentional resources that are needed to evaluate and bind the object features correctly. This takes longer when the numbers of targets increase in an array of distractors, because the 'search light' has to attend to each object in turn. The main premise of feature integration theory, therefore, is that attention binds primitive features into objects (Treisman and Gelade, 1980). One of the criticisms of feature integration theory is that it

requires that primitive features are processed preattentively, as in an early selection model.

The early vs late selection debate is still argued, but one contributor has tried to resolve this issue. Whilst reviewing previous research, Lavie found a basic inconsistency in comparative methodologies. Experiments espousing late selection typically based their findings on low perceptual load, whereas supporters of early selection favoured paradigms employing higher perceptual load (Lavie and Tsal, 1994). Consistent with perceptual capacity limitations of early selection and assumed automatic late perception, the load theory of attention asserts that if task-relevant (targets) of high perceptual load (e.g. multiple stimuli) 'take up' full capacity there is no capacity left to process task-irrelevant (distractors) stimuli. However, in situations where the target is of low perceptual load (e.g. one target, one distractor), capacity is not taken up and what is left will process the distractors (Lavie, 2005).

Another major contributor to limited capacity theories of visual attention is Posner. Posner et al. (1980) conducted an experiment whereby a cued and non-cued light was randomly flashed up on a screen in one of four locations. Participants were instructed to push a button immediately they saw the light. Reaction times were faster for the cued stimuli than the non-cued, thus suggesting that detection is more efficient when highlighted by a location in space, hence the spotlight metaphor used to describe focal attention (Posner et al., 1980). However, the spotlight metaphor has been criticised for its incomplete analogy. For instance, a spotlight scans localities, whereas attention disengages and relocates (Cave and Bichot, 1999). A more comprehensive metaphor was introduced to illustrate the on/off analogy, that of a stage light which illuminates various actors/stimuli in turn (Sperling and Weichselgartner, 1995).

Focal attention (spatial search), feature-based attention (feature search) and selected attention (look for one feature in a whole object and receive further object information) are all examples of top-down, goal-directed processing which is generated from outside the visual cortex; and evidence from many studies points to the involvement of a fronto-parietal network, reviewed by Corbetta (Corbetta, 1998). A criterion not yet discussed that is relevant for visual attention is saliency, i.e. a stimulus that is conspicuous

relative to its surroundings. Independent of focal attention, a salient object is stimulus driven, faster, more potent and is relevant for selection purposes and automatically attracts bottom-up attention. Saliency makes feature selection easy and conjunction selection more difficult. A flying insect on a still summer afternoon or a lone bluebell in a field of sunflowers are blatantly obvious in relation to their surroundings (Koch, 2004). This conspicuous selection is managed by the neurons in a saliency map, thought to be in the visual cortex (Treue, 2003), that are encoded for prominence. The most prominent input will have the maximum neuronal firing rate to secure attention via a gating procedure. Neurons excite and suppress one another and a 'winner takes all' mechanism continues in a searchlight manner for a short time and inhibition of return automatically causes a move onto the next salient location (Koch and Ullman, 1985).

According to an influential theory (Koch, 2004), visual attention is gained within a hierarchy of visual areas processing competitive interactions from signals from visual input. Higher areas send bias signals modulating bottom-up saliency which focused attention responds to (Braun, 2003). Hence, awareness occurs with the combination of both bottom-up and top-down feedback, combining an interactive model of entry and reentry connections (Koch, 2004).

Theories of attention and capacity limitations have considered both bottom-up and top-down processing hypothesising a serial visual search. This principle, however, has been challenged with the work of Li et al. (2002) who used categorisation tasks within briefly flashed natural images and found that this rapid and fairly complicated visual search connected with high level cortical regions. Their participants were able to identify animals and vehicles within natural scenes, which represent a level of processing beyond the extraction of simple features. Moreover they were able to do this in peripheral vision while carrying out an attentionally demanding letter discrimination task at the fovea. These findings challenged previous theories of attention by contesting preceding notions of capacity limitations (Li et al., 2002) (see also section 1:7:2).

To elaborate further, studies investigating attention with natural everyday images will now be discussed.

1:5 Vision and Natural Images

The visual cortex has been described as a highly evolved connectionist system organised as feedforward networks in parallel processing layers (Thorpe and Imbert, 1989). Thorpe and Imbert (1989) have shown on the basis of timing arguments that only a single forward pass is enough for a significant amount of visual analysis. In a tight linear fashion, as each unit emits one spiking discharge, the next unit in a subsequent layer has to respond. These electrical firing rates in themselves are not enough for efficient coding, but the addition of spikes (or action potentials) from different sources, (e.g. the enormous parallel processing indicative to visual system), enables precise coding of analog information. Thorpe and Imbert (1989) also discuss the presence of feedback pathways, but postulate that normal visual processing does not have the time to take advantage of these except for taking into account other perspectives such as imagery, attention, context etc. Equally, the advantages of extensive parallelism almost eradicate the need for iterative loops (Thorpe and Imbert, 1989).

Specific information is communicated rapidly between neurons (Koch, 2004) and at only one spike per neuron at each processing stage, the most strongly activated neuron fires first with others firing at different times, and this firing order of units is called *Rank Order Coding* (VanRullen et al., 1998). This is just one example of coding that considers the pattern of spikes and the order in which neurons fire. Other coding schemes of the same ilk include: *Count Code* whereby the number of neurons are counted that have spiked; *Binary Code* which is a more efficient way of counting neurons that have spiked, but does lose its validity over relatively longer periods of time; and *Codes using Synchrony* to group neurons into possible phases in a small period of time. The computational implications of different combinations of neurons afford far greater insight into the mechanisms to rapid visual processing of complex stimuli (Thorpe et al., 2001a).

This is by no means an exhaustive list, but these models do illustrate the possible efficacy and flexibility of different coding schemes that consider spiking neurons.

These hypotheses run counter to traditional coding models, whereby a firing *rate code* is calculated by the mean of a continuous value of a sequence of spikes which transmit information carried by each neuron. The advent of research into the visual processing of natural images has brought into question the efficiency of this conventional view, as it does not accommodate rapid visual processing of complex tasks such as animal detection in everyday images. Such Ultra Rapid Visual Categorisation (URVC) was previously thought to be privy to certain categories only (e.g. faces) (Thorpe et al., 2001a).

To discuss the apparent features of URVC, a brief explanation is necessary. From the retina, projections are sent to the thalamic relay station called the lateral geniculate nucleus (LGN), which in turn sends signals to the primary visual cortex (V1). Contained in the LGN are two major classes of neurons. The magnocellular neurons do not show differential wavelength responses from inputs from red, green and blue cones and are therefore considered colour blind (Livingstone and Hubel, 1987). They are also transient with large receptive fields affording excellent contrast sensitivity and temporal resolution. It has been proposed that they mediate information regarding motion and depth. The parvocellular cells respond to colour and form, their receptive fields are smaller, and they prefer slower sustained input. It has been proposed that they mediate fine grained processing for high-acuity vision (Koch, 2004).

It has been argued that URVC relies on the faster magnocellular pathway as monochromatic images are processed more effectively than colour images (Delorme et al., 2000). In an experiment presenting photographs for 30ms in a categorisation task with animals or food as targets, it was found that coarse achromatic information was rapidly processed, indicative of the magnocellular pathway (Delorme et al., 1999). A subsequent go/no-go study supported this view, suggesting that magnocellular (achromatic) information reaches V1 approximately 20ms before parvocellular (chromatic) (Nowak et al., 1995) information and as such may be enough for object recognition associated with the ventral stream (Mace et al., 2005). However, functional interpretations of differences between the magnocellular and parvocellular systems are controversial. The anatomical differences that indicate a distinction between colour sensitivities is not in question. Other functional

differences, however, are difficult to evaluate as beyond the retina, the two magnocellular layers and four parvocellular layers in the LGN unite into the primary visual cortex (V1) pathway, which complicates investigation. Critics also argue that ascribed functional differences derive from averaged data and reflect marginal differences in receptive field properties (Skottun and Skoyles, 2006).

As already mentioned, URVC does not appear to be category specific. URVC for animals, food, novelty, as well as vehicles demonstrates that biological significance is not relevant (VanRullen and Thorpe, 2001c). Furthermore, animal detection in natural images with a brief exposure duration of 28ms flashed at unpredictable locations, provided evidence of highly efficient processing in peripheral vision (Thorpe et al., 2001b). That said, recently it was found that ultra rapid face detection in natural images was even more efficient than animal detection. Using a saccade task, accurate response to the face stimuli was less than 120ms. With only time for a feedforward pass and one spike per neuron it was hypothesised that the familiarity of faces and their very frequent presentations 'trains' neurons to fire sooner at each exposure. Thorpe explains that when visual input is unfamiliar, the afferents will not have sufficient strength in connections to initiate quick response for a neuron, therefore many afferents are necessary. With repeated stimulation, however, some afferents are strengthened until a relatively small number are sufficient to spark the neuron more and more quickly. Therefore, just a few combinations of visual features would be enough to process faces very rapidly indeed (Thorpe et al., 2006).

This premiss, however, contradicts an earlier categorisation study. Using novel images it was found that, even after a three week training period, speed of processing did not improve. The inferences made were that complex novel stimuli were processed as efficiently as familiar stimuli, suggesting that context is not necessary and the speed of visual categorisation is a highly automatic feedforward procedure (Fabre-Thorpe et al., 2001).

There is no doubt that the evidence for the remarkable speed of visual processing of complex images will lead to some fascinating insights, new experiments, and much conjecture. Fast feedforward, one spike per neuron mechanisms have plausibly shown how complex natural images can be

processed rapidly, with neuroimaging and innovative paradigms proving to be efficient tools in this line of enquiry.

1:6 fMRI Regions of Interest

The cortical areas reviewed in this section have been functionally charted in previous fMRI research as having particular importance in affective or cognitive/affective processing. The nine regions of interest (ROIs) discussed in this section are: amygdala, anterior cingulate cortex (ACC), medial prefrontal cortex (mPFC), orbitofrontal cortex (OFC), dorsolateral prefrontal cortex (DLPFC), parahippocampal gyrus, fusiform gyrus, insula, and superior temporal gyrus (STG). A brief summary of each will now be discussed in relation to the variables of interest in this thesis. It is prudent at this point to signpost the fact that neuroimaging studies have progressed at a fast pace and investigations have moved beyond functional localisation to analysis of distributed networks, most recently identifying remote but interconnected networks that are mutually influential in terms of affect (Vuilleumier and Driver, 2007). As this is an investigation using a wide range of complex affective stimuli, however, it is wise to consider functional localisation for comparison purposes with previous findings using simpler affective stimuli relative to the nine selected ROIs.

1. Amygdala

A cluster of nuclei, the amygdala (from Greek 'almond') is an almond like shape situated in the medial temporal lobe at the tip of each hippocampus and is the core of one of the major limbic circuits (Figure 1.2, p 37). As such, it is highly complex in its emotional functions and its projections to subcortical and cortical regions (Sah et al., 2003). However, for the purposes of this discourse, the amygdala will be referred to and discussed as a single unit involved in various functions with emotional processing.

There is an abundance of literature associating the amygdala with fear-related processing and fear-conditioning (Adolphs et al., 1995, LeDoux, 2003, Morris et al., 1998a, Whalen et al., 1998a). However, there is also growing

evidence of the diversity of its functions. For instance, the amygdala has been found to interact with systems associated with cognition and awareness. This has supported the notion that there is an interaction between emotion and cognition. Take, for instance, emotional regulation, which refers to cognitive reappraisal of a situation to 'defuse' an emotional response. A study by Ochsner et al. (2002) found more activation in the amygdala when attending to images of emotional scenes than when reappraising the same category of images (Ochsner et al., 2002). There is also evidence that the amygdala is involved in the enhancement of attentional processing, perhaps by altering perceptual processing. As the amygdala is highly interconnected with reciprocal connections to the sensory cortex, it is able to provide a constant vigilance and reappraisal of emotional stimuli. This monitoring of the significance of input is mediated by two pathways through which the amygdala receives information. One is via a subcortical route that transmits fast, coarse visual information bypassing cortical processing, and the other is a slower, more complete sensory processing from the cortical sensory regions (LeDoux, 1998). Amygdala activation via this subcortical route (e.g. for fear perception) (Vuilleumier et al., 2003b) affords a response to stimuli presented below the threshold of conscious perception (e.g. a response to a fearful face even in the absence of awareness of the face) (Morris et al., 1998b, Whalen et al., 1998b). The amygdala response to significant but unattended stimuli appears to temporarily engage the cortical areas in conscious adaptive behaviours (Baars and Gage, 2007).

There is also evidence to suggest that the amygdala has a more generalised role in emotional processing, which includes the detection of stimulus salience (Liberzon et al., 2003) and the recognition of social emotions through facial expressions such as happiness (Adolphs et al., 2002, Breiter et al., 1996), sadness (Blair et al., 1999) and anger (Whalen et al., 2001). It is apparent that the amygdala responds to valence in facial expressions, but it has also been found that the amygdala rapidly habituates to these stimuli (Breiter et al., 1996).

A recent synopsis collating evidence from animal and human studies summarised the functions of the amygdala as a set of cognition-emotion interactions: "implicit emotional learning and memory, emotional modulation

of memory, emotional influences on attention and perception, emotion and social behaviour, emotion inhibition and regulation" (Phelps and LeDoux, 2005, p 175).

It is also interesting to note that the modulation of levels of affective arousal is associated with the amygdala. For instance, a patient who underwent a right temporal lobectomy which included ablation of the right amygdala, was asked to rate a series of affective visual stimuli. Measures of valence were concordant with the calibration of the stimuli, however, arousal scores differed significantly, with pleasant images rated high in arousal and unpleasant images low in arousal, equivalent with the arousal scores of neutral images (Morris et al., 1991).

2. Anterior Cingulate Cortex (ACC)

The ACC is a 'collar' partially surrounding the corpus callosum and situated in the mPFC and forming the uppermost part of the limbic lobe (Figure 1.2, p 37). Therefore it is anatomically linked to the PFC, and traditionally its function has been linked to emotion. It has afferent and efferent connections with the hippocampus via cortical circuits, and it has numerous connections with other areas in the limbic system (Nolte, 2002). Recent studies have identified its role in monitoring the autonomic nervous system (ANS), such as heart rate and blood pressure (Matthews et al., 2004, Xiao and Barbas, 2004). The importance of the ANS is in organising the bodily response to motivational and emotional states, and the perception of these states in signalling bodily states of arousal is integral to emotional and cognitive awareness and appraisal (Critchley et al., 2002). The orbitofrontal and insular cortices are two areas anatomically and functionally connected to the ACC and which have also been linked with ANS stimulation (Oppenheimer et al., 1992).

The diversity of the functions ascribed to the ACC suggests that it is significant in emotional and cognitive processing and the monitoring of complex behaviours. These functions include associations with working memory, attention and emotion (Bush et al., 2000, Damasio, 1994), emotional processing (Vuilleumier et al., 2001), the mediation and interaction of cognitive and emotional tasks (Reiman et al., 1997, Whalen et al., 1998a, Bush

et al., 2000), voluntary attention and divided attention as evidenced by conflictual tasks (Bush et al., 2000), reward (Breiter et al., 1997), anticipation of affective stimuli (Bermpohl et al., 2006) and pain and empathy (Becerra et al., 2001, Singer et al., 2004). In fact, it has been suggested that the ACC may be the start point for urgent signals, such as pain, and redirects the information for further neural processing (Rose, 2006). There is also evidence that the ACC responds to angry facial expressions (Blair et al., 1999) and that this region identifies emotional significance, then responds and regulates a reactive affective state (Phillips et al., 2003).

A connection between emotions, the amygdala and the ACC is long-established in previous literature (Papez, 1937, McLean, 1949). The selection of the amygdala and ACC as ROIs for the present study was based on the work of Damasio (1994), who asserts that if a person knows that something causes fear there are two ways of behaving. The first is a reaction out of our conscious control, it is innate. The second way is to avoid the situation, based on past experience. The innate feeling, Damasio argues, is a primary emotion that depends on prime systems such as the amygdala and ACC (Damasio, 1994). Further evidence of an interaction between these two regions comes from data mapping signals of valence responses from the amygdala to the ACC, which is activated when a cognitive task is required to process emotional stimuli (e.g. as in rating emotional stimuli) (Phan et al., 2002).

3. Medial Prefrontal Cortex (mPFC).

The PFC is associated with emotional and social behaviour and inhibitory control over emotion and consciousness (Solms and Turnbull, 2002). The earliest and most famous case study of damage to the PFC was that of Phineas Gage who, whilst working with dynamite, became victim of a freak accident whereby a tamping rod was propelled through his cheek bone through the frontal lobe and out through his skull, the speed of which cauterised the wound and he survived without even losing consciousness (Harlow, 1848). The selective damage included the mPFC and OFC (Damasio, 1994). The consequences were a distinct change in personality, partly characterised by an inability to plan for the future and a complete disregard for social norms that he

previously adhered to, thus rendering his behaviour socially unacceptable (Harlow, 1868).

The mPFC (Figure 1.1, p 37) has also been associated with the OFC for emotional self-regulation and suppression of sadness in children (Levesque et al., 2004) and, as in the OFC, the ventromedial prefrontal cortex has been associated with reward and punishment (Bechara et al., 1999).

Experiments using film clips to elicit emotion, and studies employing the personal recall of happy and sad experiences, or the generation of disgust, have also reported activation in the mPFC (Lane et al., 1997b, Reiman et al., 1997).

mPFC activations are evident both with and without cognitive demand, such as the rating of emotional stimuli (Phan et al., 2002). Responsiveness to cognitive load would be expected from the proposal that the PFC is a top down modulator, (e.g. if an automatic task suddenly needs conscious control, the PFC is activated) (Dehaene and Naccache, 2001). However, studies investigating the ventral mPFC (vMPFC) have shown significant activations when processing emotional tasks without associative cognitive processing (Grimm et al., 2006, Phan et al., 2002).

The connectivity of the vMPFC affords cross-modal involvement as it is afferent from all five sensory modalities (Barbas, 2000).

A study investigating the emotion surprise highlighted that the mPFC, which is known to be reciprocally connected to the amygdala, was activated during presentations of surprised facial expressions and not to fear-related stimuli (Kim et al., 2003).

It is hypothesised that the mPFC holds an attentional role in order to differentiate between conflicting inputs from other brain regions (Simpson et al., 2001a, Simpson et al., 2001b). A study investigating anticipation of stimuli in terms of spatial location found significant activations in the mPFC for expected motivational affect, indicating a role for attention and motivation (Small et al., 2003).

4. Orbitofrontal Cortex (OFC)

The OFC sits above the orbits of the eyes in the ventral prefrontal lobe (Figure 1.1, p 37) and in part receives information from the inferior temporal visual cortex relaying information regarding the representation of objects. Receiving afferents from the amygdala and projections to and from the ACC (to name but a few of its limbic connections), the OFC, once damaged, results in emotional changes such as irresponsibility, impulsiveness and immaturity (Rolls, 2005).

A recent fMRI study demonstrated activations in the lateral part of the OFC with punishment and the medial OFC for monetary rewards (O'Doherty et al., 2001). Activation in the ventromedial prefrontal cortex has also been identified with reward and punishment (Bechara et al., 1999). The right OFC has also been associated with voluntary suppression of sadness (Levesque et al., 2003). There is also evidence that the OFC responds to facial expressions such as anger (Blair et al., 1999).

The medial OFC has been related to emotional processing whereas the lateral OFC is said to specialise in emotion-cognition synthesis (Drevets and Raichle, 1998).

5. Dorsolateral Prefrontal Cortex (DLPFC)

DLPFC (Figure 1.1, p 37) is connected to the orbitofrontal cortex and is associated with working memory and executive functions. It has recently been of interest to those seeking neural correlates of consciousness (Lau and Passingham, 2006). Again, a variety of functions has been ascribed to it.

This area is associated with processing spatial information to facilitate the ability to learn sequences of actions via cortical and subcortical regions (Robertson et al., 2001).

A recent study using IAPS stimuli comparing emotional perception and expectancy observed activations in the DLPFC for emotional perception (Bermpohl et al., 2006). The DLPFC is also associated with emotional self-regulation with the RH as part of a neural circuit in voluntary suppression of sadness (Levesque et al., 2003).

Evidence suggests that the DLPFC continues developing until late adolescence. It is not until this stage that cognitive control abilities are fully matured, as demonstrated in a go/no-go task investigating voluntary suppression and inhibition of response (Durston et al., 2002).

Recent studies are highlighting hemispheric lateralisation in the PFC, with the left DLPFC cited for the possible integration of emotion and memory, and encoding nonverbal material lateralised more to the right (Sergerie et al., 2005).

The DLPFC has been shown to be involved in emotional evaluation and regulation, thus suggesting a more generalised role in emotional processing (Phan et al., 2002). Lesion studies support this premise, for instance patients with damage to this region are said to be devoid of personality with a general indifference and flattening effect (Baars and Gage, 2007).

It is also hypothesised that the site of the selective control of attention location is in the DLPFC as part of the PFC (LaBerge et al., 2000).

6. Parahippocampal Gyrus.

Adjacent to the hippocampus (the core of another limbic circuit), the parahippocampal gyrus (Figure 1.3, p 38) receives afferent projections from multiple areas and is efferent to the hippocampus (Gupta, 1999, Nolte, 2002).

Within the parahippocampal gyrus is an area known as the parahippocampus place region (PPR) because it responds to scenes, landmarks and houses (Epstein and Kanwisher, 1998, Epstein et al., 1999, O'Craven and Kanwisher, 2000).

This region has also been associated with surprise and novelty detection (Schroeder et al., 2004), with weak responses found when processing bodies, faces and inanimate objects (Baars and Gage, 2007).

7. Fusiform Gyrus

The fusiform gyrus is a long gyrus that runs along the inferior surface of the cortex from the temporal lobe to the occipital lobe (Figure 1.3, p 38), hence it

is also known as the occipitotemporal gyrus. It is also bound medially by the parahippocampal gyrus (Nolte, 2002).

Part of the fusiform gyrus has been especially identified for processing faces, this area is known as the fusiform face area (FFA) (O'Craven and Kanwisher, 2000, Schultz et al., 2003). Damage to this area can result in prosopagnosia, an inability to recognise faces (Wada and Yamamoto, 2001). The FFA has also been associated with the processing of emotional facial expressions. Ganel and colleagues (2005) found that the FFA showed higher activations when making judgements of facial expressions than when making judgements of facial identity (Ganel et al., 2005).

The FFA does not process faces exclusively as it is also activated when visually processing objects. One theory is that, as there is evidence for both face and object processing by the FFA, this area may be specialised in the expertise of object recognition, the idea being that whilst people are all experts at face recognition if visually able, testing subject-matter-experts with representations of their expertise may also reveal activation of the FFA. Car and bird experts were presented with faces, familiar objects, cars and birds. The results confirmed the 'expertise hypothesis' in that the RH did respond more favourably to the target stimuli for each group (Gauthier et al., 2000).

Although the FFA is very small, it is found that in the healthy, the FFA is larger in the RH than the LH (Koch, 2004).

8. Insula.

Situated at the floor of the lateral sulcus, the insula (its appearance is that of a separate island of cortex) is a large area of cortex which is concealed by the temporal, frontal and parietal lobes (Figure 1.1, p 37) and as a consequence of its hidden location is little understood (Solms and Turnbull, 2002). However, it is known to receive afferents from autonomic regions, sending efferents to brain regions such as the amygdala, which play a critical role in the regulation of autonomic response (Davidson and Irwin, 1999).

The insula is well documented for processing the emotion disgust (Calder et al., 2001, Phillips et al., 1997, Phillips et al., 2004). This may be because it is situated in an area known for gustatory processing, which is

associated with distaste (e.g. disliked food) and it is thought that distaste has evolved with increasing cognitive involvement into the emotion disgust (e.g. in avoidance of contaminated food) (Rozin et al., 1994). This account runs in parallel with the notion of a role of the insula in interoception, (e.g. gut feelings, feelings of inner organs) (Baars and Gage, 2007). The primary function of the insula could be interpreted as assimilating bodily information into cognitive and emotional systems. In fact, asymmetry of the insula is evident for control of autonomic activity, (e.g. LH yields parasympathetic effects and RH sympathetic effects) (Craig, 2005).

Others have argued that the insula has more of a generalised role in emotional processing (Critchley et al., 2002) such as identifying emotional significance and automatically responding with an appropriate affect (Phillips et al., 2003).

9. Superior Temporal Gyrus (STG).

Close to the lateral sulcus, the STG sits at the top of the temporal lobe (Figure 1.1, p 37). The size and configuration is different in each hemisphere, with the left generally being the larger (Nolte, 2002). Wernicke's area, responsible for speech perception and production, is adjacent to the auditory cortex in the Sylvian fissure and STG (Baars and Gage, 2007). The right STG has been linked to the processing of emotional vocalisations (Fecteau et al., 2007) and humour (Mobbs et al., 2005), but its functions are not limited to auditory and linguistic stimuli.

There is evidence that the STG responds to selective attention to emotional perceptions of faces (Narumoto et al., 2001). Others using fMRI with picture and film stimuli found activation in the STG when viewing joy/amusement and sadness (Britton et al., 2006a), and another study presenting visual stimuli evoking sexual arousal also noted significant activity in the STG (Yang, 2004).

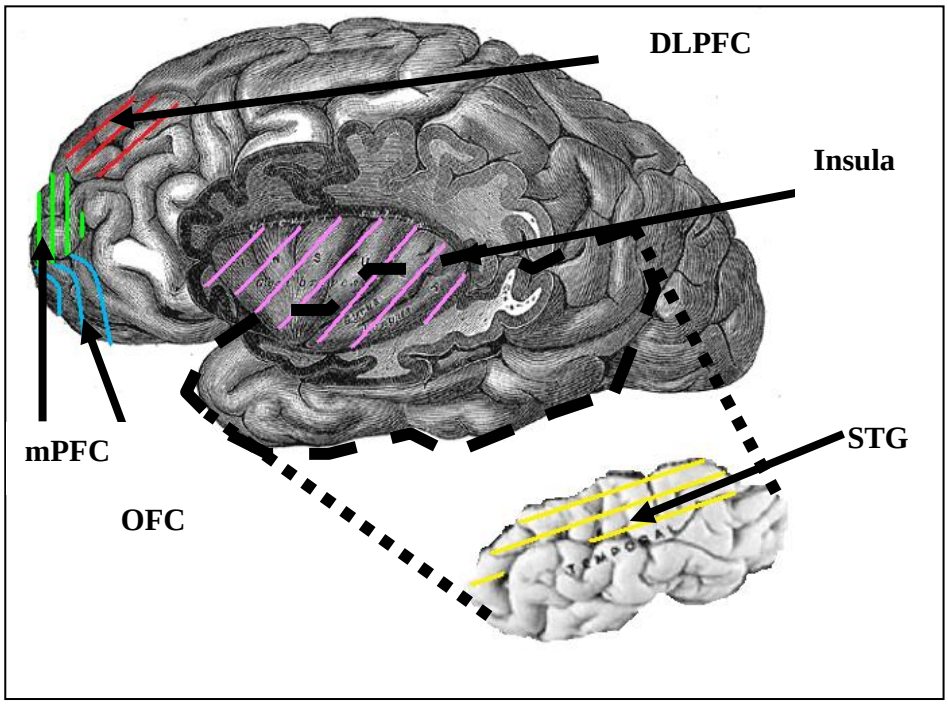


Figure 1.1 Lateral view of the brain showing selected brain regions – DLPFC; Insula; mPFC; OFC; and STG

Modified from:
http://basis.typepad.com/photos/uncategorized/2007/06/12/ashes2_21.jpg and
http://www.medicine.uiowa.edu/CDD/Images/brainSM.jpg

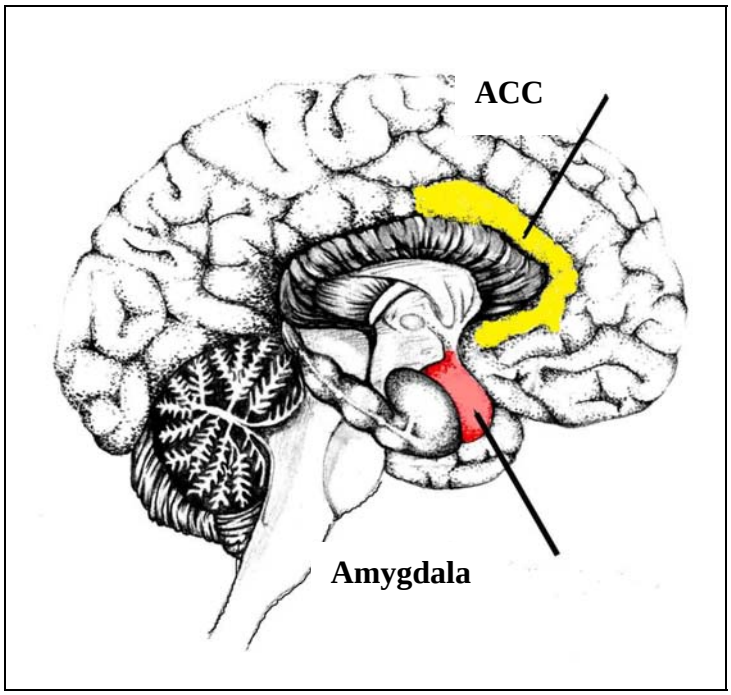


Figure 1.2 Medial view of the brain showing selected brain regions – ACC and Amygdala

Modified from:
http://thesituationist.files.wordpress.com/2007/06/amygdala.jpg

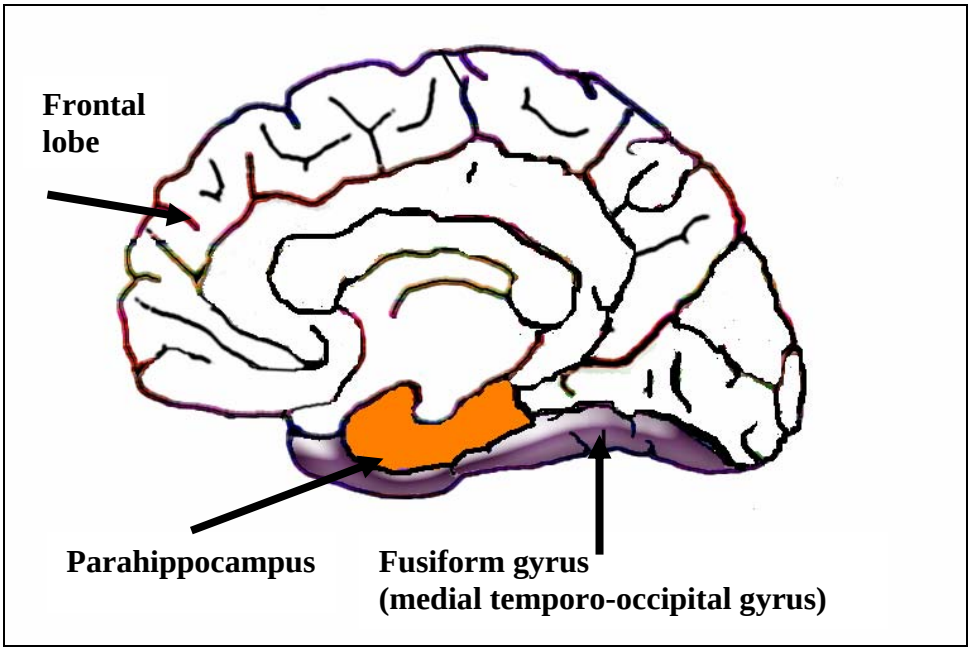


Figure 1.3 Medial view of the brain showing selected brain regions – Fusiform gyrus and Parahippocampus
Modified from:
http://www.psypress.com/zaidel/images/figures/figure3_3.jpg

All these regions continue to be the subject of lively debate as to their functions, and all nine target areas attract fervent research in both conscious and unconscious studies of emotion and are the framework for this discourse.

1:7 Processing of Complex Affective Visual Images.

1:7:1 Introduction

An enormous amount of data has derived from lesion studies, animal studies, behavioural and neuroimaging studies using simple visual stimuli. However, the volume of previous research using complex, natural, affective images is much more limited. The following section will therefore review studies that have used natural images to investigate early visual processing, studies using affective natural images including IAPS stimuli (focusing particularly on the issue of automatic emotional processing), and fMRI studies relevant to emotional valence discrimination in terms of the different levels of spatial scale available in natural images. This will highlight what is known, what has been tried, what has worked, what has been disputed, and what still needs to be

investigated. The review will therefore point towards and provide a rationale for the main research questions to be addressed in this thesis.

1:7:2 Natural Images

Using natural images, the effect of rapid serial visual presentation (RSVP) has been studied for nearly forty years. Potter and Levy (1969), for instance, were concerned with understanding how perception of rapidly presented images was processed in a recognition memory study using 16 static colour photographs of various complex pictures presented in rapid succession. The results of the subsequent recognition task led the authors to conclude that visual stimuli presented rapidly are not held in short-term memory, but are processed individually, dependent on viewing time (Potter and Levy, 1969). Potter continued using this paradigm in further detection studies whereby identification of the presence of a target, (e.g. a car), or recognition of a correct picture sequence, revealed that it takes as little as 100ms to understand a picture and therefore be immune to visual masking (Potter, 1976).

A very extensive literature from Thorpe and colleagues has continued this line of enquiry, demonstrating, for example, ultra rapid processing of complex natural images (20ms exposure) using ERPs (Thorpe et al., 1996). Investigating how fast the human visual system can process naturalistic images, they employed a go/no-go categorisation task. Their results indicated that less than 150ms of visual processing is needed to decide if an image contained an animal or not. Their findings provided evidence that a minimum of coarse information was enough to correctly decide the presence or absence of an animal in a natural scene. This level of rapid processing was previously thought to be associated with face processing only. On the basis of the many known neural stages of processing in the visual pathways, and the rapidity of visual processing in behavioural experiments, the involvement of a feedforward mechanism was speculated (Thorpe et al., 1996).

Thorpe et al. (2001b) noted that very little data was available on visual perception of natural images presented in the periphery. To investigate further, the same go/no go categorisation task was used with stimuli presented in the retinal periphery, in which unmasked natural images randomly appeared in one

of nine locations for 28ms. This challenging method of presentation meant that attention needed to be widely distributed across the visual field without time for saccades. Even under these conditions, a significant level of correct scores was recorded in the periphery. This experiment demonstrated that high-level analysis on coarse visual information is possible, regardless of the orientation of spatial attention in a fusion of characteristics such as colour, shape and size (Thorpe et al., 2001b).

Contemporaries of Thorpe have reported similar results. These include experiments using novel, compared to familiar, natural scenes in a go/no-go animal detection task (Fabre-Thorpe et al., 2001), faces compared to animals (Rousselet et al., 2003, Rousselet et al., 2004b), presenting one, two or four natural scenes in a peripheral paradigm (Rousselet et al., 2004c) and comparing 'natural' animals with 'artificial' means of transport (VanRullen and Thorpe, 2001a).

Together these findings support the concept of an automatic feedforward mechanism (i.e. bottom-up ascending wave of action potentials, non-iterative) and parallel processing, in that the processing of complex images does not necessarily need sequential focal attention, but can be rapidly accessed in parallel (Rousselet et al., 2002).

Thorpe and colleagues explain that if stimuli are presented for 10ms or less, there is only time for neurons to generate just one spike and the neuron to fire first is the most strongly activated one. Thus, the order of this rapid feedforward influence can be observed and inferences can be made about the stimuli (Thorpe et al., 2006).

Since Thorpe first set the temporal parameters for single-fixation visual processing at 150ms (Thorpe et al., 1996), others have since shown that the minimum saccadic reaction time was as little as 120ms. Using a forced-choice animal detection task, two complex images were flashed left and right of fixation. A simple decision of left or right was made with the mean reaction times at 228ms and a mean accuracy of 90% (Kirchner and Thorpe, 2006). As a result Kirchner and Thorpe reasoned that if saccades are made as quickly as 110ms with a 20ms initiation time lapse, this is further evidence of only a feedforward pass. To verify this explanation, Thorpe et al. (2006) carried out a version of Kirchner and Thorpe's saccade-choice task. Two images were

displayed for 400ms to the left and right of fixation; one contained a natural image of a human face and the other a natural scene. An electrooculogram (EOG) recorded the direction of the initial saccade, classifying eye movements towards the face stimuli as correct and the scene images as incorrect. The mean RT was 147ms with a mean accuracy of 94.4%, the highest level of accuracy was for the fastest RTs of 100-109ms stimulus onset asynchronies (SOAs) (Thorpe et al., 2006). The ultra-rapid success of face detection was seen as support for feedforward processing on two counts. Firstly, the work of VanRullen and Thorpe has shown that relatively large objects can be identified in complex images when <1% of ganglion cells in the retina have fired only one spike (VanRullen and Thorpe, 2001b). Secondly, (as briefly mentioned in section 1:5) studies have shown that by repeating stimuli presentations, a neuron will fire faster and faster, some synapses are strengthened and then depressed. If this process continues, the synapses become so strong that fewer are necessary to fire the neuron (Guyonneau et al., 2004). Thorpe raises the question that, if training has such an effect, then perhaps the fact that human beings process faces so often throughout their lives may mean that selective face detection is possible on very little information, which would explain the incredible speed of the face detection results (Thorpe et al., 2006) (see also section 1.5).

It should be noted at this point that much of the work by Thorpe and colleagues uses response times (RTs). RTs have the inherent disadvantage of including not only the time interval to process visual input, but also the time interval to initiate a motor response. Considering this, however, these experiments do demonstrate the incredible speed of visual processing, but this does not necessarily indicate the timing of the onset of a visual conscious percept. In fact, critics note that animal detection is achieved with virtually the same exposure duration with or without masking, even when participants have hardly consciously seen anything at all (Koch, 2004).

Equally, it is widely acknowledged that a single feedforward pass will not extract all necessary information about a complex image, therefore an animal detection task may also involve top-down influences (Fize et al., 2005), perhaps due to the involvement of the PFC for categorisation purposes even under ultra-rapid presentations (Masquelier and Thorpe, 2007). Others have

proposed that the visual system needs both feedback and feedforward loops in multiple computational arrangements to process complex natural images (Lee et al., 1998). For instance, Codispoti et al. (2006b), interested in the neural sources of selective attention, conducted a study using a forced-choice paradigm of whether an animal was present or not in a natural scene. They found that early ERP activity (150ms) indicated top-down influences facilitating the rapid categorisation task (Codispoti et al., 2006b). Hochstein and Ahissar (2002) also suggest that feed-forward processing can only extract a generalised interpretation of an image which they describe as "vision at a glance", whereas top-down processes are needed for more detailed conscious visual perception, in their words "vision with scrutiny" (Hochstein and Ahissar, 2002, p 791).

As mentioned in the introduction, other contributors, Li et al. (2002) compared simple visual stimuli – Ts and Ls – with natural scenes in attentionally demanding tasks. They found that, when challenging attention capacity with rapid peripheral categorisation of a single or dual task, the natural images were far more robust in speed of processing than the simple geometric shapes (Li et al., 2002). Even though Potter, Thorpe and contemporaries have continued to scrutinise the speed of visual processing of natural images, Li et al.'s experiment was considered pivotal because it demonstrated that observers could process the gist of a natural image outside the focus of attention more efficiently than simple shapes, thus challenging previous notions that only elementary features of an image such as orientation and brightness can be processed in the near absence of attention. As such, this counteracts the erroneous belief that capacity limitations can be generalised from traditional geometric shapes to natural images (Braun, 2003).

These papers try to explain how complex natural images can be processed rapidly and, of course, this debate is still being developed. By employing categorisation/detection tasks measuring RTs and/or ERP recordings, these contributions challenge traditional views of the necessity of serial focal attention for high level visual processing and elucidate the value and importance of using natural images. However, the question posed in this thesis is whether or not the affective content of natural images can be extracted in rapid, parallel fashion as is employed in the detection of animals, faces, or

means of transport. To continue this review, studies using affective natural images will now be discussed. This relevant but separate literature examines what happens when rapidly processed emotional stimuli are introduced, whereby affective evaluation takes place automatically, below conscious threshold for everyday images.

1:7:3 Affect and Natural Images including IAPS

Appetitive and aversive images evoke strong motivational, affective responses that rapidly modulate attention (Lang et al., 1997). Emotionally evocative images are used to induce positive (high valence) and negative (low valence) emotions with moderate to high levels of arousal, the highest levels of arousal being induced by erotica and threat, which are of primary biological relevance (Bradley et al., 2001a). Subjective reports, physiological events such as SCRs and bioelectric events have been used as measures of the temporal characteristics of emotional response (Lane and Nadel, 2000).

Using an oddball paradigm with mostly high arousal IAPS stimuli interspersed with unpleasant symbols and words, Schupp and colleagues (2000) showed that emotional pictures enhance late positive potentials (LPPs). A stimulus was displayed for 1.5s, followed by a categorisation task that took between 1.5s - 3s. The participants initiated each sequence. EEG and EOG readings firstly demonstrated that the LPPs did not change with intermittent symbolic stimuli and secondly, that the LPPs were similar for pleasant and unpleasant stimuli, which were both greater than those to neutral pictures. The authors concluded that affective stimuli sustain LPPs and LPP amplitudes increase with higher arousal and the motivational relevance of emotion-inducing stimuli modulates late ERPs (Schupp et al., 2000). Continued investigations support this conclusion. By using briefly presented stimuli at 120ms, it was found that LPP amplitudes during ERP studies were larger in response to late selective processing over centro-parietal areas and a greater negative shift in ERPs over temporo-occipital sensors indicated early selective processing at around 150ms (Schupp et al., 2003, Schupp et al., 2004). High arousal showed greater sensitivity, however Schupp et al. (2003a) noted erotic images elicited greater response than all other stimuli. They noted a problem

with the gender ratio in their sample (14 women and 2 men) and reflected upon gender differences being a consideration (Schupp et al., 2004).

These LPP findings were supported in an EEG experiment by Cuthbert et al. (2000) who were interested in assessing the brain's motivational systems when presenting affective images. Using pleasant and unpleasant IAPS pictures of high arousal and neutral stimuli, a positive voltage change began at 200-300ms, reaching maximum amplitude at 1s and sustained for 6s. In addition, they also found that the duration of the positive slow waves was maintained for 5s, suggesting continued affective perceptual processing. This suggests that the processes giving rise to the LPP begin relatively early and that consequently the emotional content is at least partially identified by this stage. Together, these results were interpreted to mean that affective stimuli reflect activity in motivational organisation in the brain and greater allocation of attentional resources due to the intrinsic biological nature of the stimuli (Cuthbert et al., 2000).

Consistent with these results, LPPs were greater when viewing emotionally arousing stimuli than neutral stimuli in the absence of external cues, judgement tasks or responses. Neither valence nor arousal affected the outcome, but Anokhin et al. (2006) recorded early content-specific ERPs by erotic stimuli as opposed to non-erotic stimuli at 185ms in the fronto-central region. The distinct rapid automatic discrimination when passively viewing erotica compared to all the other positive, negative, and neutral stimuli, led them to speculate a specific neural network for processing biologically and evolutionary relevant stimuli. However, the content of some of the other pictures was also biologically significant, (e.g. threat related scenes), from which they further hypothesised that the apparent content dissociation may be specific to social meaning as opposed to biological significance. The study was limited in as far as the sample group were all female and only a small number of EEG electrodes (19) were used, which casts a doubt over the accuracy of localisation of electrical activity. The results of content specificity associated with fronto-central regions are unusual in ERP studies, whereby more general measurements of neuroelectrical responses relating to affect are the norm (Anokhin et al., 2006).

Hajcak et al. (2007) were interested to know if a difficult concurrent task would modulate electrocortical response to everyday images of emotional content. Using a mathematical competing task they presented positive, negative and neutral IAPS stimuli for 2000ms in an EEG study. In line with previous passive viewing paradigms, LPP modulation was greater for positive and negative stimuli than neutral stimuli and the concurrent competing task had no impact on affect, although the mathematical performance was not measured in terms of influencing emotional processing (Hajcak et al., 2007).

Investigating affective anticipation in an EEG study, Takeuchi et al. (2005) set out to refine previous findings on the effect of emotional content on stimulus-preceding negativity. By manipulating negative, positive and neutral IAPS stimuli they found that the negative pictures elicited higher arousal during the anticipatory period (Takeuchi et al., 2005). In support of these results, a recent study investigating a bias in attention towards negative IAPS stimuli presented for 1200ms, observed greater amplitude in P2 in response to negative affective stimuli than positive, indicating very early negativity bias. There was also a greater amplitude in late positive components (LPC) to negative stimuli, demonstrating later evaluative processing, and a shorter lateralised readiness potential (LRP), meaning a negative shift preceding motor processes, signifying a faster response to negative affective stimuli, thus demonstrating a negative valence bias (Huang and Luo, 2006).

Equally, ERPs were able to detect differences between early and late processing of targets, however due to spatial resolution constraints, interpretation of ERP activity was restricted, both in terms of inferences about the brain structures giving rise to the waveforms studied, and inferences about their related functions (Huang and Luo, 2006).

So far, it has been demonstrated that pleasant and unpleasant images evoke larger LPP responses than neutral images and that ERP responses are sensitive to motivational biological relevance (Bradley et al., 2003). On the whole, emotional arousal was reflected in the ERPs, but to a lesser extent so was valence in that greater ERP positivity was found for unpleasant images than pleasant or neutral images (Cuthbert et al., 2000).

Additionally, SCR has been widely used to investigate rapid affective processing. Investigating hemispheric differences to IAPS emotional visual

stimuli in a masked paradigm, Kimura and colleagues (2000) presented target stimuli in the left or right visual field for 30ms with EOG and no saccadic eye movements were indicated. They found right hemisphere dominance (RHD) in SCR response to negative stimuli without awareness (Kimura et al., 2004). However, only negative and neutral stimuli were used and the sample group were purely male, therefore, valence bias and a biased sample render it difficult to generalise. All the same, a previous study recorded RHD for briefly presented stimuli with greater effect for negative stimuli than positive (Hartikainen et al., 2000).

Pleasant IAPS pictures were employed by Ribeiro, et al. (2007), to investigate physiological responses to arousal. Measuring facial electromyographic (EMG) activity, heart rate, SCRs and peripheral temperature, eight highly pleasant arousing, eight highly pleasant relaxing, eight neutral and eight highly unpleasant arousing IAPS pictures were used. The rationale was that sets of pleasant photographs may contain mixed arousal levels because they included 'arousing' and 'relaxing' pictures (Ribeiro et al., 2007). This logic seems flawed. First, if all the pleasant and unpleasant stimuli were rated equally for arousal there would be no need for two subsets in the pleasant category. Secondly, the valence bias could distort the results. However, the overall findings were that physiological responses varied depending upon valence and arousal.

Prior to this experiment, in order to examine the organisation of emotional perception in terms of motivational systems such as pleasure and arousal, Lang and colleagues (1993) presented IAPS stimuli for 6s, implemented ratings, personality and cognitive attributes questionnaires and then re-presented the stimuli measuring corresponding feelings. Regardless of personality factors and gender differences, a significant relationship was found between facial EMG, output valence judgements and SCRs with arousal (excited/calm) (Lang et al., 1993).

Other contributors have found larger electrodermal responses such as SCRs for high arousing stimuli such as threat and erotica (Bradley et al., 2001a, Bradley et al., 2001b) and a correlation between valence and facial EMGs (Davis et al., 1995).

By using physiological methods such as EMG and SCRs and adding affective information to RSVP, autonomic and somatic responses indicate emotional processing of rapidly presented affective stimuli. This was evidenced in a rapid picture viewing paradigm whereby physiological responses were heightened when viewing unpleasant IAPS stimuli as opposed to pleasant and neutral pictures (Smith et al., 2006).

It is clear by the evidence presented here that natural images are successfully used to investigate affect when using the temporal advantages of electrodermal responses measured by SCR and neuroimaging techniques such as EEG. Equally neural activity measures such as ERP are highly sensitive to synchronised firing of neurons but have indeterminate spatial resolution. One of the advantages of using fMRI is that it provides excellent spatial resolution without depending on fine temporal scales. Therefore, fMRI and affect will now be discussed in detail, examining studies of both conscious and unconscious affective processing.

1:7:4 fMRI

Measuring the Blood Oxygenation Level Dependent (BOLD) response to regional blood flow changes affords more accurate spatial data with regard to brain circuitry and functions. This has led to a miscellany of affective fMRI research projects being explored in recent years. Topics ranging from gender differences (LaBar et al., 1998, Levesque et al., 2004, Wrase et al., 2003), schizophrenia (Fahim et al., 2004), suppression (Beck, 2002), expectancy (Beck, 2002), supraliminal and subliminal exposure duration (Williams et al., 2006), and comparative stimuli studies such as fearful and angry faces versus other types of fearful and angry images (Hariri et al., 2002), have rapidly enlightened our understanding of emotion and the neural correlates.

Studies investigating gender differences in brain activations during emotional processing, for instance, have found some disparity in neuronal structures, enough to suggest that gender should be taken into account when interpreting results. One such study by Wrase et al. (2003) presented IAPS stimuli for 750ms. Their findings demonstrated that men showed greater activations in the left amygdala and frontal lobe than women when viewing

positive stimuli, whilst viewing negative stimuli, women showed greater activations in the anterior and medial cingulate gyrus (Wrase et al., 2003). However, LaBar et al. (1998) conducted another gender analysis using fMRI and IAPS images and found RHD in the amygdala in female subjects compared to male, but in both, the amygdala showed greater activation when evaluating negatively arousing scenes (LaBar et al., 1998). In addition, Levesque et al. (2004) observed greater BOLD activations in the PFC in female children in a suppression of sadness paradigm as compared to adult females using the same method. These findings were related to the immaturity of the PFC (Levesque et al., 2004).

In order to pinpoint brain regions that correlate with previous ERP studies, a replication of Thorpe's ERP paradigm of an animal go/no-go categorisation task briefly presented for 33ms was carried out (Thorpe et al., 1996). Using fMRI, similar robust results were found, highlighting regions that correlate with previously reported early selective processing (Fize et al., 2000).

Whilst making the point that diligence needs to be practised when discussing the distinction between perception of emotional valence and elicited emotional experience, Beck (2002) made plain the differences in the neural correlates activated by the two conditions: perception of positive and negative stimuli was associated with parieto-occipital cortex; and experience or 'feelings' involved the mPFC. In the same paper, she investigated the conscious inhibition of sadness and amusement. Whilst watching the same emotional film clips as the previous experiment and following the instruction of suppressing any emotional feelings, they found that in both conditions activations in the inferior frontal gyrus and insula were evident. The experience of amusement, however, witnessed greater activations in the STG, putamen, parahippocampus, medial temporal lobe and the thalamus, and the suppression of sadness was associated with the visual cortex, thus indicating that the regulation of emotion is subserved by discrete neural correlates (Beck, 2002).

Beck's study investigated conscious inhibition of affect, but fMRI does not have the temporal parameters to pick up true affective change (Panksepp, 1998). As previously mentioned, PET is far better suited for the necessary

time course, as evidenced by other investigators. Damasio, for example, used PET to compare recalled and re-experienced personal emotional episodes inducing the feelings of sadness, happiness, anger and fear. By monitoring the specific neurochemical system afforded by PET technique, neural patterns were observed in direct relation to the immediacy of the associated feeling (Damasio et al., 2000). Whereas fMRI measures blood oxygenation related to local changes and therefore, does not measure neuronal responses directly, moreover the fMRI time-course of the haemodynamic response does not necessarily reflect the time course of the underlying neural activity (Jezzard et al., 2001).

Although Beck quite rightly emphasised the distinction between affective feelings and perception, her study did not take this into account on a pragmatic level. This is a pivotal point. Therefore, as the central premise of the present discourse is to investigate specific ROIs in relation to neural correlates of conscious and unconscious processing of emotion, for which fMRI is best suited, it is pertinent to focus on the cognitive perception of affective stimuli only (Panksepp, 1998).

Comparing cued emotional and neutral IAPS stimuli to elicit expectancy with uncued emotional and neutral pictures to gauge perception, Bermpohl and colleagues found that the two conditions recruited discrete neuronal networks. The resultant dissociation led them to deduce that expectancy and perception are two different components of affective processing (Bermpohl et al., 2006). However, they stated that the IAPS pictures are matched for colour, complexity, semantic content and luminance, relating to valence, but IAPS make no such claim; in fact it is difficult, to balance all these criteria in this selection of natural images. Equally, their experiment was not valence-specific. Therefore, it was difficult to know exactly what stimuli they used and how criterion was established.

Many studies use IAPS stimuli in supraliminal presentations. One such study implemented by Bradley et al. (2003) investigated the motivational view of emotional organisation, in that appetitive and defensive motives direct attention. Presenting IAPS stimuli with Japanese and Caucasian faces, which were rated for arousal and valence following the IAPS scale, for 12s each, they found that greater cortical activations were in direct relation to stimuli with

high ratings of arousal, such as erotica and evidence of threat, (e.g. body mutilation), regardless of colour/greyscale presentation. Therefore, greater functional activity was observed for survival-related stimuli providing evidence of motivational attention (Bradley et al., 2003). This was an all male study and it was not clear who rated the non-IAPS stimuli, therefore values and effect of arousal may have been biased by gender considerations.

Effects of IAPS ratings of arousal levels were also investigated in another gender biased study with nine females profiled as fearful and nine profiled as non-fearful, where activity in the amygdala and inferotemporal visual cortex was examined. Presented with threatening and non-threatening categories of stimuli for 6s, it was demonstrated that the amplitude of activation in the two ROIs is directly correlated with ratings of arousal levels and is sensitive to individual disposition (Sabatinelli et al., 2005).

In an effort to match the properties of the content of a selection of IAPS stimuli (e.g. colour), Northoff and colleagues (2000) presented various categories of stimuli rated for positive and negative affect for 6s. Using a combination of fMRI and magnetoencephalography (MEG), the investigators were able to present evidence of early, strong activation in the medial OFC when processing negative emotion, and later, weaker lateral OFC and lateral PFC when viewing positive emotion. These results demonstrated that the medial and lateral OFC subserve different affective functions (Northoff et al., 2000). Although the authors state, however, that the images only differed in valence and not in arousal, they also explain the picture selection by giving the example of a ‘mutilated face’ for a negative image and a ‘smiling baby’ for a positive image. These two examples are quite clearly different arousal ratings, so it is not clear what was actually being measured.

Grimm, et al. (2006), who supports the view that regions in the PFC process distinct emotional functions, conducted a very neat study. Using IAPS stimuli of human faces and human figures, they compared affective judgement with affective viewing whilst watching each image for 4s. They reported involvement of the vMPFC with valence processing; the right ventrolateral PFC controlling arousal judgement; the DLPFC with valence evaluation; the dorsomedial PFC with an interaction with attention and judgement of affective arousal; and the perigenual ACC with recognition of response (Grimm et al.,

2006). The stimuli chosen were emotionally evocative human images only. It would have been interesting to test for the effect of non-human affective images (e.g. inanimate objects), to clarify if the results were purely an indication of the comparison between judgement and viewing conditions or indicative of the chosen stimuli.

Research using fMRI and IAPS stimuli investigating conscious processing of emotion are harvesting both interesting and excellent results. Some of these use facial expressions with IAPS stimuli as in enquiries if the amygdala demonstrates stronger activations for faces relative to stimuli of less social significance with regards to fear and threat (Hariri et al., 2002), or ROI analysis examining the effect of happy, sad, angry and fearful conditions revealing distinct and overlapping neural correlates of faces and IAPS stimuli (Britton et al., 2006b), or a design using IAPS images with additional photographs from various photographic sources calibrated by independent raters (Mourao-Miranda et al., 2003). Equally, there are those studies that use IAPS only and divide them into categorical subsets. For instance, Hariri et al. (2003) chose two subsets of IAPS stimuli depicting threat, one set was of *natural* images such as snakes and sharks and the second set of *artificial* images (e.g. guns and air crashes). There were three experimental conditions, one was a matching task, selecting which 2 out of 3 images matched, the second condition showed a target image and two linguistic labels, '*natural'* and '*artificial',* and the participants were asked to label the picture accordingly, the third was a control condition. The purpose of the study was to investigate the dynamics between the limbic system (engaged by the matching condition) and the neocortical regions (stimulated by the higher cognitive demands from the labelling condition). It was found that perceptual processing in the matching task activated the amygdala bilaterally, but amygdala response was attenuated when cognitive evaluation took place, which correlated with greater activation in the right PFC and ACC. Thus highlighting the importance of the role of the PFC and ACC in modulating amygdala response through conscious appraisal and evaluation (Hariri et al., 2003).

What of fMRI studies looking at emotional processing below the threshold of conscious awareness?

Most of the fMRI studies investigating unconscious affective processing report findings from stimuli of facial expressions. These include studies on healthy participants examining the effects on the amygdala when presented with unattended fearful faces (Etkin et al., 2004, Pessoa et al., 2005b, Reinders et al., 2006, Zipern, 2004), with masked (Whalen et al., 1998b) and selectively attended fearful and happy faces (Williams et al., 2005), as well as an emotional learning study using masked angry faces demonstrating amygdala lateralisation; RH for masked presentations and LH for unmasked presentations (Morris et al., 1998b).

Amygdala activations have been investigated along with other brain regions in a study using sad and happy faces in a backward masking experiment (Killgore and Yurgelun-Todd, 2004). The target stimuli were presented for 20ms followed immediately by a neutral face for 100ms. Bilateral activations were evident in both the amygdala and ACC for happy faces, but sad faces generated only ACC activations in the LH. Equally, when comparing faces mediating fear and disgust, the amygdala responded to covert fear and the insula to covert disgust (Phillips et al., 2004). Both these studies are examples indicating that different regions are components of distinct neural networks for affective face processing below the threshold of conscious awareness.

Patient studies contribute enormously to our understanding of implicit affective visual processing. For instance, blindsight is a result of damage to the striate cortex (V1), the result of which is blindness in the contralateral visual field. However, some patients are able to accurately 'guess' the presence of stimuli in their blindfield, even when they are not consciously aware of stimuli presentation (Weiskrantz et al., 1974). These include emotional facial expressions, as evidenced when patient GY was presented with greyscale fearful and happy faces during an fMRI experiment. Results indicated that fear related stimuli can be processed without visual awareness in the amygdala as part of an extrageniculostriate neural pathway (Morris et al., 2001). Another blindsight patient study found that angry, happy and fearful faces involved the right amygdala in unconscious processing of all three emotions (Pegna et al., 2005).

There is a corpus of literature investigating implicit visual affective processing with fMRI, but few to date have used a wide range of complex natural images.

1:7:5 Natural Stimuli and Category Membership

Finally, it is necessary to briefly address authors who divide natural stimuli into categorical subsets to use as separate conditions. Already discussed are VanRullen and Thorpe's experiment comparing IAPS natural animals with artificial means of transport (see section 1:7:2) (VanRullen and Thorpe, 2001a) and Hariri et al. employing IAPS natural and artificial images of threat (see section 1:7:4) (Hariri et al., 2003).

Others examining category specificity have used a diverse set of images. Kreiman et al. (2000) using electrodes, were particularly interested in the medial temporal lobe and noted selective responses to faces of emotional expressions, household objects, animals, cars, photographs of famous people, drawings of people and cartoon characters (Kreiman et al., 2000), whilst Gorno-Tempini and Price (2001) identified fusiform activation when presented with famous faces and parahippocampal/lingual areas responded preferentially to buildings (Gorno-Tempini and Price, 2001).

For clarity the key points of this review will now be summarised.

1:7:6 Summary

The key points to this review are as follows:

- We know from recent evidence from ERPs, EOGs and RTs that complex images are processed rapidly in categorisation tasks.
- Using affective images, physiological responses demonstrate distinct effects of valence and arousal.
- ERP studies report both early and late processing of affect.
- Arousal and valence of affective visual stimuli are reliably rated when presented supraliminally.

- fMRI experiments have afforded a wealth of data implicating ROIs and neural networks activated by implicit and explicit processing of affective faces in both healthy and brain damaged participants.
- Little or no previous research has been conducted on the unconscious processing of emotional valence using a wide range of complex natural images (with the exception of faces), using fMRI.

It is argued here that abstract visual stimuli such as dots and gratings do not capture certain essential properties of visual processing and, as such, are neither ecologically valid nor is there an obvious evolutionary rationale for predicting responses to such stimuli, therefore more experiments on natural images are needed to advance our understanding.

On the basis of the literature reviewed here, there is a lack of information on the neural mechanisms that allow us to identify affective properties (such as emotional valence and intensity) in complex images. Furthermore, there is a lack of information on whether the affective properties of such stimuli can be identified when they are presented subliminally, that is, below the threshold of detection.

I believe this line of enquiry is fruitful. Work on subliminal perception suggests that the affective content of certain stimuli can be detected at very brief exposures, even when the observer is unaware of having seen the stimulus. fMRI studies of facial emotion suggest that there is a direct and rapid subcortical route to the amygdala that mediates unconscious perception. Threats and opportunities that are important in evolutionary terms do not present themselves in the form of standardised visual stimuli in an uncluttered scene. It is likely, as the works of Thorpe and collaborators show, that the brain has evolved to extract categorical information very rapidly from complex scenes (Fabre-Thorpe et al., 2001, Rousselet et al., 2002, Rousselet et al., 2003, Rousselet et al., 2004b, Rousselet et al., 2004c, Thorpe et al., 1996, Thorpe et al., 2001b, VanRullen and Thorpe, 2001a). It is hypothesised here that one of the important items to be extracted is affect, and the experiments conducted in this thesis will test this idea.

1:8 Present Research Programme

The purpose of the present study is to further the theory of automatic emotional processing, but in the context of natural everyday vision, by comparing response to emotional valence using complex natural images. Differences in the responses to complex stimuli, differing in emotional valence, will be studied both in a behavioural paradigm and in relation to BOLD response of the nine selected ROIs – Amygdala, ACC, mPFC, OFC, DLPFC, Fusiform Gyrus, Parahippocampus, Insula and STG.

1:8:1 Key Points of this Research Programme

- Aims:

(1) To determine whether the emotional valence of complex visual stimuli can be detected subliminally in brief, masked presentations.

(2) To determine whether the emotional valence of complex visual stimuli can be determined on trials when the observer is unaware there is a target stimulus present.

(3) To identify neural correlates of positively and negatively valenced emotional stimuli in brief, masked presentations, as well as in free viewing, using fMRI.

(3a) To determine whether masked emotion-inducing stimuli activate brain areas (ROIs) known to be associated with the conscious awareness of visual stimuli.

(3b) To address the question of whether positive and negative emotions involve ROIs that are distinct in the two hemispheres.

4) To identify possible category-specific effects of complex visual stimuli using behavioural and fMRI methods.

- Procedures:

  A forward and backward masking paradigm is developed in a behavioural experiment and the first fMRI experiment. This is followed by a dual image compound stimulus design in the second fMRI experiment.

- Working definitions:

  See Glossary page x.

- Originality:

  This thesis will provide new evidence of the breadth of variety in the types of affective visual stimuli we are able to perceptually process close to the threshold of conscious perception, and identify brain regions that are differentially activated by the affective valence of such stimuli.

1:9 Hypotheses

The aims of this thesis are to try to add to our understanding of the attentional and perceptual requirements needed for affective complex image processing. By increasing the difficulty of complex image categorisation of affect with challenging tasks, it is hypothesised that:

H¹ The valence of complex images can be identified both above and below the threshold for detecting the presence of the image in a forward – backward masking experiment.

H² There are valence-specific effects of complex images on fMRI activations in some or all of the nine ROIs identified from the literature as responding to affective stimuli.

H³ In brief, masked images there are valence-specific effects of complex images (presented close to the threshold for conscious detection) on fMRI activations in some or all of the nine ROIs.

H^4 In dual image presentations, there are valence-specific effects of complex images on fMRI activations in some or all of the nine ROIs responding to affective stimuli, both for 'attended' and for 'to-be-ignored' images.

To summarise, the next chapter (Chapter 2) will detail with the methodology used for all three experiments. Hypothesis One will then be investigated with a behavioural experiment (Chapter 3) seeking to determine the efficacy of the stimuli using a forward and backward masking paradigm. By measuring detection of stimuli and discrimination of valence response, perception of natural images below the threshold of conscious awareness is reported and validity of the stimuli established.

The effects of the same stimuli are then objectively measured in a very similar paradigm using fMRI (H^2) (Chapter 4). To test temporal parameters, the target presentation of just 10ms (see section 2:1:2) provided evidence of a limited, but significant level of emotional processing near or below the level of conscious perception in some of the nine ROIs (H^3).

To further the overall line of enquiry into the breadth and experimental viability of natural images, a second fMRI experiment (Chapter 5) was designed to divide attention between highly visible images in a dual image presentation (H^4), using a small image superimposed on a large image of opposite valence with the instruction to ignore the surrounding stimulus. The implications of this will be discussed in Chapter 6.

Chapter 2 Stimuli and fMRI Methodology

2:1 fMRI Experiments

To ensure clarity and avoid repetition, the first section of this chapter discusses details that are relevant to both fMRI experiments. In the second section, a list of stimuli for all experiments is presented.

2:1:1 MNI Coordinates

The averaged Montreal Neurological Institute (MNI) (Friston et al., 1995) coordinates (Table 2.1) were selected as the centres of 10mm and 8mm radius spherical ROIs for second level fMRI analyses. They were taken from published literature of previous research and validated using PickAtlas (Maldjian et al., 2003).

Anatomical location of cluster	x	y	Z
Amygdala	±24	-3	-19
ACC	±12	28	20
mPFC	±16	52	0
OFC	±48	30	-6
DLPFC	±46	38	-10
Parahippocampus	±20	-36	-11
Fusiform Gyrus	±34	-48	-20
Insula	±36	12	8
STG	±58	4	-4

Table 2.1 Second level MNI coordinates

This analysis was first conducted using a sphere of 10mm radius, but there was a concern that this radius was quite large and may include areas that are not relevant, which means that the average effect size might be quite small,

(i.e. a 10mm radius gives a sphere of 155 voxels using a voxel size of 3x3x3mm), therefore a second analysis was performed using an 8mm radius giving a sphere of 79 voxels, which is a fair balance between sensitivity and accuracy.

2:1:2 fMRI Data Acquisition

Brain images were acquired using a 3 Tesla Siemens Trio MRI scanner with an 8 channel array head coil. This scanner is located at Royal Holloway University of London[2].

In order to present stimuli and obtain responses with some precision the Cogent 2000 toolbox was used[3] (LON Cogent 2000 team and Romaya, 2000) (http://www.vislab.ucl.ac.uk/Cogent) and was added to the MATLAB toolbox (MATLAB Inc, 2002) (http://www.mathworks.com/products/matlab). The Cogent output in the form of a log file was obtained from every participant and each was carefully checked to verify the actual block and scan timings. Where a log file identified errors in presentation or scans these participant data were eliminated. This would have included occasions when images were not displayed for the correct period of time.

The stimulus display was controlled from a Sony Vaio laptop computer connected to the scanner, from which synchronised pulses effected stimulus changes. It needs to be noted that with the screen resolution used, the refresh rate of the laptop was 60Hz, which may have provided an actual image display time of 16.6˙ms where the design required a target display time of 10ms. This is still considered to be near or below conscious awareness. However, every precaution was taken to increase accuracy of image display timings. First, the laptop displayed directly onto the projector with no intervening software. To obtain the highest possible frame rate on the scanner projector, the laptop display was set to the external projector only, so that the laptop monitor was

[2] Royal Holloway are part of the CUBIC (Combined Universities Brain Imaging Centre) consortium and have the largest share at 40%, whilst Brunel, Reading and Surrey universities own 20% each. This research facility was largely funded from a Science Research Investment Fund (SRIF) grant.

[3] *"This experiment was realised using Cogent 2000 developed by the Cogent 2000 team at the FIL and the ICN and Cogent Graphics developed by John Romaya at the LON at the Welcome Department of Imaging Neuroscience"*

blank. In addition, the windows task manager was used to update speed in Matlab to the highest priority.

The scanner employs an LCD projection system (Sanyo projector: Model: PLC-XP40L) that transmits the stimulus onto a screen located behind the participant's head, reflected by a mirror mounted in the participants visual field with a viewing distance of 88cm.

In order to minimise excessive head movement, and to aid comfort, the participants, whilst lying supine in the scanner, were supported with foam wedges in the lateral space between the coil and their head.

An intercom system is installed to facilitate communication between the participant and control room. In case of an emergency or breakdown in communication, an alarm button was available to the participant in the scanner at all times.

2:1:3 fMRI Design

The dual image and masked experiments were block designs, whereby each unit or trial was presented to compare neural responses in a discrete epoch of time. A series of trials were presented in blocks where a discrete emotional stimulus condition was maintained. This paradigm accommodates many trials in a row and the signal acquired in each block is compared to signals from other blocks where different emotional stimuli are involved. In addition to these 'target' blocks, as 'baseline' a rest condition of no stimulus was introduced. This means that the block design alternates periods of activation (e.g. negative emotion stimuli A) and periods of rest (task B). This method used with fMRI gives maximum BOLD signal and maximal signal-to-noise ratio, which refers to a signal of interest, (e.g. activation from stimulation), compared with 'noise' which is inescapable arbitrary differences in image intensity even when no stimulation is presented (Jezzard et al., 2001).

The decision to run these experiments as an explicit emotional categorisation task was to try to ensure as far as possible that the participants continuously attended to the pictures without distraction.

2:1:4 fMRI Analysis

Prior to functional image acquisition, high-resolution anatomical images for each participant were recorded in the same orientation as the functional data (see sections 4:3:4 and 5:3:4) to enable accurate location of individual brain activity. In both the fMRI experiments in this study, anatomical images were acquired using an MP-RAGE three dimensional T1-weighted, gradient echo sequence (Mugler and Brookeman, 1990) (TR=1830ms; TE=4.43s; FoV 256x256 mm) in which 176 1mm sagittal slices were obtained.

Statistical parametric mapping software SPM2 (Friston and Wellcome Department of Imaging Neuroscience, 2003) (http://www.fil.ion.ucl.ac.uk/spm) was used for the statistical processing, which was implemented in MATLAB. Prior to the statistical analysis, the data files or time series (a series of images in time) were converted from Digital Imaging and Communications in Medicine (DICOM) format, realigned to ensure spatial alignment in case of slight participant movement. Where translation was greater than 2mm and/or more than 2° rotation during acquisition, the participants' data sets were discarded. All functional images were then coregistered with the anatomical images for accurate individual neuroanatomical alignment. These were then normalised (once only for each participant) into an averaged anatomical space to facilitate comparison and deduction (by warping functional and anatomical images to fit a standard brain template). These data were not spatially smoothed as this would introduce blurring which would defeat the constructs of the chosen ROIs in these experiments (Huettal et al., 2004).

After pre-processing, using SPM2, the experimental design was convolved with a haemodynamic response function (hrf) to model the haemodynamic lag in the BOLD response.

The basic statistical assumption used was the cognitive subtraction method, whereby the activations in blood oxygenation related to local changes in neural activity associated with task A (emotional response) were subtracted from those in task B (control). This, in theory, identifies cortical regions involved in task A.

However, the subtraction method has been criticised in that conditions employed may elicit several different signal changes (Jezzard et al., 2001). To

take account of this possible disadvantage, every effort was made to make the conditions identical in every aspect apart from the point of interest.

For the sake of comparison, the same ROIs and MNI coordinates were investigated for both fMRI experiments. An exploratory first level analysis was performed across nine ROIs utilising PickAtlas (Maldjian et al., 2003) with a significance level of $p<0.05$ using value adjustments family-wise error (FWE) to estimate the fixed effects of the experimental conditions on each participant. This was followed by second level analysis using MarsBar toolbox for SPM2 (Brett et al., 2002) (http://marsbar.sourceforge.net**).** Using the general linear model, a group random effects analysis was carried out measuring the level of activations in the sphere of 8mm radius centred around the averaged ROI symmetrical coordinates as defined by MNI, which were chosen from previous research (see section 2:1:1).

The statistic table for the output from MarsBar provides (for each ROI) a contrast value, a t-statistic, an uncorrected one-tailed p-value for this t-statistic, and a corrected p-value (corrected for the number of ROIs in the analysis). The data used as input for the second level analysis is the contrast value.

> "For a t-statistic, contrast value is an effect size…. A t-statistic consists of an effect size divided by the standard deviation of this effect……. (the contrast values are the same as the value of the parameters in the visual event). The value of these parameters will be the best-fitting slope of the line relating the height of the hrf regressor to the fmri signal. This effect size measure is the number that SPM stores for each voxel in the con_0001.img, con_0002.img…series, and these are the values that are used for standard second level / random effect analyses". MarsBaR-development tutorial http://marsbar.sourceforge.net

2:2 Stimuli - International Affective Picture System (IAPS)

Neuroimaging studies have shown variable neuronal activations when studying visual emotion-laden stimuli. This may be due to the diverse selection of uncalibrated stimuli employed to evoke an emotional response. In the present

study, the content of stimuli is balanced with regard to emotional meaning, using two determining factors: valence (negative value of things to be avoided or positive value of things that are appealing); and arousal (level of sensory excitability) content. This was achieved by using a calibrated, standardised set of pictures of various emotion inducing animals, faces, scenes and inanimate objects from the IAPS collection (Center for the Study of Emotion and Attention [CSEA-NIMH], 2001). The valence and arousal IAPS ratings are set at 9 for positive valence or high arousal and 1 for negative valence or low arousal. An experiment using the complete range of valence scores found a linear correlation with BOLD signal continuum in the PFC and insula, thus supporting the IAPS sliding rating system of positive and negative stimuli (Heinzel et al., 2005).

The IAPS series has been used as an emotionally evocative inducer for a wide range of behavioural and neuroimaging studies, results of which correlate with physiological measures such as SCR (Lang et al., 1993), and enjoys the reputation of reliability and ecological validity by facilitating the comparison of results, replication between studies and tighter experimental control when selecting real photographic visual stimuli.

The pictures varied in magnification, colour, viewing angle, luminance and spatial frequency in accordance with everyday vision. These variations are consistent with a previous study using high-speed presentations of emotional visual stimuli, which found that affective discrimination was unconnected with the image properties listed above as well as complexity (Junghofer et al., 2001). Equally, the presentation of each set of stimuli in the present study was not influenced by prior familiarity as the participants had not been exposed to the pictures before (NB different IAPS pictures were used in the pre-experimental briefing).

It has been argued that there are two main dimensions to emotional experience – valence and arousal (Watson and Tellegen, 1985). Equally, it is postulated that these primary dimensions may be controlled by different neural systems (Heller, 1993). As this is a study researching valence effect, only levels of valence were manipulated. Therefore, levels of arousal were equalised between high and low valence stimuli and remained consistent in the

three studies described (see Table 2.2). The neutral images used as controls were low in arousal and intermediate in valence.

The level of arousal for the target stimuli were set moderately high (5.00 – 7.21), which is not the highest rating. This was because images calibrated for very high arousal were of erotica (positive) and body mutilations (negative), and as the participants were drawn from a cross section of society (e.g. various ages and religious backgrounds), ethically it was decided not to use those that may cause discomfort or offence. Therefore, moderately high arousal images were used.

2:2:1 Images Used - Behavioural Experiment

The stimuli consisted of 24 pictures. The two conditions were twelve images of high valence (> 6) and high arousal (5.00-7.21) plus twelve low valence (< 4) and high arousal (5.00-7.21). In addition 24 neutral pictures were chosen with valence (v) of ($4 < v < 6$) and low arousal (< 5) (Table 2.2) (Lang et al., 2001).

All emotional stimuli were presented at short exposure (10 ms) and were masked before and after each presentation (mask duration 150 ms). The pre-mask and post-mask stimuli were different neutral pictures, paired at random. They were used as a pair twice, once masking a pleasant picture and once masking an unpleasant. This counterbalancing was to avert the possibility of the emotional response to specific neutral pictures influencing the pleasant/unpleasant decision overall. Therefore, 24 neutral pictures (12 pairs) were used twice to mask the 24 emotional targets.

Twelve different neutral pictures (6 pairs) were used in the control condition. The control condition consisted of a pair of masking stimuli without the intervening emotional target (control duration 150 ms each). These neutral pictures were also randomised and repeated twice to ensure that the participants did not identify that the control condition was different from the experimental condition (Table 2.2). For further explanation of this experimental design see section 3:3:2.

Description	Slide Number	Valence Mean	Valence SD	Arousal Mean	Arousal SD	Category and Valence
Puppies	1710	8.34	1.12	5.41	2.34	Animal (HVa)
Jaguar	1650	6.65	2.25	6.23	1.99	HVa
Monkeys	1811	7.62	1.59	5.12	2.25	HVa
Att Female	4250	6.79	2.05	5.16	2.76	Face (HVf)
Baby	2071	7.86	1.32	5.00	2.34	HVf
Athletes	8380	7.56	1.55	5.74	2.32	HVf
Skier	8190	8.10	1.39	6.28	2.57	Scenes (HVs)
Skydivers	5621	7.57	1.42	6.99	1.95	HVs
Waterfall	5260	7.34	1.74	5.71	2.53	HVs
Money	8501	7.91	1.66	6.44	2.29	Inanimate (HVi)
Icecream	7270	7.53	1.73	5.76	2.21	HVi
Fireworks	5480	7.53	1.63	5.48	2.35	HVi
Shark	1932	3.85	2.11	6.47	2.20	Animal (LVa)
Attack Dog	1525	3.09	1.72	6.51	2.25	LVa
Snake	1050	3.46	2.15	6.87	1.68	LVa
Baby Tumour	3170	1.46	1.01	7.21	1.99	Face (LVf)
Angry Face	2120	3.34	1.91	5.18	2.52	LVf
Batt Female	3180	1.92	1.13	5.77	2.21	LVf
Bomb	9630	2.96	1.72	6.06	2.22	Scenes (LVs)
Air Crash	9611	2.71	1.95	5.75	2.44	LVs
Car Crash	9911	2.30	1.37	5.76	2.10	LVs
Toilet	9301	2.26	1.56	5.28	2.46	Inanimate (LVi)
Elect Chair	6020	3.41	1.98	5.58	2.01	LVi
Flies on Pie	7360	3.59	1.95	5.11	2.25	LVi
Lamp	7175	4.87	1.00	1.72	1.26	Neutral/Mask
Chair	7235	4.96	1.18	2.83	2.00	Neutral/Mask
Bowl	7006	4.88	0.99	2.33	1.67	Neutral/Mask
Tissue	7950	4.94	1.21	2.28	1.81	Neutral/Mask
Book	7090	5.19	1.46	2.61	2.03	Neutral/Mask
Clothes Rack	7217	4.82	0.99	2.43	1.64	Neutral/Mask
Abstract Art	7185	4.97	0.87	2.64	2.04	Neutral/Mask
Trash Can	7060	4.43	1.16	2.55	1.77	Neutral/Mask
Towel	7002	4.97	0.97	3.16	2.00	Neutral/Mask
Clock	7190	5.55	1.34	3.84	2.06	Neutral/Mask
Mug	7035	4.98	0.96	2.66	1.82	Neutral/Mask
Stool	7025	4.63	1.17	2.71	2.20	Neutral/Mask
Baskets	7041	4.99	1.12	2.60	1.78	Neutral/Mask

Beads	7207	5.15	1.46	3.57	2.25	Neutral/Mask
Cabinet	7705	4.77	1.02	2.65	1.88	Neutral/Mask
Abstract Art	7184	4.84	1.02	3.66	1.89	Neutral/Mask
Mushroom	5510	5.15	1.43	2.82	2.18	Neutral/Mask
Mug	7009	4.93	1.00	3.01	1.97	Neutral/Mask
Hair Dryer	7050	4.93	0.81	2.75	1.80	Neutral/Mask
Shoes	7038	4.82	1.20	3.01	1.96	Neutral/Mask
Mushrooms	5533	5.31	1.17	3.12	1.92	Neutral/Mask
Fork	7080	5.27	1.09	2.32	1.84	Neutral/Mask
Fire Hydrant	7100	5.24	1.20	2.89	1.70	Neutral/Mask
Abstract Art	7187	5.07	1.02	2.30	1.75	Neutral/Mask
Shadow	2880	5.18	1.44	2.96	1.94	Neutral/Control
Umbrella	7150	4.72	1.00	2.61	1.76	Neutral/Control
Basket	7010	4.94	1.07	1.76	1.48	Neutral/Control
Clock	7211	4.81	1.78	4.20	2.40	Neutral/Control
Rolling Pin	7000	5.00	0.84	2.42	1.79	Neutral/Control
Light Bulb	7236	5.64	1.31	3.79	2.24	Neutral/Control
Shoes	7031	4.52	1.11	2.03	1.51	Neutral/Control
Light Bulb	7170	5.14	1.28	3.21	2.05	Neutral/Control
Still Life	5535	4.81	1.52	4.11	2.31	Neutral/Control
Rug	7179	5.06	1.05	2.88	1.97	Neutral/Control
Pole	7161	4.98	1.02	2.98	1.99	Neutral/Control
Agate	7830	5.26	1.38	4.08	2.11	Neutral/Control

Table 2.2 Ratings of IAPS stimuli – behavioural experiment. Valence and arousal measures of IAPS pictures used for the behavioural experiment. (Lang et al., 2001).
Key: HV = High Valence; LV = Low Valence; Att = Attractive; Batt = Battered; Elect = Electric.

2:2:2 Images Used - Masked fMRI Experiment

To ensure consistency, the same IAPS pictures (Lang et al., 2001) were used as emotional targets as those in the behavioural experiment, and categorised as animals, faces, scenes and inanimate objects. In masked stimulus blocks, each target was presented for 10ms (see section 2:1:2) and was masked by 2 neutral stimuli presented for 1s each. Three repetitions of this target picture combination occurred within a block, each separated by 2s blanks, with different targets having the same valence type. However, additional IAPS pictures were needed for the second normal viewing condition, in which the

presentation time of the emotional stimuli was 1.01s (forward masked by neutral stimuli for 1s), but the same block structure, categories, valence and arousal measures were maintained (Table 2.3) (Lang et al., 2001). The masked blocks were followed by two randomised normal viewing blocks, each separated by a 3s blank to ensure return to baseline level. For more detail of this experimental design see section 4:3:2.

Description	Slide Number	Valence Mean	Valence SD	Arousal Mean	Arousal SD	Category and Valence
Coyote	1640	6.16	1.88	5.18	1.93	Animal (HVa)
Lion	1720	6.79	1.56	5.32	1.82	HVa
Jaguars	1722	7.04	2.02	5.22	2.49	HVa
Baby	2058	7.91	1.26	5.09	2.48	Face (HVf)
Romance	4601	6.82	1.22	5.08	2.01	HVf
Tennis Player	8350	7.18	1.56	5.18	2.28	HVf
Mountains	5660	7.27	1.59	5.07	2.62	Scene (HVs)
Mountains	5600	7.57	1.48	5.19	2.70	HVs
Liftoff	5450	7.01	1.60	5.84	2.40	HVs
Sports Car	8531	7.03	1.50	5.41	2.15	Inanimate (HVi)
Money	8502	7.51	1.72	5.78	2.49	HVi
French Fries	7460	6.81	2.08	5.12	2.49	HVi
Spider	1200	3.95	2.22	6.03	2.38	Animal (LVa)
Roaches	1274	3.17	1.53	5.39	2.39	LVa
Snake	1120	3.79	1.93	6.93	1.68	LVa
Toddler	2095	1.79	1.18	5.25	2.34	Face (LVf)
Eye Disease	3160	2.63	1.23	5.35	1.79	LVf
Batt Female	3181	2.30	1.43	5.06	2.11	LVf
Ship	9600	2.48	1.62	6.46	2.31	Scene (LVs)
Fire	9495	3.34	1.75	5.57	2.00	LVs
Ruins	9470	3.05	1.51	5.05	1.98	LVs
Aimed Gun	6260	2.44	1.54	6.93	1.93	Inanimate (LVi)
Dirty	9300	2.26	1.76	6.00	2.41	LVi
Bomb	2692	3.36	1.61	5.35	2.19	LVi
Checkerboard	7182	5.16	1.31	4.02	2.12	Neutral
Shadow	2880	5.18	1.44	2.96	1.94	Neutral
Mug	7009	4.93	1.00	3.01	1.97	Neutral
Hair Dryer	7050	4.93	0.81	2.75	1.80	Neutral
Baskets	7041	4.99	1.12	2.60	1.78	Neutral

Shoes	7038	4.82	1.20	3.01	1.96	Neutral
Fire Hydrant	7100	5.24	1.20	2.89	1.70	Neutral
Pole	7161	4.98	1.02	2.98	1.99	Neutral
Light Bulb	7170	5.14	1.28	3.21	2.05	Neutral
Clock	7190	5.45	1.34	3.84	2.06	Neutral
Rug	7179	5.06	1.05	2.88	1.97	Neutral
Scarves	7205	5.56	1.39	2.93	2.16	Neutral
Light Bulb	7236	5.64	1.31	3.79	2.24	Neutral
Clothes Rack	7217	4.82	0.99	2.43	1.64	Neutral
Checkerboard	7183	5.58	1.39	3.78	2.19	Neutral
Stool	7025	4.63	1.17	2.71	2.20	Neutral
Fan	7020	4.97	1.04	2.17	1.71	Neutral

Table 2.3 Ratings of IAPS stimuli – masked experiment. Valence and arousal measures of additional IAPS pictures used for the fMRI masked experiment. (Lang et al., 2001)
Key: HV = High Valence; LV = Low Valence; Att = Attractive; Batt = Battered; Elect = Electric.

2:2:3 Images Used – Dual Image Experiment

To ensure a direct comparison with the behavioural and first fMRI experiment, exactly the same target IAPS images were used for the dual image experiment (Table 2.4). Therefore all three experiments used the same target images, apart from the additional normal viewing images used in the masked experiment (Table 2.3).

A block consisted of three neutral images (1s duration each) separated by a 1s blank, this was followed by a 2s blank and three target images of the same valence and arousal (again 1s duration each). Each block was randomised and presented three times as different conditions – control condition one - large-field, control condition two - small-field and the experimental condition: - dual image. For greater detail of this experimental design see section 5:3:2.

Description	Slide Number	Valence Mean	Valence SD	Arousal Mean	Arousal SD	Category and Valence
Puppies	1710	8.34	1.12	5.41	2.34	Animal (HVa)
Jaguar	1650	6.65	2.25	6.23	1.99	HVa
Monkeys	1811	7.62	1.59	5.12	2.25	HVa

Att Female	4250	6.79	2.05	5.16	2.76	Face (HVf)
Baby	2071	7.86	1.32	5.00	2.34	HVf
Athletes	8380	7.56	1.55	5.74	2.32	HVf
Skier	8190	8.10	1.39	6.28	2.57	Scenes (HVs)
Skydivers	5621	7.57	1.42	6.99	1.95	HVs
Waterfall	5260	7.34	1.74	5.71	2.53	HVs
Money	8501	7.91	1.66	6.44	2.29	Inanimate (HVi)
Icecream	7270	7.53	1.73	5.76	2.21	HVi
Fireworks	5480	7.53	1.63	5.48	2.35	HVi
Shark	1932	3.85	2.11	6.47	2.20	Animal (LVa)
Attack Dog	1525	3.09	1.72	6.51	2.25	LVa
Snake	1050	3.46	2.15	6.87	1.68	LVa
Baby Tumour	3170	1.46	1.01	7.21	1.99	Face (LVf)
Angry Face	2120	3.34	1.91	5.18	2.52	LVf
Batt Female	3180	1.92	1.13	5.77	2.21	LVf
Bomb	9630	2.96	1.72	6.06	2.22	Scenes (LVs)
Air Crash	9611	2.71	1.95	5.75	2.44	LVs
Car Crash	9911	2.30	1.37	5.76	2.10	LVs
Toilet	9301	2.26	1.56	5.28	2.46	Inanimate (LVi)
Elec Chair	6020	3.41	1.98	5.58	2.01	LVi
Flies on Pie	7360	3.59	1.95	5.11	2.25	LVi
Umbrella	7150	4.72	1.00	2.61	1.76	Neutral
Lamp	7175	4.87	1.00	1.72	1.26	Neutral
Cabinet	7705	4.77	1.02	2.65	1.88	Neutral
Plate	7233	5.09	1.46	2.77	1.92	Neutral
Chair	7235	4.96	1.18	2.83	2.00	Neutral
Dustpan	7040	4.69	1.09	2.69	1.93	Neutral
Spoon	7004	5.04	0.60	2.00	1.66	Neutral
Bowl	7006	4.88	0.99	2.33	1.67	Neutral
Basket	7010	4.94	1.07	1.76	1.48	Neutral
Tissue	7950	4.94	1.21	2.28	1.81	Neutral
Clock	7211	4.81	1.78	4.20	2.40	Neutral
Ironing Board	7234	4.23	1.58	2.96	1.90	Neutral
Book	7090	5.19	1.46	2.61	2.03	Neutral
Clothes Rack	7217	4.82	0.99	2.43	1.64	Neutral
Rolling Pin	7000	5.00	0.84	2.42	1.79	Neutral
Light Bulb	7236	5.64	1.31	3.79	2.24	Neutral
Abstract Art	7185	4.97	0.87	2.64	2.04	Neutral
Trash Can	7060	4.43	1.16	2.55	1.77	Neutral

Towel	7002	4.97	0.97	3.16	2.00	Neutral
Shoes	7031	4.52	1.11	2.03	1.51	Neutral
Abstract Art	7186	4.63	1.60	3.60	2.36	Neutral
Clock	7190	5.55	1.34	3.84	2.06	Neutral
Iron	7030	4.69	1.04	2.99	2.09	Neutral
Mug	7035	4.98	0.96	2.66	1.82	Neutral

Table 2.4 Ratings of IAPS stimuli – dual image experiment. Valence and arousal measures of IAPS pictures used for the fMRI dual image experiment. (Lang et al., 2001).
Key: HV = High Valence; LV = Low Valence; Att = Attractive; Batt = Battered; Elect = Electric.

2:3 Ethical Considerations

The research was carried out in accordance with Brunel University's ethical guidelines and procedures for research involving human participants: http://intranet.brunel.ac.uk/registry/minutes/researchethics/ethicsguidelinesv2.pdf and was given ethical approval by the Research Ethics Committee of the Brunel University School of Social Sciences.

Additionally, the conduct of fMRI experiments was in accordance with the Rules of Operation of the Combined University's Brain Imaging Centre (Rules of Operation is an internal document dated 2002 which was also approved by the Brunel Ethics Committee) (Appendix I). It was also made clear to the participants that the fMRI experiment was for research purposes only and should not be substituted for medical opinion.

The nature of the experiments was thoroughly explained and informed consent obtained. During the briefings, participants were informed of the non-invasive nature of fMRI. It was emphasised that some of the images may be unpleasant and the participants could withdraw at any time. The very high arousal images for both pleasant (erotica) and unpleasant (bodily mutilations) categories were also removed so as not to cause offence.

These experiments were conducted in accordance with all the principles outlined in the British Psychological Society Code of Conduct (BPS, 2000).

2:4 Notes on Participants

All the participants were healthy adults from a wide range of backgrounds with ages ranging from 16 years to 75 years with normal or corrected to normal vision.

Chapter 3 Behavioural Experiment: Valence discrimination of complex affective stimuli, with and without conscious awareness of detection

3:1 Abstract

The response valence to 24 different images of complex visual stimuli was measured in a backward and forward masking paradigm by asking participants to classify the overall impression as pleasant or unpleasant. Employing previously calibrated IAPS stimuli, the IAPS stimulus valence rating predicted the identification of pleasant versus unpleasant overall impression, but a response bias in favour of pleasant responses was found. However, the findings also confirmed that even when the presence of the target was not consciously detected (subliminal processing), valence discrimination was significant for the majority of stimuli. In addition, confidence ratings were acquired, but it was found that confidence in impression was not strongly correlated with accuracy in processing valence. Although responses differed from the IAPS prediction for some of the images, it was concluded that this present paradigm was robust and suitable to be used in a follow-up fMRI study.

3:2 Introduction

A forward and backward masking experiment was carried out to establish if it is possible to detect the presence of the target picture, and discriminate its valence using a wide range of 24 natural images.

Stimuli compete for processing resources when common characteristics put demands on the same brain regions. For instance, when two stimuli are rapidly presented sequentially in the same spatial proximity, the processing of one interferes with the other. As a consequence, this phenomenon has been exploited in visual masking paradigms. The most popular of these paradigms is that of backward masking, where the second stimulus, the mask, reduces or totally 'masks' the conscious perception of the first stimulus, the target. (Breitmeyer and Ogmen, 2000, VanRullen and Koch, 2003b). However,

although detection of the target stimuli may have been prevented, it can still be subliminally processed at a significant level (Koch, 2004).

Backward masking was employed in the present study, but to achieve even greater temporal restraints, a forward masking image was also introduced as a contaminating factor in the preliminary processing of the target image. The hypothesis is that information processing proceeds in microgenetic stages, where the initial presentation of a stimulus to the cognitive percept of the said stimulus is made up of 'bottom-up' processing stages that are not conscious (Flavell and Draguns, 1957). Thus, the mask image (presented first) modifies the microgenesis of the target image (presented second), by interfering in the integration period of processing the target (Bachmann et al., 2004). Efron (1973) demonstrated the concept of an integration period in an experiment, presenting a red disk for 10ms rapidly followed by a green disk also for 10ms. Participants reported seeing a single yellow disk instead of two separate disks of different colours. Thus the temporal parameters of Efron's experiment blended two stimuli into a unitary yellow image, implying an integration period (Efron, 1973). Moreover, there is a great deal of evidence to support automatic feedforward processing in the visual system (Delorme and Thorpe, 2001, Thorpe et al., 1996).

The temporal parameters for the presentations of the overt (masks and controls) and covert (target) stimuli were established from previous studies. VanRullen and Koch used a backward masking paradigm to determine that selective motor responses can be achieved with stimuli presented for only 26ms (VanRullen and Koch, 2003b). In addition, Phillips and colleagues established a discrimination threshold (the point at which an emotion could be discriminated) of 30ms and a detection threshold (the point at which a target could be detected) of 10ms using backward masking, exploring facial expressions of fear and disgust (Phillips et al., 2004). Thus, in order to ensure strict temporal restraints, a critical time period was set at target presentation time of 10ms (see section 2:1:2) with both forward and backward masks of 150ms each. Therefore, the combination of very short target stimulus duration and heavy masking was to weaken the strength of the target stimulus to below the threshold of conscious perception.

A concurrent detection task determined whether one, two or three images were seen and this was recorded with self-report questionnaires (Appendix II) to ascertain if the participants were aware of a target image. The answer 'two' was taken as indication that a target was successfully presented below conscious threshold and the answer 'three' meant that the stimulus was 'seen' and therefore above conscious threshold. However, each participant could have used a different criterion to report perception with or without awareness, for example they may have approached this experiment cautiously and reported that they were unaware of a stimulus unless they were completely aware, conversely they may report awareness when they were only partially aware or 'felt' there was a third stimulus (Cheesman and Merikle, 1986). In order to assess these graded levels of awareness, a confidence rating was employed to measure how confident they were of having seen (or not seen) a third image. To assess the perception of valence, a single-interval forced-choice discrimination task was introduced, asking whether the images were pleasant or unpleasant. Higher than chance levels of concordant identification of valence, in the absence of reported detection of the third (target) stimulus, was taken as the operational definition of perception without awareness.

Response bias, however, is still an issue in forced-choice single-interval designs, as the participants could have a pleasant or unpleasant disposition. For this reason, control stimuli were included in which the target was absent but the neutral masks were present. Control trials on which the participant saw only two images (correct rejections) could be compared with target-present trials on which the participant saw only two IAPS-neutral mask images (misses). The response bias could then be assessed by the proportion of pleasant and unpleasant responses to the correct control trials.

Additionally, subjective confidence ratings for each task were used to provide further analytical information on a) the level of conscious detection of the target and b) confidence in the overall impression of valence, the rationale being that the participants would not be fully confident of valence or number of images seen unless they are aware or partially aware of this information. Therefore, confidence ratings relate to degrees of certainty in accuracy, with a low score (i.e. 1) indicating that they were guessing their detection or discrimination response and a high score (i.e. 9) reflecting complete certainty

of response. Conversely, if the confidence ratings varied randomly to concordant and discordant scores, there would be no evidence of awareness of the information and confidence would be unrelated to accuracy (Kunimoto et al., 2001).

Another potential problem with using IAPS ratings to determine whether a response is concordant or discordant is that emotional responses to pictures can be very individual. For instance, one participant described a low valence image of a rat as 'cute'. The data presented will be group data, so that individual variation will be addressed by standard statistical arguments, but to ensure that the participants' responses to IAPS stimuli were comparable with published norms, post-hoc ratings of the stimuli were obtained.

The purpose of this first experiment is a) to evaluate if it is possible to measure subliminal processing using natural images; b) to test for any significant differences in valence; c) to assess if concordance is or is not an indication of perception below conscious threshold; and d) to enquire if confidence is a measure of subliminal perception. The main hypotheses are as follows:

- H^1 Participants can discriminate between positive and negative valence masked stimuli, on trials when there is no detection of the presence of the target stimulus (subliminal trials).
- H^2 There is a difference in perception of positive and negative valence between subliminal and supraliminal visual stimuli.
- H^3 Confidence ratings for detection of the target, and confidence ratings of target valence are both correlated with detection of the target.

3:3 Method

The details regarding stimuli used for this experiment are described in sections 2:2 and 2:2:1.

3:3:1 Participants

217 participants completed this experiment: 39 male and 178 female, age range 16 to 75 years (mean age 25.29 years) from a cross section of society.

3:3:2 Design

The emotional targets were presented with an exposure time of 10ms (see section 2:1:2). These were 'sandwiched' between a pre-mask and post-mask stimulus, each with an exposure time of 150ms (Figure 3.1). The control condition consisted of 2 neutral stimuli each of which were presented for 150ms (Figure 3.2). The frame size for each picture was 485 x 349 pixels and designed in Jasc Paint Shop Pro 7 (Animation Shop 3.00, 2000) software (http://www.jasc.com).

The order of the presentation of stimuli were randomised and counterbalanced for valence (see 2:2:1). It was also counterbalanced across the participants with 117 participants completing the first sequence and 100 participants completing the same sequence, but in reverse order.

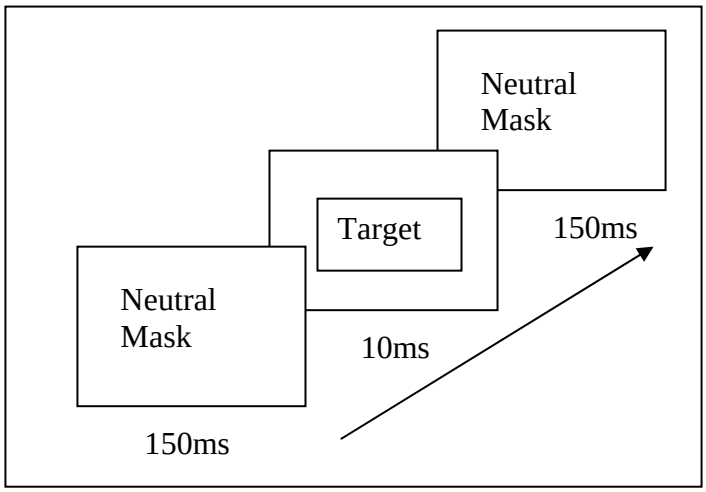


Figure 3.1 Experimental set of slides
Key: ms = milliseconds

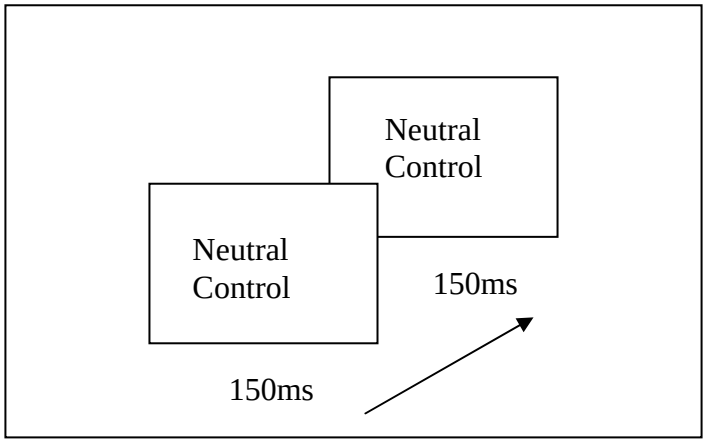


Figure 3.2 Control set of slides.
Key: ms = milliseconds

3:3:3 Procedure

The experiment was thoroughly explained, with time for questions and answers, after which the participants were invited to leave if they felt unhappy with the procedure. Consent forms (Appendix III) were then distributed, signed and collected before the experiment began.

The experiment was displayed either on a laptop computer or via a projector and each participant had a clear visual perspective of the stimuli. The experimenter had control of the timing of each trial, so that the participants had time to answer each question in the correct order.

In the first questionnaire (Appendix II) there were four questions for each image. The first question asked "What was your overall impression - pleasant or unpleasant?" The forced-choice design required the marking of one of two boxes - pleasant or unpleasant was then ticked. A Likert scale of 1-9 followed, measuring how confident they were with their answer. The third question asked "How many images did you see?" One of three boxes was then ticked - one, two or three. Again a Likert scale of 1-9 for their confidence rating regarding this answer was presented. There were two practice images before the experiment began, at which point there was an opportunity to ask more questions if unsure of the procedure. The experiment then continued for 36 trials (24 experimental trials and 12 control trials).

Once the experiment was completed, the individual slides were displayed on a Power Point presentation, so that each participant could rate the pictures themselves. They were given a 'ratings' questionnaire (Appendix IV) that had three questions for each slide. The first was "On a scale of 1-9, how pleasant or unpleasant did you find this image? Please tick one of the following, 1 = very unpleasant, 9 = very pleasant". The same format was applied asking how arousing they found this image. Thirdly, they were asked "Do you remember seeing this picture in the experiment? Yes / No / Not Sure". Again, there were two practice trials to clarify understanding. Thirty one images were then displayed individually, which included all of the target images and a sample of the neutral images.

Following the experimental procedure, a debriefing form (V) was distributed with more information on the nature of this research project, with an accompanying reading list. An unrestricted question time was made available.

3:4 Statistical Analysis

For each target slide, the frequency (across participants) of pleasant and unpleasant responses was determined, both for those participants who saw two slides (target missed) and those who saw three slides (target seen). Both sets of frequencies were then compared with expected values, which were the proportions (across participants and slides) of pleasant and unpleasant responses to the neutral-mask control slides (correct rejections). One-sample Komolgorov-Smirnov tests were used for discrimination of valence and discrimination of target trials from control trials.

Since the data were categorical, Chi-square was calculated for each target slide in both two-seen and three-seen conditions using an online calculator (http://www.graphpad.com/quickcalcs/chisquared1.cfm). The expected values used were the mean frequencies of valence response (pleasant and unpleasant) to the control stimulus set, across all participants, when two stimuli were seen. This made it possible to ascertain if there was any discrimination of valence for each individual slide.

Examination of valence response found some stimuli responses differed from the IAPS prediction. As a result, and in order to test detectability of elements within the IAPS stimli, the *saliency toolbox* (Walther and Koch, 2006) was employed using Matlab compatable software (http://www.saliencytoolbox..net).

To examine the relationship between the IAPS rating norms and the current participant sample's ratings of the stimuli, Pearson correlation coefficient was used.

To analyse the confidence ratings, Univariate General Linear Model Analysis (UNIANOVA) was employed using SPSS (SPSS Inc, 2005-8) (https://www.spss.com). In addition, Wilcoxon was used to test the mean detectability of the images and to calculate the response of individual slides ANOVA was used.

3:5 Results

The operational definition of subliminal perception adopted in this chapter was the perception of stimulus valence in the absence of detection of the stimulus. This was tested by examining the valence of the response (discrimination task) on those trials where three pictures were presented, but the participant reported seeing only two (detection task). It was predicted that the valence of response on these trials will be influenced by the valence of the short-exposure stimulus. The null hypothesis (no subliminal perception) would predict that the proportion of negative and positive valence responses is the same whether the target is positive or negative in valence.

The small number of trials where participants report seeing one image were eliminated as it is likely that this was due to reporting errors.

3:5:1 Discrimination of Valence

The overall impression of a trial (valence response) was coded as +1 for a 'pleasant' response, and -1 for an 'unpleasant' response. There was no neutral category of response. Valence of response was averaged separately across all IAPS high valence target trials (IH) (Mean = 0.633), and all IAPS low valence

target trials (IL) (Mean = 0.141), whether or not the presence of the target was detected between the two neutral masks. The mean valence of response was also measured for neutral mask control trials (CN) (Mean = 0.591), in which no target was present. It was found, in one-sample Komolgorov-Smirnov tests, that the distributions of response valence deviated significantly from normal for all three trial types (IH: $Z=2.8$, $p<0.00005$; IL: $Z=1.53$, $p<0.05$; CN: $Z=2.56$, $p<0.000005$).

3:5:2 Discrimination of Target Trials from Control Trials

The next question to be considered was whether the presence of the brief target slide on target trials could be discriminated reliably from its absence on control trials. This was tested by asking participants to judge how many pictures were presented in a trial, thus the correct answer for target trials would be three, and for control trials two. Misses would be indicated by the response two on a target trial, and false positives by the response three on a control trial. This was averaged across all IAPS high valence target (IH) trials (Mean = 2.659), all IAPS low valence target (IL) trials (Mean = 2.601) and all neutral control nontarget (CN) trials (Mean = 2.060). It is clear that the discriminability of target and nontarget trials is good. The false positive rate is low (6%) and although more than 60% of target trials are detected, the level of missed targets is relatively high (34.1% IH, 39.9% IL). Again, a one-sample Komolgorov-Smirnov test showed significant departures from normality for all three variables (IH: $Z=1.806$, $p<0.005$; IL: $Z=2.096$, $p<0.0001$; CN: $Z=4.73$, $p<0.0001$).

3:5:3 Discrimination of Valence in Individual Images.

For every individual observer, the response to a trial will fall into one of four categories: pleasant two pictures seen; pleasant three pictures seen; unpleasant two pictures seen; unpleasant three pictures seen. As shown in Table 3.1, the frequency of responses concordant with the IAPS valence rating varies widely from slide to slide. It is not possible with this information alone to determine whether, for an individual slide, the obtained frequency of pleasant and

unpleasant responses reflects discrimination of stimulus valence, or whether it reflects response bias.

The control stimuli, however, provide an independent estimate of response bias, and this estimate can be used to provide expected values for the proportion of positive and negative valence responses. It is reasonable to argue that control stimuli in which two stimuli are reported (i.e. excluding false positives) would be identical with target stimuli in which two stimuli are reported, unless the target is having a subliminal effect. The control stimuli showed a surprisingly large bias towards pleasant responses. For all control trials on which two stimuli were reported, the proportion of pleasant and unpleasant responses was measured. The percentage of pleasant impressions, across all control slides and all participants, was 80.43% and the percentage of unpleasant impressions was 19.57%.

This allows us to estimate whether the observed frequencies of positive and negative valence responses to individual slides are significantly different from the expected (control) values, using a chi-square test with one degree of freedom. In the supraliminal case, it is conceivable that the mere detection of the presence of a third slide (without detection of its contents), in itself affects the valence of response, but this factor should have equal effects, if any, on all slides. Results for the target slide set are shown in Table 3.1, for both supraliminal (3 seen) and subliminal (2 seen) trials.

16/24 slides provide concordant discrimination of valence in the supraliminal condition, and 15/24 slides provide concordant discrimination of valence in the subliminal condition (Table 3.1 - yellow highlights indicate discordant responses). This represents a greater than chance discrimination of response valence for stimuli on which the target is undetected (Table 3.1).

Frequency of pleasant and unpleasant impression responses with % concordance.						
	Supraliminal (3 seen)			Subliminal (2 seen)		
Slide	Un-pl	Pl	% C	Un-pl	Pl	% C
6 HVA jaguar	13	121	90.3	8	73	90.1
24 HVA puppies	6	177	96.7	4	29	87.9
31 HVA monkeys	71	63	47.0	39	43	52.4
10 LVA attack dog	57	29	66.3	67	61	52.3
15 LVA shark	16	102	13.6	10	87	10.3
33 LVA snake	92	36	71.8	62	27	69.7
18 HVF baby	13	163	92.6	7	34	82.9
20 HVF athletes	11	175	94.1	2	28	93.3
30 HVF att fem	31	148	82.7	11	26	70.3
7 LVF batt female	106	74	58.9	21	14	60.0
21 LVF angry man	161	28	85.2	17	11	60.7
35 LVF baby tumour	96	55	63.6	7	55	11.3
1 HVS skydivers	9	98	91.6	8	97	92.4
19 HVS skier	54	48	47.1	63	50	44.2
23 HVS waterfall	23	71	75.5	36	86	70.5
2 LVS air crash	3	60	4.8	15	136	9.9
8 LVS bomb	49	59	45.4	47	61	43.5
25 LVS car crash	23	113	16.9	8	73	9.9
4 HVI fireworks	6	142	95.9	7	59	89.4
13 HVI money	8	106	93.0	14	89	86.4
22 HVI ice cream	26	127	83.0	3	60	95.2
11 LVI flies on pie	39	123	24.1	3	52	3.6
26 LVI elec chair	40	71	36.0	44	62	41.5
36 LVI toilet	91	34	72.8	40	49	44.9

Table 3.1 Frequency of valence responses with % concordance.
Key: C = Concordant; Un-pl = Unpleasant; Pl = Pleasant; att = attractive; batt = battered; elec = electric.

A significant chi-square indicates that the frequency of high valence and low valence responses differs from the expected value (mean frequency of high and low valence responses to control slides), and thus indicates that the trial's valence can be distinguished from control. The direction of the deviation from expected value indicates whether the discrimination is in the expected direction (concordant with IAPS rating) or in the opposite direction (Table 3.2).

Frequency of pleasant and unpleasant impression responses, relative to control (expected frequencies).
ex = significant effect in expected direction (concordant with IAPS)
op = significant effect in opposite direction (discordant with IAPS)

	Supraliminal (3 seen)			Subliminal (2 seen)		
Slide	Chi-square	p		Chi-square	p	
6 HVA jaguar	8.288	<0.005	ex	4.834	<0.05	ex
24 HVA puppies	30.853	<0.0001	ex	1.163	n.s.	
31 HVA monkeys	95.073	<0.0001	op	40.825	<0.0001	op
10 LVA attack dog	119.221	<0.0001	ex	87.363	<0.0001	ex
15 LVA shark	2.707	<0.1	op	5.283	<0.05	op
33 LVA snake	222.508	<0.0001	ex	141.904	<0.0001	ex
18 HVF baby	16.594	<0.0001	ex	0.162	n.s.	
20 HVF athletes	22.033	<0.0001	ex	3.173	<0.1	ex
30 HVF att fem	0.576	n.s.		2.427	n.s.	
7 LVF batt female	176.821	<0.0001	ex	36.352	<0.0001	ex
21 LVF angry man	517.028	<0.0001	ex	30.119	<0.0001	ex
35 LVF baby tumour	185.806	<0.0001	ex	2.699	n.s.	
1 HVS skydivers	8.463	<0.005	ex	9.525	<0.005	ex
19 HVS skier	72.179	<0.0001	op	94.001	<0.0001	op
23 HVS waterfall	1.434	n.s.		7.659	<0.01	ex
2 LVS air crash	6.514	<0.05	op	8.905	<0.005	op
8 LVS bomb	45.683	<0.0001	ex	39.361	<0.0001	ex
5 LVS car crash	0.610	n.s.		4.834	<0.05	op
4 HVI fireworks	22.633	<0.0001	ex	3.368	<0.1	ex
13 HVI money	11.409	<0.001	ex	2.337	n.s.	
22 HVI ice cream	0.644	n.s.		8.775	<0.005	ex
11 LVI flies on pie	2.090	n.s.		6.961	<0.01	op
26 LVI elec chair	19.126	<0.0001	ex	32.422	<0.0001	ex
36 LVI toilet	225.046	<0.0001	ex	36.412	<0.0001	ex

Table 3.2 Frequency of valence responses relative to control (expected frequencies).
Key: n.s. = not significant; ex = significant effect in expected direction (concordant with IAPS); op = significant effect in opposite direction (discordant with IAPS); p = significance level; att = attractive; batt = battered; elec = electric.

Overall, 18/24 of the slides on supraliminal trials, and 17/24 of the slides on subliminal trials show significant valence discrimination at $p<0.05$, compared with controls. However, on supraliminal trials, 4/24 slides (highlighted) are discriminated significantly from control trials but in the opposite direction to that predicted from IAPS valence. On subliminal trials 6/24 slides (highlighted) are discriminated significantly from control, but in the opposite direction to that predicted from IAPS valence (Table 3.2). A significant concordant effect in the expected direction for subliminal discrimination was observed for the following slides: (one tailed) HVA (jaguar); LVA (attack dog, snake); HVF (athletes); LVF (battered female, angry man); HVS (skydivers, waterfall); LVS (bomb); HVI (fireworks, ice cream); LVI (electric chair, toilet)

(Table 3.2). The majority of these instances would survive a full Bonferroni correction for multiple comparisons ($P<0.0021$ two-tailed). However, significant discrimination in the direction opposite to that predicted was found in a minority of slides: HVA (monkeys); LVA (shark); HVS (skier); LVS (air crash, car crash) and LVI (flies on pie) (Table 3.2). It is possible to make a case (with hindsight) that each of these slides changes its visual characteristics at short exposure. In the case of flies on pie and skier, the pie and snow (low spatial frequency) is more visible than the flies and skier (high spatial frequency) at brief exposures. Equally, the image of the shark is in an unusual view, and out of its normal context as its head is exposed out of water in a 'pyramid' shape. In the case of monkeys, they are exposing teeth, and this may be a salient threat stimulus at brief exposure. The air crash and car crash are scrambled stimuli – containing scattered parts – and may require scrutiny for recognition to occur. However, these are all post hoc explanations.

It would seem, without any special pleading, that these anomalous images can be explained by two main types of explanation: either a failure to detect relevant features or misrepresentation. However, we need some way of testing these ideas. In order to test detectability of features or elements within these images, the *saliency toolbox* (Walther and Koch, 2006) was used to predict where automatic visual attention goes. This toolbox allows an implementation of a basic version of Itti & Koch's (2001) model of visual attention (Itti and Koch, 2001) (see section 3:3). The model starts by detecting low-level image features (colour, intensity and orientation) then passes these in parallel through opponent (centre-surround, normalising) operators that detect discontinuities in each feature type. These parallel streams are then linearly combined to produce a saliency map. To generate predictions of the scan path (sequence of fixations) the most salient location is selected (winner takes all). The next feature is selected by inhibition of return, and so on. The scan path is ultimately circular, returning to the first fixation when inhibition is decayed. The model predicts several aspects of human psychophysical and oculomotor performance (Itti and Koch, 2001).

It was hypothesised that emotive features were not detected in early fixations in the anomalous pictures. However, the results revealed that in all six instances the relevant features were detected (by the model) at early

fixation (e.g. flies on pie – first fixation was a fly, skier – first fixation was a skier). Rather than failing to detect emotive features, therefore, it is probable that the images were not identifiable under rapid presentations and as such were misrepresented.

In summary, concordant valence response was evident during target trials when only two images were reported, thus suggesting subliminal processing. However, there were a minority of anomalies that were discordant in valence response.

3:5:4 Independent Ratings Evaluation

Accuracy of concordant results could be influenced by each individual's perception of the image, dependent on the said individual's own cognitive schema. There may also be overall differences between the sample used in this study and the normative IAPS sample. Therefore, to investigate group differences in emotion perception, the published IAPS ratings for each slide was compared to those of this experimental group. The average ratings in the post experiment questionnaire (Appendix IV) were calculated and marginal differences were found with a number of images (Table 3.3). However, it is worth re-iterating here that the images chosen for the experiment were rated in IAPS as high valence >6, high arousal >5; low valence, <4 high arousal >5; neutral valence >4 <6, low arousal <5 and the sample group complies with these criteria for valence, but with six images scoring slightly less than 5 for arousal. Notwithstanding this, it has to be acknowledged that the post-experiment scoring had the advantage of extended exposure time and does not indicate a 'concordant or discordant' response under subliminal conditions.

	Valence		Arousal	
Images in Experiment	Sample	IAPS	Sample	IAPS
Skydivers	6.99	7.57	5.11	6.99
Air Crash	2.35	2.71	5.73	5.75
Fireworks	7.41	7.53	5.46	5.48
Jaguar	7.06	6.65	5.49	6.23
Battered Female	2.03	1.92	5.64	5.77
Bomb	2.90	2.96	5.18	6.06
Attack Dog	2.41	3.09	6.08	6.51
Flies On Pie	2.69	3.59	4.90	5.11
Money	7.51	7.91	6.05	6.44
Shark	2.95	3.85	5.62	6.47
Baby	8.19	7.86	6.47	5.00
Skier	7.27	8.1	5.55	6.28
Athletes	6.81	7.56	4.84	5.74
Angry Face	2.59	3.34	4.61	5.18
Ice Cream	6.42	7.53	4.93	5.76
Waterfall	7.38	7.34	5.97	5.71
Puppies	7.82	8.34	6.20	5.41
Car Crash	1.84	2.3	5.55	5.76
Electric Chair	2.13	3.41	5.44	5.58
Attractive Female	6.29	6.79	4.29	5.16
Monkeys	6.06	7.62	4.76	5.12
Snake	3.32	3.46	5.43	6.87
Baby Tumour	1.42	1.46	6.72	7.21
Toilet	1.33	2.26	6.08	5.28
Neutral chair	5.27	4.96	2.22	2.83
Neutral basket	5.38	4.94	2.31	1.76
Neutral stool	4.77	4.63	2.33	2.71
Neutral iron	4.42	4.69	2.47	2.99
Neutral fork	4.83	5.27	2.39	2.32
Neutral book	5.06	5.19	3.05	2.61
Neutral hairdryer	4.96	4.93	2.70	2.75

Table 3.3 Scores of average ratings post experiment.
Key: Sample Valence = Sample average valence score; Sample Arousal = Sample average arousal scores.

The relationship between the sample ratings and IAPS ratings were further investigated using Pearson correlation coefficient. There was a strong positive correlation between sample valence and IAPS valence ($r = .97$, $n=31$, $p<0.0005$) plus a strong positive correlation between sample arousal and IAPS arousal ($r = .90$, $n=31$, $p<0.001$).

Establishing that the experimental group ratings of the stimuli fall within the same ranges as those of the IAPS ratings, allows us to eliminate this as a possible explanation for any disparity in impression of the stimuli. However, it is possible that concordance is not the only measure of subliminal

processing. Perhaps confidence in one's answers is also an indication of subliminal perception.

3:5:5 Confidence Ratings: Analysis for Individual Slides

Another way of looking at subliminal perception is to assume that there is no distinct 'subliminal process', but rather, there is a graded ability to process stimuli, and no fixed threshold. It is possible to use confidence ratings to investigate this hypothesis. If a subliminal stimulus is simply a weakly detected stimulus, for example, the observer's confidence in the overall pleasant or unpleasant impression given by a trial should be higher when the target is detected. Moreover, confidence in the overall pleasant or unpleasant impression given by a trial should be higher for 'correct' (concordant with IAPS rating) than 'incorrect' (discordant with IAPS rating) trials.

Participants were asked to rate how confident they were in their overall judgement of valence for the trial as a whole. This measure is the valence 'impression confidence' (coni). A univariate analysis of variance was conducted for each individual slide. The dependent variable was the confidence in the impression of valence (coni) and the independent variables were the response concordance (i.e. whether the response was concordant or discordant with the IAPS valence rating) and the number of pictures seen (2=subliminal, 3=supraliminal). Significant main effects of response concordance on valence impression confidence were found in 11/24 slides, and significant main effects of number of pictures seen on valence impression confidence were found in 5/24 slides (confirming H^2). Significant interactions (response concordance x number of pictures seen) were found in 3/24 slides. It was expected that valence impression confidence would be higher for concordant responses and seen targets, but there were exceptions to this. For some low valence slides, confidence was higher for discordant responses (shark, air crash, car crash and electric chair). This is because not only is there a response bias towards pleasant responses, there is also a confidence bias: other things being equal, confidence ratings are higher for pleasant responses (mean = 7.23) than unpleasant (mean = 6.66). This may be an indication that more sensory information is required to feel confident in ones answer coupled

with a natural reluctance to report an unpleasant response; this is addressed in greater detail in the discussion. Where subliminal and supraliminal trials differ in valence impression confidence, this is in the expected direction, with confidence being higher for seen trials. However it is notable that valence impression confidence for the majority of trials does not seem to depend strongly on whether the target is seen. Where there is an interaction, a strong relationship of valence impression confidence with concordance for supraliminal trials is matched with a weaker relationship in the opposite direction for subliminal trials (for summary see Appendix VI column 5).

Participants were also asked to rate how confident they were in their response to the question "how many pictures did you see?" This measure is the 'seen confidence' (cons). A second UNIANOVA was carried out on confidence in how many seen (DV), with the same IVs.

Significant main effects of correct number seen on confidence in how many images seen (cons) and was found for 8 out of 24 images: athletes $F(1,212) = 5.38$, $p<0.05$; icecream $F(1,212) = 5.62$, $p<0.05$; puppies $F(1,212) = 12.26$, $p<0.001$; car crash $F(1,213) = 25.68$, $p<0.001$; attractive female $F(1,212) = 12.16$, $p<0.001$; monkeys $F(1,212) = 24.23$, $p<0.0005$; snake $F(1,213) = 11.68$, $p<0.001$; and toilet $F(1,210) = 7.60$, $p<0.01$).

There were four images with a significant main effect concordant response on confidence in how many images seen: attack dog $F(1,210) = 8.68$, $p<0.005$; car crash $F(1,213) = 5.30$, $p<0.05$); electric chair $F(1,213) = 4.84$, $p<0.05$; toilet $F(1,210) = 5.68$, $p<0.05$.

Lastly, nine significant interactions were recorded for number seen x concordance on confidence in how many images seen: battered female $F(1,211) = 11.19$, $p<0.001$; bomb $F(1,212) = 5.06$, $p<0.05$; attack dog $F(1,210) = 5.15$, $p<0.05$; flies on pie $F(1,213) = 6.79$, $p<0.01$; baby $F(1,213) = 5.40$, $p<0.05$; angry man $F(1,213) = 25.56$, $p<0.001$; car crash $F(1,213) = 11.13$; $p<0.005$; attractive female $F(1,212) = 5.33$, $p<0.05$; toilet $F(1,210) = 6.98$; $p<0.01$.

Although coni and cons were moderately positively correlated with each other (mean spearman rho = 0.4 – 0.6), cons was less frequently predicted by concordant response (5/24) than was coni (11/24). Conversely, the number

of images where cons was predicted by number of images seen (8/24) was slightly higher than for coni.

3:5:6 Conclusions from ANOVA of Individual Slides.

As shown in section 3:5:3, the analysis of responses to individual slides (Appendix VI) shows that for particular slides there is clear evidence of valence discrimination, even when the presence of the slide is undetected. In section 3:5:5 it is shown that for a substantial number of slides, the confidence in the overall impression of valence is increased for concordant relative to discordant responses. However there are a number of exceptions or anomalies revealed by this analysis. For certain slides, there is discrimination of valence, but in the opposite direction to that predicted by IAPS ratings (Section 3:5:3). Likewise for certain slides, the confidence in valence impression is higher for discordant relative to concordant responses (Section 3:5:5). Three possible explanations for anomalies have been considered. The first is that there is a response bias towards high valence responses, as is evident from the response to control trials. The second is that the spatiotemporal properties of the visual system are such that the relative salience of different components or features of an image is changed by the brief presentation: most obviously there is a loss of high relative to low spatial frequency information. The third explanation, however, using the saliency toolbox, identified misrepresentation as a possible reason for the anomalous results.

In the next section we consider whether (despite these anomalous responses to certain images) it is possible to draw general conclusions about the influence of valence and stimulus category on detection, discrimination of valence, and confidence ratings.

3:6 Analysis of Response to Stimuli Grouped by Category and Valence.

3:6:1 Detectability of Stimuli (nseen).

To determine the detectability of each stimulus, it is assumed that if two stimuli were seen (i.e. the two masks) the target was not detected. If three stimuli were

seen, the target was detected. Therefore the detectability of a stimulus is the 'number seen' minus two. This was averaged over categories and over participants to give the mean probability of detection (henceforth 'detectability'). Of the a priori category differences in detectability Wilcoxon showed significant differences in detectability with faces seen more than animals ($z = 8.225$, N – Ties 56, $p<0.0005$), faces seen more than scenes ($z = 10.507$, N – Ties 41, $p<0.001$), faces seen more than inanimate objects ($z = 8.474$, N – Ties 65, $p<0.0005$), animals seen more than scenes ($z = 7.281$, N – Ties 47, $p<0.0005$), and inanimate objects more than scenes ($z = 7.927$, N – Ties 55, $p<0.0005$). Of the four categories, faces were substantially the most detectable, whilst scenes were the least (Figure 3.3).

However, it was only for the category of animals that there was a significant difference in the mean positive and negative detectability of valence ($z = 7.954$, N – Ties 90, $p<0.0005$). There was no significant difference in the detectability of valence in the other three categories. Therefore it is concluded that positive and negative valence stimuli in these categories may be considered matched in their average valence detectability (Figure 3.3).

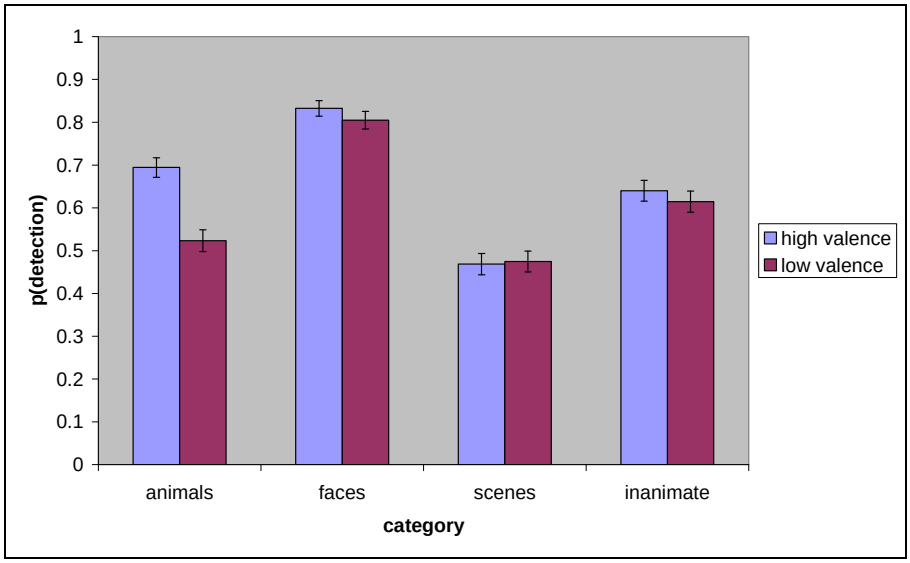


Figure 3.3 Mean probability of target detection by category and valence.

In Figure 3.3 the mean probability of detecting the target stimulus is shown on the Y axis. It is assumed that if the number of stimuli seen (including the masks) is three, then the target has been detected (probability = 1), and if the number of stimuli seen (including the masks) is two, then the target has not

been detected (probability = 0). Probabilities are averaged across instances (slides) and participants for four categories of stimuli (X axis). The two data series represent the high valence and low valence slides within each category.

3:6:2 Effects of Stimulus Detectability (nseen) on Seen Confidence (cons) and Valence Impression Confidence (coni).

It will be expected that seen confidence will be high for trials on which the target is clearly detected, and low for trials on which the target is not clearly detected. Thus there should be a positive correlation between detectability (nseen-2) and seen confidence. But what about valence impression confidence? If overall impression of valence depends on detecting the target, then there should be a positive correlation also between detectability and valence impression confidence. The means (across all participants) and the standard errors of seen confidence and valence impression confidence were determined for every target slide and are shown in Figure 3.4. There was a positive correlation in each case, but the association between detectability and seen confidence (r^2 = 0.85) was much stronger than that between detectability and valence impression confidence (r^2 = 0.4).

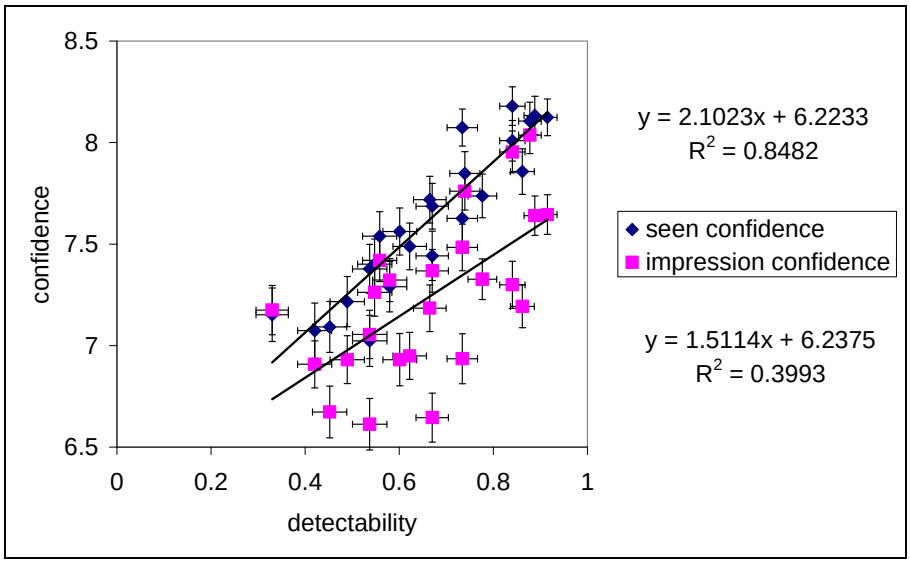


Figure 3.4 Mean confidence ratings for seen confidence and valence impression confidence.

In Figure 3.4 the mean confidence ratings for stimulus detection (seen confidence) and for judgments of overall impression of valence (impression

confidence) are plotted as a function of the mean detectability (nseen – 2) of the target for the 24 target slides. Error bars = 1 S.E.M.

3:6:3 Effects of Stimulus Valence and Category on Seen Confidence (cons).

To find out how seen confidence varied as a function of stimulus valence and stimulus category, seen confidence ratings differed for high and low valence stimuli for animals (Wilcoxon z = 7.366, N – Ties 30, $p<0.005$) and faces (Wilcoxon z = 2.232, N – Ties 76, $p<0.05$). Scenes and inanimate objects showed no significant difference in seen confidence for high and low valence stimuli. Therefore we can consider that high and low valence versions of these categories of stimuli are balanced with respect to the confidence ratings for detection. As expected, the marginal means showed a similar pattern (Figure 3.5) to that shown for detectability (Figure 3.3).

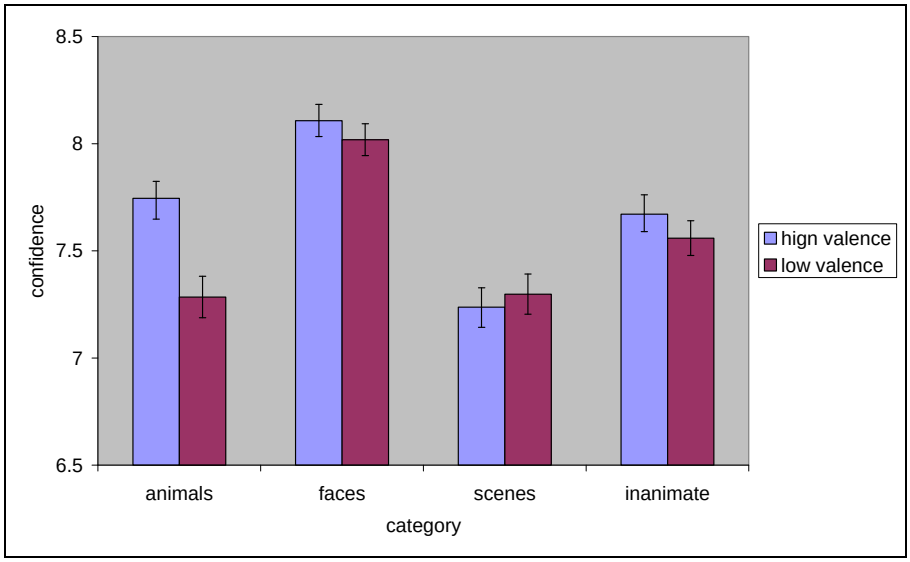


Figure 3.5 Mean confidence rating for the number of stimuli seen (including the masks) (Y axis). Ratings are averaged across instances (slides) and participants for four categories of stimuli (X axis). The two data series represent the high valence and low valence slides within each category.

3:6:4 Effects of Stimulus Valence and Category on Overall Impression of Valence (imp).

The overall impression of valence of a stimulus trial (consisting of a target plus masks) was analysed as a function of the IAPS valences and categories of the target slides. The overall impression of valence (imp) was scored +1 for 'pleasant impression' and -1 for 'unpleasant impression'. Means were then calculated across the three exemplar slides of each type (valence x category) for each participant, generating a four-point scale (+1, +0.33, -0.33, -1). Data was averaged across both supraliminal (3 seen) and subliminal (2 seen) trials. The means are shown in Figure 3.6. Note that the difference in means is smaller (and in the opposite direction) for scenes. Note also that there is an overall bias in favour of pleasant responses, as already discussed above.

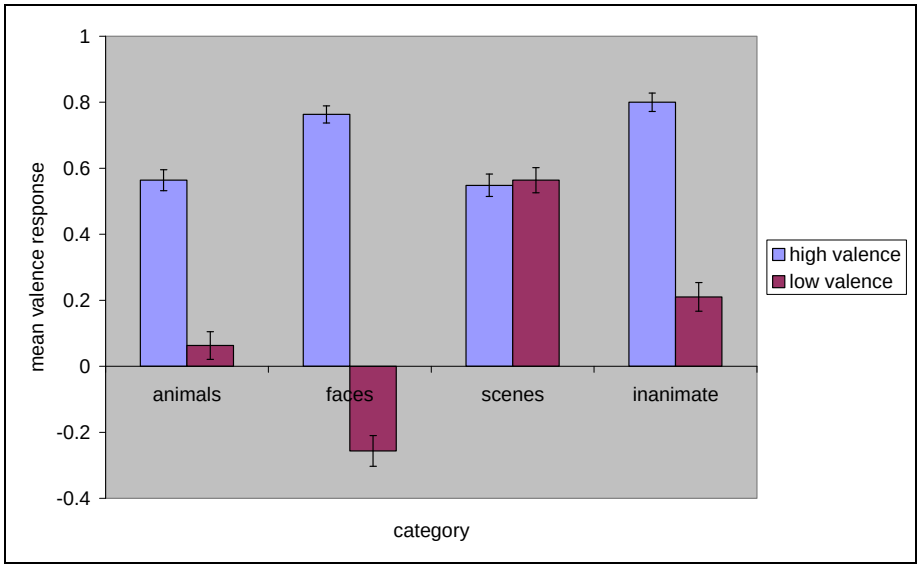


Figure 3.6 Mean overall impression of valence (Y axis). Valence responses are averaged across instances (slides) and participants for four categories of stimuli (X axis). The two data series represent the high valence and low valence slides within each category.

To test for differences in response to high and low valence Wilcoxon was used. Significant differences were found for animals ($z = 9.294$, N – Ties 65, $p<0.0005$), faces ($z = 10.824$, N – Ties 25, $p<0.0005$), scenes ($z = 3.751$, N – Ties 95, $p<0.0000005$) and inanimate objects ($z = 9.707$, N – Ties 64, $p<0.0005$).

3:6:5 Effects of Stimulus Valence and Category on Confidence in the Overall Impression of Valence (coni).

Finally, Wilcoxon tests were carried out to determine how confidence in the overall impression of valence (coni) differed for high and low valence stimuli, for each category of the stimulus. Again, a similar overall pattern emerged, with significant effects for high and low valence for animals ($z = 4.511$, N – Ties 35, $p<0.001$), faces ($z = 3.195$, N – Ties 52, $p<0.005$) and inanimate objects ($z = 3.276$, N – Ties 37, $p<0.005$).

Mean confidence ratings for valence impression are shown in Figure 3.7 and the overall greater impression confidence for high valence stimuli and faces may be seen.

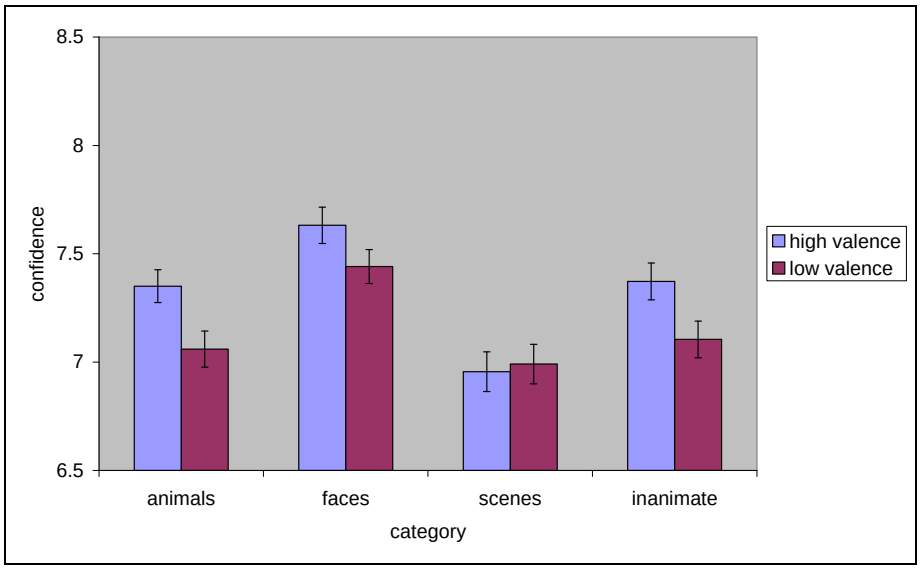


Figure 3.7 Mean confidence rating for the overall impression of valence (Y axis). Ratings are averaged across instances (slides) and participants for four categories of stimuli (X axis). The two data series represent the high valence and low valence slides within each category. Error bars ±1 SEM. This is consistent with the response bias for pleasant responses already discussed.

3:6:6 Conclusions from the Analysis of Response to Stimuli Grouped by Category and Valence.

- The detectability of high and low valence stimuli is not significantly different for faces, scenes and inanimate objects.
- The detectability of high valence animals is higher than that of low valence animals.

- Categories differ in detectability. Faces are the most detectable, scenes the least.
- The confidence in detectability (number seen) is strongly correlated with detectability.
- Confidence in impression of the stimulus valence is less strongly correlated with detectability.
- The overall impression of valence is higher for high valence stimuli than low valence stimuli for animals, faces and inanimate objects. Scenes are anomalous in that there is a significant difference in the opposite direction to that predicted by IAPS.
- Confidence in the impression of valence was significantly different for high and low valence with animals, faces and inanimate objects. There is no significant difference for scenes.

3:7 Discussion

The rationale of the design was to measure affective discrimination when participants deny awareness of target stimuli, thus suggesting unconscious emotional perception (Merikle et al., 2001). Stimulus discrimination was measured ('overall impression pleasant vs unpleasant') and harvested strong support for discrimination of valence in brief, masked presentations of IAPS stimuli. If such stimuli can be discriminated, they must necessarily be capable of producing differential effects in the brain. There is thus strong justification for predicting that brief, masked IAPS stimuli will generate detectable valence-related differences in fMRI activations.

Choosing a forced-choice pleasant versus unpleasant discrimination task has the obvious advantage of preventing irresolute submission ('don't know'), which reaps little reward in data collection. The problem with this is that single-interval forced choice methods are still susceptible to response bias. An accepted technique to measure sensitivity that is independent of response bias is signal detection theory (SDT). However, a preliminary analysis of the data in this chapter showed that a SDT approach was not tractable. Instead, a method using nonparametric chi-square was adopted, which meant that

categorical data, response bias and any missing data were accounted for in valence analysis of individual images. Evidence for subliminal processing had to be sought at the level of responses to individual slides, because the design of the experiment required each trial to be classified as 'target detected (nseen = 3)' or 'target not detected (nseen=2)'. This means that nseen is necessarily a between-participants variable, and furthermore the assignment of each participant's response to the 'target detected' or 'target undetected' group varies for each slide. Therefore, responses to detected and undetected trials cannot be averaged across slides. Examining each picture one at a time rendered it possible to recognise evidence for subliminal perception and also to detect the small number of anomalies that were indicated by significant valence discrimination in the wrong direction.

The main point to consider is valence discrimination in subliminal (seen 2) responses. Taking into account only those trials on which the target was undetected, 17 out of 24 slides (Table 3.2) showed significant differences in 'overall impression of valence' compared with control (target absent) slides. Relying on the operational definition of subliminal perception, this would indicate that the valence was detected without conscious awareness. However in 6 out of those 17 slides (Table 3.2), the predominance of valence impressions was opposite to the expected direction, even after taking into account the response bias revealed by the control stimuli. This is confirmation that some IAPS stimuli are effectively processed below the level of conscious awareness.

It was found that despite the low detectability of the stimuli, participants were able to reliably assign a level of confidence to the overall pleasant or unpleasant impression given by a stimulus trial. Concordance or discordance with the IAPS rating produced a significant effect on confidence in the stimulus valence impression in 11 out of 24 stimuli (Appendix VI, column 4). In 7 of those stimuli, confidence was significantly higher for the concordant response, and in four, confidence was higher for the discordant response (Appendix VI, column 5). All of the latter were low valence stimuli, suggesting that participants are more confident in giving a positive than a negative valence response. All of the remaining HV stimuli showed a trend in the expected direction (confidence higher for concordant responses) but for LV

stimuli the results were much more variable. The conclusion that confidence was generally higher for HV responses was confirmed in the overall analysis (regardless of detection or non-detection of targets) for animals, faces and inanimate objects.

A possible explanation for the strong positive bias for valence response and confidence ratings is that more sensory evidence is required to report a negative than a positive valence stimulus. This is indicative of a response process such as response suppression in perceptual defence. Rather than response suppression signifying a defensive blocking of conscious perception, it is well documented that perceptual defence is explained by response inhibition. Using a set of neutral and taboo words, it was found that a recognition task reflected how the participants responded, not what they perceived (Zajonc, 1962). In other words, response to unpleasant stimuli is inhibited for various internal events, such as personal values and attitudes, as well as expectancies of the situation (Erdelyi, 1974). It is also plausible that, due to discomfort, participants have a natural reluctance to label a stimulus as unpleasant until certain of the content, therefore needing extra time for discrimination (Kline et al., 1998). This view would explain why the briefly presented unpleasant stimuli were sometimes discordant in response.

It was found that confidence scores in how many seen were strongly correlated with the detectability of the stimulus. Confidence in the overall valence impression was less strongly dependent on the detection of the target, lending support in this present study, to the notion that perception of valence was occurring below conscious detection threshold (VanRullen and Koch, 2003b). If participants were concordant in their valence response and reported seeing only 2 slides, but were not confident with their answer then this can be argued as a case for graded conscious perception. This is because it is likely that participants would not be highly confident if their valence response was based on a simple ‘feeling’ that a trial was pleasant or unpleasant.

This supports the mounting evidence for graded conscious perception in that the distinction between conscious and unconscious visual perception is not as dichotomous as previously assumed. The ‘all-or-nothing’ idea would appear unlikely, as in this instance it is evident that some information from unconsciously perceived visual stimuli reaches beyond the early stages of the

visual system to higher cortical or subcortical levels which are selectively activated to valence (Li et al., 2002).

Previous studies investigating subliminal perception using confidence ratings have produced conflicting results. For instance, a study replicating blindsight in normal participants presented two displays of visual texture stimuli, one visible and the other not. They found no correlation between confidence levels and detection or localisation of target (Kolb and Braun, 1995). By attempting to replicate Kolb and Braun's study, Morgan, et al., (1997) found that confidence ratings correlated highly with accuracy in performance. To explain the discrepancy in results, the authors criticised Kolb and Braun for instructing the participants to use the full range in the confidence scale regardless of the level of certainty (Morgan et al., 1997). More recently, Kolb and Braun's study was duplicated by Robichaud and Stelmach (2003) in terms of methodology but added a pointing response as an extra condition. The results were the complete opposite to those of Kolb and Braun (1995), and supported those of Morgan, et al. (1997) in that confidence ratings and accuracy were correlated well (Robichaud and Stelmach, 2003). Scharli, et al. (2003) supported these findings in another simulation of blindsight. Detection and localisation performance was measured on visual stimuli presented below level of awareness. It was concluded that correct detection and localisation did correlate with confidence regarding accuracy, which they interpreted as an impoverished level of conscious awareness (Scharli et al., 2003).

In the present study, there was a strong positive correlation between confidence in how many seen and detectability (number of stimuli seen). Lack of confidence implies 'guessing', suggesting that participants are unaware of any information that leads to their detection and discrimination response. This premise is supported by Kunimoto and colleagues, who assert that the association between confidence and accurate response is a measurable criterion for awareness and participants are only aware of stimuli when confidence is related to concordance (Kunimoto et al., 2001). The strong correlation between confidence in the number seen and probability of detection meets the criterion of Kunimoto et al. (2001). There is a significant positive relationship between concordance and valence impression confidence for some slides, a negative relationship for others, and for further slides there is no relationship,

therefore on this criterion, conscious awareness of valence is somewhat weak and variable across the sample of stimuli.

Therefore, this experiment succeeded in presenting stimuli both above and below conscious awareness. Equally, when taking incorrect detection of target stimuli as no awareness (i.e. subliminal - seen 2 images when 3 presented) and taking into account response bias when calculating valence response on undetected stimuli, there is also evidence of subliminal processing.

This investigation now requires further analysis. Repeating the behavioural study using fMRI eliminates concerns over response processes and potentially can reveal evidence for neural processes underlying valence discrimination across diverse categories of stimuli. The behavioural study, however, revealed some anomalous valence responses to certain images. The most likely explanation for this was the probability that these images were not identifiable under rapid presentations and therefore misrepresented. This necessitates a further procedure for the next fMRI experiment and so, the decision was made to choose another full set of stimuli as a second condition. These were matched as closely as possible for valence, arousal and category with the first target set. The only difference was that they were a completely different set of images, so that their physical properties were necessarily different. The two sets were thus matched for the variables of interest (valence and category), but not for image features. It is also worth reiterating that Wilcoxon tests in the behavioural experiment did show that high and low valence stimuli were matched for detectability, for the faces, scenes and inanimate objects. Therefore, any effects of valence for these categories were not confounds with detectability.

Finally, when re-examining these data by averaging responses across categories, there was some evidence of category effects over and above the variation in individual slides. The faces were the most detectable category, and they also showed the clearest discrimination between high and low valence stimuli. The animals and inanimate objects were also relatively well detected and showed differential valence responses to IAPS high and low valence stimuli. The scenes showed the most anomalous valence responses and the lowest detectability. Equally, when considering the neuroimaging literature it is clear that stimuli are frequently defined in terms of *a priori* categories, e.g.

animals (Bacon-Macé et al., 2005, Delorme et al., 1999, Delorme et al., 2004, Fize et al., 2000, Fize et al., 2005, Kirchner and Thorpe, 2006, Li et al., 2002, Rousselet et al., 2004b, Thorpe et al., 1996, Thorpe et al., 2001b, VanRullen, 2007); *faces* (Delorme and Thorpe, 2001, Rousselet et al., 2004b, Rousselet et al., 2004a, VanRullen et al., 1998, VanRullen et al., 2005); *scenes* (Delorme et al., 1999, Delorme et al., 2004, Fabre-Thorpe et al., 2001, Mace et al., 2005, Rousselet et al., 2005, Thorpe, 2002); *objects* (Thorpe et al., 1996, Thorpe et al., 2004, VanRullen and Koch, 2003a, VanRullen and Koch, 2003b); *vehicles* (Li et al., 2002, VanRullen, 2007, VanRullen and Thorpe, 2001c); and *food* (Delorme et al., 2000).

Therefore, to facilitate critical assessment of the fMRI findings with previous research and to investigate any apparent category variation in the fMRI activations to the images, the stimulus blocks in the following fMRI study in Chapter 4 will now be defined in terms of category membership as well as valence.

3:8 Conclusion and Summary

Concordant responses and confidence ratings were taken as a measure of subliminal processing of affect. It was shown that it is possible to rapidly evaluate valence discrimination in complex natural images when presented below the threshold of conscious awareness (confirming H^1).

Hypothesis two was partially confirmed, as there was a significant difference in valence perception between subliminal and supraliminal presentations for 6 out of 24 slides. However, for most slides, the subliminal effect was similar to the supraliminal one but slightly weaker.

Hypothesis three was confirmed, in that there was a positive correlation between confidence in seeing the target and target detection. There was also a positive but much weaker correlation between confidence in the impression of valence and target detection. This can be taken as indicating a partial independence between valence discrimination and target detection.

There is strong evidence that the chosen natural images are effective stimuli for emotional valence even when presented in brief, masked exposures. There was partial validation of the division of stimuli into four *a priori*

categories, in that category effects showed some consistency, but this was complicated by the large variation in detection and valence discrimination responses to individual images. In order to objectively re-examine the effectiveness of the complex pictures, they will now be presented as categories to map the neural correlates of affective processing. Therefore, the next step is to conduct this experiment using fMRI.

Chapter 4 fMRI Masked Experiment: fMRI activations in different brain regions (ROIs) to complex affective stimuli. Effects of brief, masked presentations, stimulus category and valence

4:1 Abstract

The previous behavioural experiment has confirmed valence discrimination without conscious awareness for a proportion of selected complex natural stimuli of affect. In order to support and complement these findings, the same stimuli in a similar forward and backward masking paradigm were re-examined using fMRI. This provided objective description of neural activations associated with stimuli category variation and valence effect. The results strengthened the initial evidence that natural images presented in normal and brief viewing conditions are effectively discriminated for valence and category in nine selected ROIs and demonstrated some hemispheric differences.

4:2 Introduction

Having established significant subliminal valence response employing natural images in a behavioural study, the next step is to examine targeted areas in the brain where valence processing of brief, masked images may occur. Therefore, using fMRI, the effect of brief, masked presentations of the same images in relation to activations in nine relevant ROIs (see section 1.6) were investigated for further objective evidence of rapid processing of valence in diverse images.

As discussed in Chapter 3, conscious visual processing does not occur without sufficient strength of visual input. This visual input can be reduced by suppressing feedforward activity by forward masking. The now weakened input can then be further suppressed by interfering with late reentrant level backward masking. A reentrant theory of perception asserts that lower level processing of sensory input cannot be analysed if it is not confirmed by higher level processing (e.g. confirmation of identification by testing initial sensory

input with previously available sensory evidence). If confirmation is interrupted, as in the case of backward masking, then the percept will decay and conscious perception will not occur (Koch, 2004). In order to present stimuli below, or close to the threshold of conscious awareness, without suppressing unconsciously perceived emotion (Dolan, 2002), as in the behavioural experiment, a forward and backward masking (by neutral images) paradigm was used.

The main purpose of the present study is to investigate processing complex affective stimuli below, or close to, the conscious threshold. Using fMRI, exploration of this phenomenon will now be considered in relation to nine ROIs in terms of high and low valence, and four different categories. Therefore, this chapter will address the following hypotheses concerning activations to contrasts between emotional and neutral IAPS stimuli within each of the nine ROIs:

- H^1 There are significant effects involving valence for normally viewed stimuli.
- H^2 There are significant effects involving valence for brief, masked stimuli.
- H^3 Valence effect is different between *normally viewed and brief, masked* presentations (interaction between valence and experimental condition).
- H^4 There are significant effects involving category.
- H^5 There are hemispheric differences between activations in paired ROIs.
- H^6 There are significant effects involving category for brief, masked presentations.

4:3 Method

4:3:1 Participants

Thirteen healthy participants took part in this experiment, seven males and six females (age range 19 – 45 years, mean age 29.3). None of the thirteen had a history of brain injury or psychiatric illness and they were not taking any

regular medication. The nature of the experiment was thoroughly explained and informed consent obtained. During the briefing, it was emphasised that some of the pictures may be of an unpleasant nature and some of the stimuli are associated with phobic reactions, (e.g. spiders, snakes etc). Armed with this information, participants could choose to continue with the experiment or not and were informed that they could stop the procedure at any time.

For those who travelled independently to the scanner, travel expenses were reimbursed. This was the only payment made.

4:3:2 Design

This was a block design fMRI study with three conditions. In the brief, masked condition, the target (T) pictures were presented for 10ms (see section 2:1:2), 'sandwiched' between two neutral (N) masking pictures with an exposure time of 1s each (Figure 4.1). This was followed by a 2s blank and the sequence was repeated three times in each block, ending with a 3s blank to ensure return to baseline level (Figure 4.2). The baseline (3s blanks) was modelled implicitly, therefore was not specified as a separate condition. The brief, masked blocks were randomised for categories. The brief, masked blocks were followed by two different normally viewed blocks 1 and 2 composed of target stimuli of the same category, valence and arousal. The target stimuli within each of the normally viewed blocks were presented for 1.01s, preceded by a neutral picture of 1s exposure (Figures 4.3 and 4.4). One of the normally viewed presentations (p) was of the same images as the preceding brief, masked condition and the images within these blocks were counterbalanced. The other normally viewed presentation (P) was a different image of the same category, but calibrated for the same valence and arousal. The order of the two normally viewed blocks was randomised. The 3 different target pictures in each block were of the same category (e.g. face) and valence (e.g. HV) (Figures 4.1 and 4.2). The purpose of using two different normally viewed stimuli sets was to establish the reliability of responses to valence and category using stimuli with diverse structure and content.

Four control blocks were introduced randomly, consisting of a neutral picture (10ms duration) 'sandwiched' between two neutral images of 1s duration.

Table 4.1 shows an example of a presentation order of blocks, (please read each row from left to right).

c	b	p	P	b	P	p	b	p	P	c	b	p	P
b	P	p	b	P	p	c	b	p	P	c	b	P	P

Table 4.1 A presentation order of blocks
Key: c = control; b = brief masked; p = same image as brief masked presented under normal viewing; P = different image presented under normal viewing.

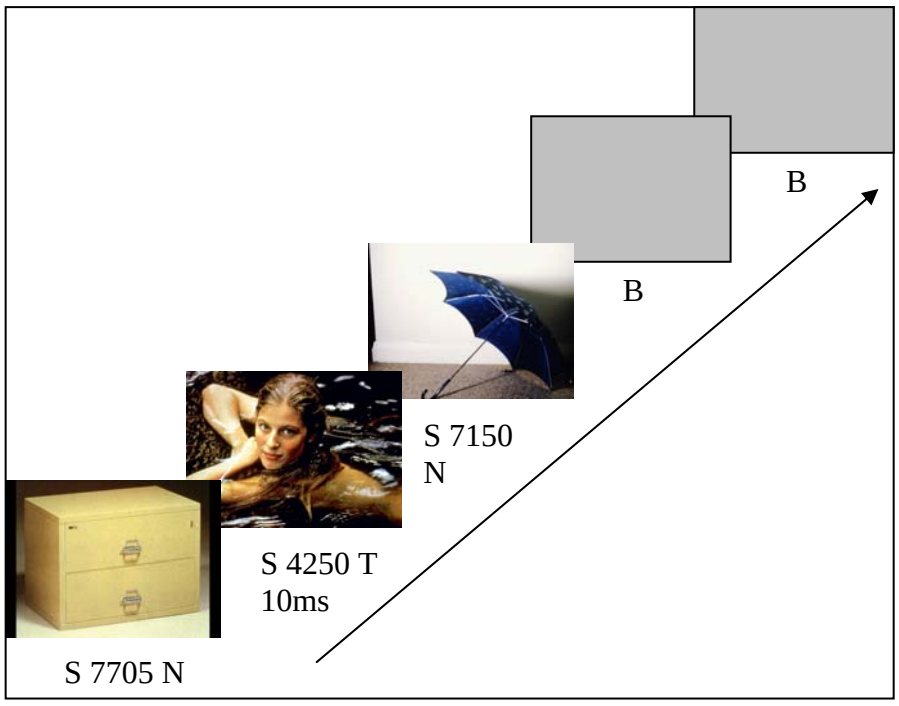


Figure 4.1 Actual image sequence for a brief masked block HVf. (Lang et al., 2001)
Key: S = Slide number; N = Neutral; T = Target; B = Blank; s = seconds; ms = milliseconds.

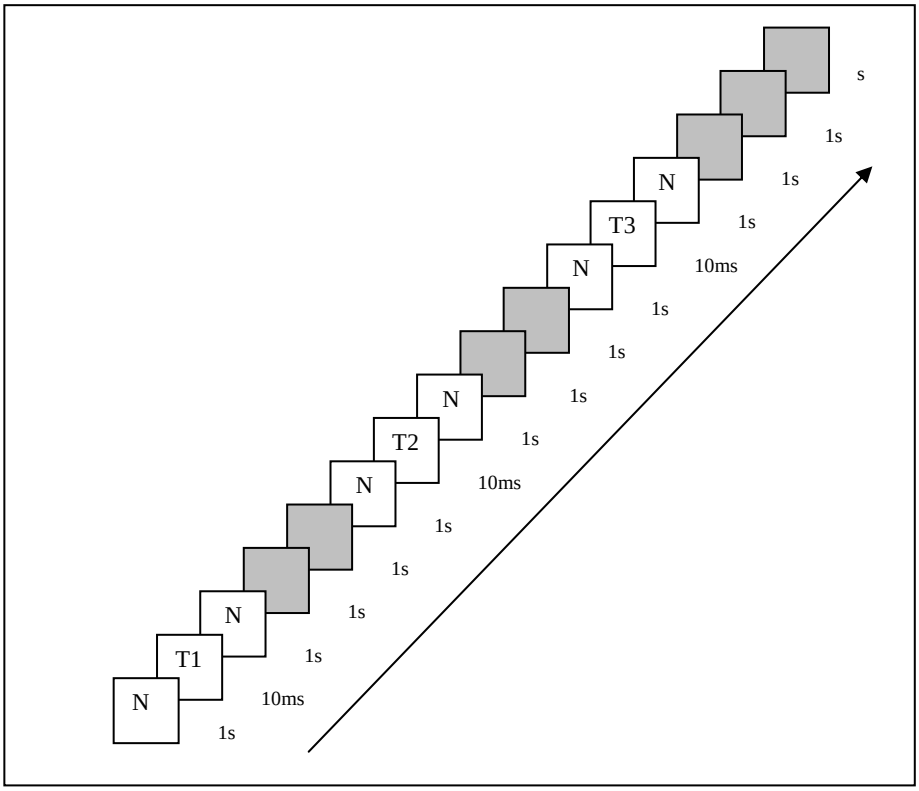


Figure 4.2 Stimulus sequence for a brief masked block
Key: N = neutral; T = target; s = seconds; ms = milliseconds.

Figure 4.2 demonstrates the brief, masked condition whereby the target stimuli (e.g. HV face 1 – Attractive Female, 2 - Baby and 3 - Athletes) of 10ms (see section 2:1:2) exposure are 'sandwiched' between two neutral stimuli of 1s exposure. The grey squares represent the blank screen between each target set.

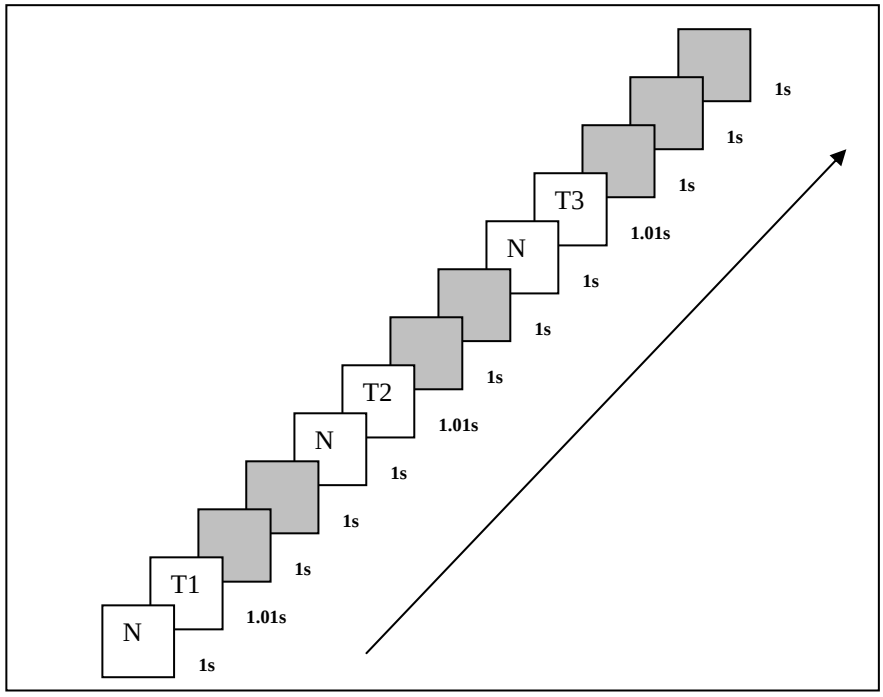


Figure 4.3 Stimulus sequence for a normally viewed (p) block
Key: N = neutral; T = target; s = seconds.

Figure 4.3. The same target stimuli were used for one of the presentations of the normally viewed condition with exposure time of neutrals 1s and target 1.01s. Again, three targets were presented in each block of the same category and valence.

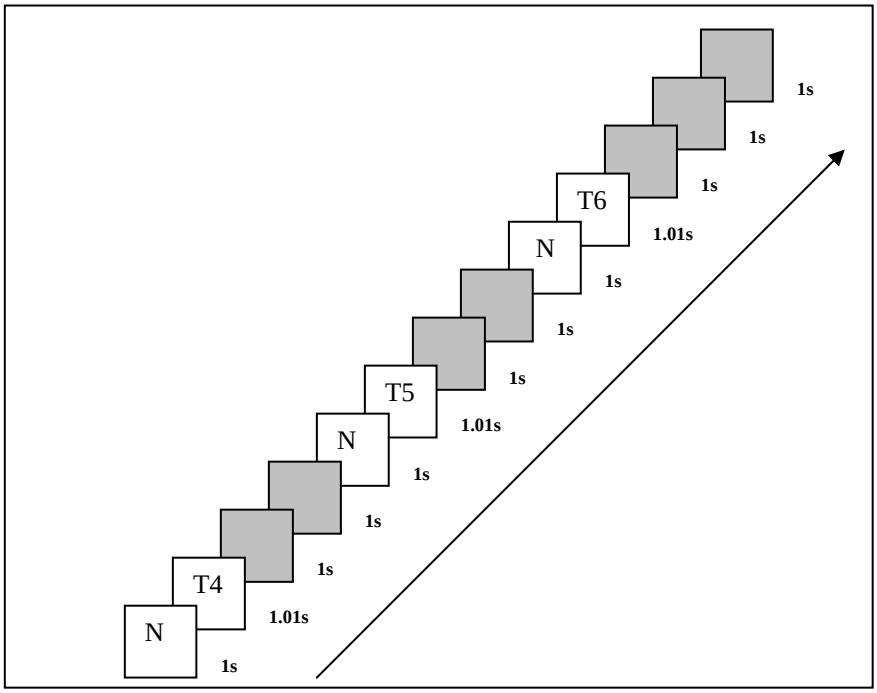


Figure 4.4 Stimulus sequence for the second normally viewed (P) block
Key: N = neutral; T = target; s = seconds.

For comparison purposes, a second normally viewed condition (P) was presented in a randomised order to the first presentation (p). Here different target pictures were used, but maintained the same paradigm as the first normally viewed condition. The purpose of the second normally viewed block was to establish the reliability of the constructs 'category' and 'valence' across variations in individual images (Figure 4.4).

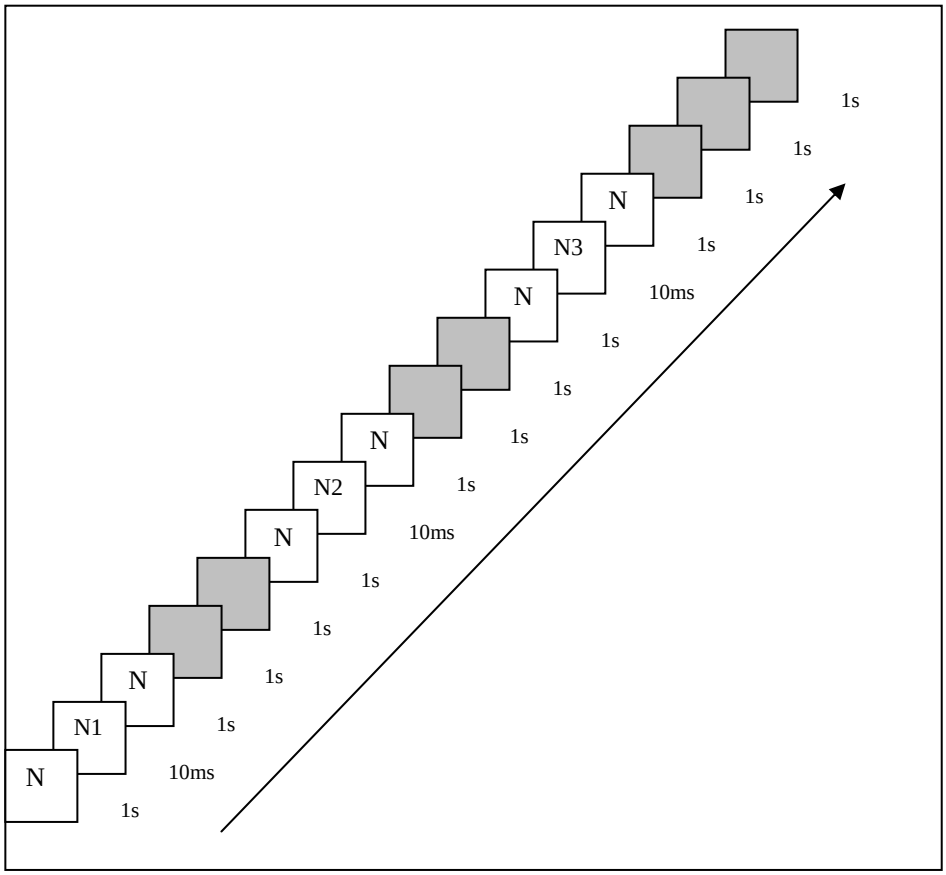


Figure 4.5 Stimulus sequence for a control block
Key: N = neutral; s = seconds; ms = milliseconds.

Figure 4.5 illustrates a control block of neutral images (10ms) sandwiched between two neutral images (1s each).

Each block ran for 13.03s, with eight brief, masked, eight normally viewed (same image as brief, masked), eight normally viewed (different images) and four controls. Thus 28 blocks were presented for a total time of 6.08 minutes.

4:3:3 Procedure

The well-being of the participants is a priority and, even though fMRI is reported to be safe by the International Society for Magnetic Resonance in Medicine (www.ismrm.org/public/index.htm), each participant was still required to complete an initial screening form (Appendix VII) to establish if they were at risk (e.g. suffering from claustrophobia, had any metal implants etc.) and if so, they would have been eliminated from the experiment without the need to go to the MRI unit. At the same time, each participant was given an information sheet with basic explanations concerning fMRI, procedures for scanning and safety requirements (Appendix VIII). This initial process was completed at least one week before scanning to allow time for an informed opinion on participation. On the day of scanning, a second screening form (Appendix IX) was filled in to ensure that all safety measures were in place, at which point a consent form was signed (Appendix X).

Whilst briefing the participants in the control room, a trial run was displayed on a laptop computer for familiarisation. This showed a group of typical pictures, not used in the experiment. This enabled the participants to ask any questions or choose to withdraw from the experiment.

The contents of an instruction slide used in the experiment were as follows:

- Each picture will appear quickly.
- Please indicate whether the images are pleasant or unpleasant.
- Press the left button for pleasant and the right button for unpleasant.
- GET READY.

The button box used in the experiment was a dummy, simply used to ensure greater attention and central fixation. The 'pleasant or unpleasant' decision via button press was required for control stimuli as well as emotional stimuli.

4:3:4 fMRI Data Acquisition

Data were acquired using procedures as outlined in section 2:1:2 and 2:1:4. Functional images were recorded using a 3T MRI scanner. Using a T2*-weighted gradient echoplanar imaging (EPI) data were attained over 6.08 minutes acquiring 35 slices per TR. The parameters set were TR 2s, TE 30ms, FoV = 192x192mm, flip angle = 90°, voxel size 3x3x3, number of measurements = 184 volumes.

4:3:5 Data Analysis

SPM2 (Friston and Wellcome Department of Imaging Neuroscience, 2003) (http://www.fil.ion.ucl.ac.uk/spm) was used for statistical processing, which was implemented in MATLAB (MATLAB Inc, 2002) (http://www.mathworks.com/products/matlab). Pre-processing was carried out as outlined in section 2:1:4.

As described in section 2:1:4, a preliminary first-level fixed effects analysis was implemented across the nine ROIs. Following on, a more comprehensive second level analysis of nine ROIs was performed using MarsBar toolbox for SPM2 (Brett et al., 2002) (http://marsbar.sourceforge.net) (again see section 2:1;4).

4:4 Results

4:4:1 First Level Analysis

Using a mean group contrast image a fixed effects analysis on the nine ROIs was carried out in order to advance initial inferences about this measured data. Activations, when presented with control stimulus, were subtracted from activations when presented with each of the experimental conditions (e.g. HV animals supraliminal > controls or HV animals subliminal > controls) with a p value of 0.05 using value adjustments family-wise error (FWE). The results of these contrasts are displayed in Table 4.2 and Table 4.3.

Having demonstrated how the normally viewed stimuli were randomised, the point of interest now is to examine if there were any differences between the two presentations. To facilitate this, the normally viewed presentations will be labelled in this section as presentation 1 (P1) and presentation 2 (P2) to identify any presentation order effect.

Table 4.2 shows significant activations to each presentation of the normally viewed stimuli (P1, P2). By displaying the significant results from the contrasts, one can see a striking similarity in activations between the first and second presentation of the normally viewed stimuli, regardless of presentation order. This firstly confirms the reliability of the categorisation of stimuli, and secondly suggests that presentation order of the normally viewed images does not have an effect. Thirdly, at first glance there appears no obvious habituation. It is also interesting to note that at this preliminary stage, there are differences evident in ROI activations according to the category and valence of stimuli.

		ACC	mPFC	Para	Amy	STG	Ins	Fusi	DLPFC	OFC
LVA	P 1	L R	L R	L		L R	L R	L	L	L
	P 2	L R	L R	L R		L R	L R	L	L	L
LVF	P 1						L	L R		
	P 2							L R		
LVS	P 1		R							
	P 2			L R				L R		
LVI	P 1	L R	L R	L R	R	L R	L R	L	L R	L R
	P 2	L R	L R	L R		L R	L R	L R	L R	L R
HVA	P 1		L R					R		
	P 2		L R					L R		
HVF	P 1	L	L	L R	L R	R		L R		L
	P 2	L R	L	L R	R	L R		L		
HVS	P 1	R		R				R		
	P 2		L							
HVI	P 1	L R	L R					L R		
	P 2	L R	L R					L R		

Table 4.2 First level analysis of normally viewed conditions after subtracting controls
Key: Pink = exactly the same image as brief masked image; Black = different image but same valence and category; P 1 = normally viewed first presentation; P 2 = normally viewed second presentation; L = left; R = right; ACC = Anterior Cingulate Cortex; mPFC = medial Prefrontal Cortex; Para = Parahippocampus; Amy = Amygdala; STG = Superior Temporal Gyrus; Ins = Insula; Fusi = Fusiform Gyrus; DLPFC = Dorsolateral Prefrontal Cortex; OFC = Orbital Frontal Cortex; LVA = LV Animals; LVF = LV Faces; LVS = LV Scenes; LVI = LV Inanimate objects; HVA = HV Animals; HVF = HV Faces; HVS = HV Scenes; HVI = HV Inanimate objects.

To ascertain if there are any differences between normally viewed and brief, masked presentations, the results of first level analysis are displayed in Table 4.3 (brief, masked results are in turquoise).

		ACC	mPFC	Para	Amy	STG	Ins	Fusi	DLPFC	OFC
LVA	B	L R	L R			L R	L R		L	L
	P1	L R	L R	L		L R	L R	L	L	L
	P 2	L R	L R	L R		L R	L R	L	L	L
LVF	B	L R	L R			L R	L			
	P 1						L	L R		
	P 2							L R		
LVS	B					L		L R		
	P 1		R							
	P 2			L R				L R		
LVI	B	R	L R			L R	L	L R		
	P 1	L R	L R	L R	R	L R	L R	L	L R	L R
	P 2	L R	L R	L R		L R	L R	L R	L R	L R
HVA	B	L R	L R	L R		L R	L R	L	L R	L R
	P 1		L R					R		
	P 2		L R					L R		
HVF	B					R				R
	P 1	L	L	L R	L R	R		L R		L
	P 2	L R	L	L R	R	L R		L		
HVS	B	L R		L R		L R	L R	L R		L
	P 1	R		R				R		
	P 2		L							
HVI	B	L R	L R							
	P 1	L R	L R					L R		
	P 2	L R	L R					L R		

Table 4.3 First level analysis comparison of brief masked condition with normally viewed condition

Key: Turquoise = brief masked presentations; Black = both normally viewed presentations. P 1 = normally viewed first presentation; P 2 = normally viewed second presentation; L = left; R = right; ACC = Anterior Cingulate Cortex; mPFC = medial Prefrontal Cortex; Para = Parahippocampus; Amy = Amygdala; STG = Superior Temporal Gyrus; Ins = Insula; Fusi = Fusiform Gyrus; DLPFC = Dorsolateral Prefrontal Cortex; OFC = Orbital Frontal Cortex; LVA = LV Animals; LVF = LV Faces; LVS = LV Scenes; LVI = LV Inanimate objects; HVA = HV Animals; HVF = HV Faces; HVS = HV Scenes; HVI = HV Inanimate objects.

Surprisingly, Table 4.3 shows that significant activations in the amygdala were absent, even for fear-related stimuli (e.g. LV faces) in both brief, masked and normally viewed presentations. There was also an unexpected absence of activations in the fusiform gyrus when viewing both HV and LV faces in the brief, masked condition.

It is equally apparent that both similarities (e.g. LVF) and differences (e.g. HVI) occur in different ROIs when comparing brief, masked and normally viewed activations. It would also appear that some regions are activated similarly by brief, masked and normally viewed presentations of the same stimuli.

Valence effects were found in the first level analysis within each category. This was demonstrated using the contrast masking facility of SPM2. Control activations were subtracted from target activations and were exclusively masked by the opposite valence (e.g. HVA > control masked by LVA > control FWE p = 0.05). This was then reversed in order to ascertain which ROIs were activated in the HV condition and not in the LV condition,

and vice versa. Some regions, (e.g. ACC), showed both HV and LV patterns of activation within a particular category. Thus, globally, the ACC shows no specific effect of valence, though it appears that it contains both HV and LV specific subregions. Equally, when looking at the black letters L and R it is clear that over all conditions (with the exception of the second normally viewed presentation of HVS) there is a scattering of valence effects in all nine ROIs. It is interesting to note that in the insula, the valence effect is exactly the same in the brief, masked and the first presentation normally viewed conditions and remains similar in the second presentation normally viewed. Strong similarities of valence effect are also seen in the STG and mPFC across all three conditions (Table 4.4).

1	2	ACC	mPFC	Para	Amy	STG	Ins	Fusi	DLPFC	OFC
BRIEF MASKED										
LVA>c	HVA>c	L R	L R			L R	L R		L R	L
HVA>c	LVA>c	L R	L R						L R	
LVF>c	HVF>c	R	L R			L	L	R	L	L
HVF>c	LVF>c								R	R
LVS>c	HVS>c							L R	R	
HVS>c	LVS>c		L						L	
LVI>c	HVI>c	L R	L R	L R	L	L R	L R	L	L R	L R
HVI>c	LVI>c	R	L R							
NORMALLY VIEWED Presentation 1										
LVA>c	HVA>c	L R	L R	L		L R	L R	L	L R	L R
HVA>c	LVA>c		L					R		
LVF>c	HVF>c						L	L R		L
HVF>c	LVF>c	L	L R	L R	L R	R		L R		
LVS>c	HVS>c		L R						R	
HVS>c	LVS>c	R	L	R				R	L	
LVI>c	HVI>c	L R	L R	L R	R	L R	L R	L	L R	L R
HVI>c	LVI>c	L R	L R					L R		
NORMALLY VIEWED Presentation 2										
LVA>c	HVA>c	L R	L R	L R		L R	L R	L	L R	L R
HVA>c	LVA>c		L R					L R		
LVF>c	HVF>c							L R		
HVF>c	LVF>c	L R	L R	L R	R	L R				
LVS>c	HVS>c			L R				L R		
HVS>c	LVS>c									
LVI>c	HVI>c	L R	L R	L R	L	L R	L R	L R	R	L R
HVI>c	LVI>c							L		

Table 4.4 First level analysis valence effects
Key: 1,2 = column 1 masked exclusively by column 2;
LVA>c = low valence animal > control; LVF>c = low valence face > control;
LVS>c = low valence scene > control; LVI>c = low valence inanimate > control;
HVA>c = high valence animal > control; HVF>c = high valence face > control;
HVS>c = high valence scene > control; HVI>c = high valence inanimate > control;
ACC = Anterior Cingulate Cortex; mPFC = medial Prefrontal Cortex; Para = Parahippocampus; Amy = Amygdala; STG = Superior Temporal Gyrus; Ins = Insula; Fusi = Fusiform Gyrus; DLPFC = Dorsolateral Prefrontal Cortex; OFC = Orbital Frontal Cortex;
Purple = animals L and R no effect of valence; green = faces L and R no effect of valence; blue = scenes L and R no effect of valence; red = inanimate objects L and R no effect of valence; black L and R = an effect of valence in any category.

4:4:2 Second Level Analysis

The first level analysis identified the brain regions that were activated on average across participants and confirmed that the quality of the data was worthy of further investigation. Unexpectedly, results from first level analysis revealed only small and variable activations in the amygdala for all categories and in the fusiform gyrus when presented with brief, masked faces. The insula, OFC and DLPFC were mainly activated by LV stimuli only and there was a difference between normally viewed activations and brief, masked activations. To be able to generalise such findings to a wider population, it is necessary to take into account the variation between participants, therefore a group random effects analysis was employed.

This was achieved by examining each ROI (same coordinates as first level analysis with an 8mm radius) and calculating the means of the contrast values for all voxels within each ROI, for each of the 24 contrasts (Table 4.5). These contrast values were the t-contrasts obtained in SPM when comparing activations in control conditions with the three experimental conditions (e.g. low valence animal brief, masked>controls) for each combination of factors (valence and category). The resulting contrast values were entered into an analysis of variance (ANOVA). Four within-participants factors were entered (hemisphere: 2 levels, condition: 3 levels, valence: 2 levels and categories: 4 levels) for each ROI with a p(crit) = 0.0167 using a Bonferroni adjustment for multiple comparison (three levels of condition, since the three conditions were regarded as replications). These means are graphically displayed for each ROI (see sections a to i below).

A Priori hypotheses held that there were a) main effects of valence (high and low) and b) category effects (animals, faces, scenes and inanimate objects) specifically for brief, masked stimuli. To test for significant effect, an ANOVA was partitioned to propagate the different stimulus conditions: brief, masked (b), normally viewed (P) and normally viewed (p) using p(crit) = 0.05.

ANOVA computed estimated marginal means for the contrast values, which were plotted to aid the interpretation of additive and interactive effects among factors. This procedure produced line graphs highlighting significant

values for the four IVs, category, hemisphere, valence and condition to guide the interpretation of the significant effects in the ANOVAs in the discussion.

To correct for a type I error, a test of the assumption of homogeneity of covariance (sphericity) Mauchly's test of sphericity was applied. Where the assumption of homogeneity of covariance was violated, the degrees of freedom of the F test were modified to make it more conservative.

In addition, to err on the side of caution and as this was a multifactor design, partial eta squared was used as a measure of the strength of association between one independent variable and one dependent variable (Tabachnick and Fidell, 2001).

The data were entered into an SPSS (SPSS Inc, 2005-8) (https://www.spss.com) spreadsheet.

Masked Experiment
Mean Contrast Values for Effect Sizes in ROIs

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
LVAb > c	0.33	0.35	-0.05	-0.04	0.05	-0.06	-0.21	0.08	0.11	0.48	0.46	-0.20	-0.10	0.33	0.24	-0.50	0.14	0.15
LVAp > c	0.27	0.46	-0.06	-0.02	0.15	-0.14	0.03	0.23	0.17	0.61	0.42	-0.23	-0.06	0.13	0.29	-0.46	0.09	0.26
LVAP > c	0.31	0.43	-0.02	0.03	0.38	-0.24	-0.10	0.24	0.10	0.67	0.51	-0.11	0.05	0.61	0.38	-0.51	0.06	0.20
LVFb > c	-0.05	-0.08	-0.18	-0.34	-0.24	-0.35	0.02	-0.43	-0.09	0.16	-0.15	-0.36	-0.26	0.07	-0.24	0.22	-0.35	-0.54
LVFP > c	-0.05	-0.13	-0.08	-0.03	-0.08	-0.36	0.01	-0.45	-0.06	0.10	-0.22	-0.24	0.04	0.04	0.01	0.39	-0.54	-0.52
LVFp > c	-0.04	-0.09	-0.21	-0.04	-0.14	-0.28	0.15	-0.46	-0.29	0.02	-0.13	-0.27	0.07	0.06	-0.09	0.45	-0.45	-0.40
LVSb > c	-0.02	-0.17	-0.09	-0.15	-0.03	-0.11	0.06	-0.38	-0.28	0.12	-0.18	-0.12	-0.16	0.02	0.02	0.24	-0.34	-0.52
LVSp > c	0.07	-0.05	0.03	-0.15	-0.15	-0.11	0.04	-0.37	-0.16	0.16	-0.04	-0.10	-0.19	-0.02	0.08	0.27	-0.40	-0.33
LVSP > c	-0.04	-0.06	0.26	-0.17	0.01	-0.18	0.05	-0.16	-0.13	0.01	-0.15	0.17	-0.23	-0.09	-0.05	0.32	-0.29	-0.46
LVIb > c	0.23	0.41	0.18	0.21	0.70	0.02	0.20	0.75	0.31	0.46	0.46	0.27	0.07	0.56	0.48	-0.34	0.34	0.62
LVIp > c	0.32	0.45	0.30	0.44	0.82	0.09	0.31	0.87	0.61	0.50	0.43	0.41	0.43	0.57	0.61	-0.22	0.47	0.72
LVIP > c	0.32	0.44	0.43	0.45	0.89	0.19	0.57	0.85	0.50	0.50	0.42	0.69	0.54	0.59	0.89	-0.01	0.39	0.65
HVAb > c	-0.01	0.36	-0.08	-0.18	0.08	-0.07	-0.13	0.15	-0.17	0.04	0.08	-0.25	-0.05	0.09	-0.58	0.12	0.21	-0.03
HVAP > c	-0.01	0.25	-0.07	-0.13	0.22	-0.06	-0.09	0.13	-0.25	-0.02	0.04	-0.11	0.02	0.04	-0.44	0.34	0.01	-0.14
HVAp > c	-0.10	0.18	-0.14	-0.18	0.13	-0.15	0.08	0.06	-0.06	-0.08	0.01	-0.22	-0.07	-0.12	-0.60	0.37	0.05	-0.06
HVFb > c	-0.07	0.06	-0.07	0.16	0.10	0.00	0.01	0.06	0.17	0.00	0.05	-0.04	0.09	0.14	0.02	-0.01	0.20	0.26
HVFP > c	-0.12	0.02	-0.01	0.31	-0.09	0.01	0.33	-0.01	0.32	-0.14	-0.07	-0.02	0.41	-0.06	-0.03	0.42	-0.04	0.14
HVFp > c	-0.04	0.17	0.06	0.28	-0.17	0.01	0.17	-0.11	0.07	-0.02	0.00	-0.01	0.39	-0.16	0.03	0.18	-0.08	-0.07
HVSb > c	-0.15	-0.08	-0.11	-0.07	-0.01	-0.01	0.00	0.02	-0.04	-0.09	-0.09	-0.12	-0.03	-0.01	-0.16	-0.10	0.05	0.06
HVSp > c	-0.14	-0.01	0.06	0.00	-0.06	-0.08	0.17	-0.13	-0.12	-0.08	-0.01	0.11	0.00	-0.05	-0.14	0.28	-0.13	-0.03
HVSP > c	0.03	0.11	0.04	-0.04	-0.36	-0.06	0.18	-0.15	-0.46	0.10	0.18	0.00	0.06	-0.26	0.07	0.01	-0.15	-0.14
HVIb > c	-0.03	0.34	-0.03	-0.19	0.09	0.00	0.01	-0.15	-0.22	0.15	0.15	-0.03	-0.12	0.07	-0.23	0.12	0.07	-0.11
HVIP > c	0.03	0.20	0.12	0.01	-0.04	-0.01	0.40	-0.02	-0.08	0.19	0.17	-0.08	0.15	-0.17	-0.25	0.34	0.03	-0.17
HVIp > c	0.05	0.05	0.24	0.13	-0.03	-0.10	0.23	-0.15	-0.28	0.17	0.16	0.05	0.17	-0.14	-0.15	0.42	-0.09	-0.26

Table 4.5 Mean contrast values for effect sizes in ROIs – masked experiment

Key: 1=L ACC 2=L mPFC 3=L Parahippocampus 4=L Amygdala 5=L STG 6=L Insula 7=L Fusiform gyrus 8=L DLPFC 9=L OFC
10=R ACC 11=R mPFC 12=R Parahippocampus 13=R Amygdala 14=R STG 15=R Insula 16=R Fusiform gyrus 17=R DLPFC 18=R OFC; c = controls

a) Anterior Cingulate Cortex

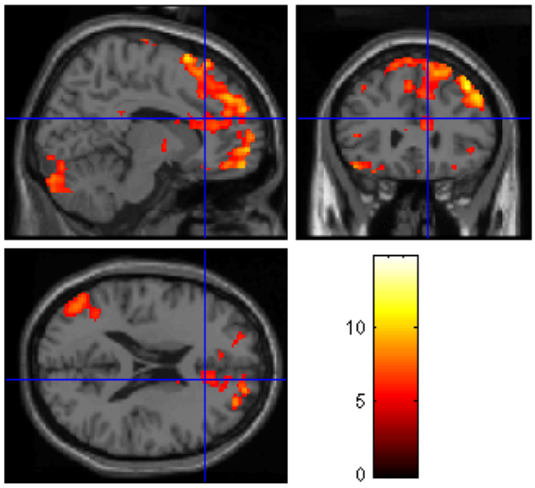


Figure 4.6 Significant cluster of activation in ACC from an individual's data. The colorimeter scale displays the percentage intensity of voxels activated. The cross-hairs show activation in the ACC right hemisphere for the significant effect of LV animals > control in the normally viewed condition

ANOVAs confirmed a significant main effect of valence ($F(1,12) = 9.1$; $p<0.0167$); with an effect size (partial eta squared) of 0.432. Although the ACC has not previously been reported as category specific, a main effect of category was found ($F(3,36) = 7.9$; $p<0.0000005$; partial eta squared = 0.398).

Partitioning the ANOVA matrix confirmed a significant effect of valence across all three conditions: in brief, masked ($F(1,12) = 6.9$; $p<0.05$; partial eta squared = 0.366); normally viewed (P) ($F(1,12) = 6.8$; $p<0.05$; partial eta squared = 0.362); and normally viewed (p) ($F(1,12) = 12.2$; $p<0.005$; partial eta squared = 0.503). A significant effect of category was also found, in each of the brief, masked ($F(3,36) = 4.4$; $p<0.01$; partial eta squared = 0.207); normally viewed condition (P) ($F(3,36) = 7.2$; $p<0.001$; partial eta squared = 0.374); and normally viewed condition (p) (Mauchly ($W=.35$, $p<0.05$)), ($F(1,12) = 6.2$; $p<0.05$; partial eta squared = 0.341).

There was no significant difference between the presentation conditions, therefore, there is no difference in ACC response to brief and longer presentations.

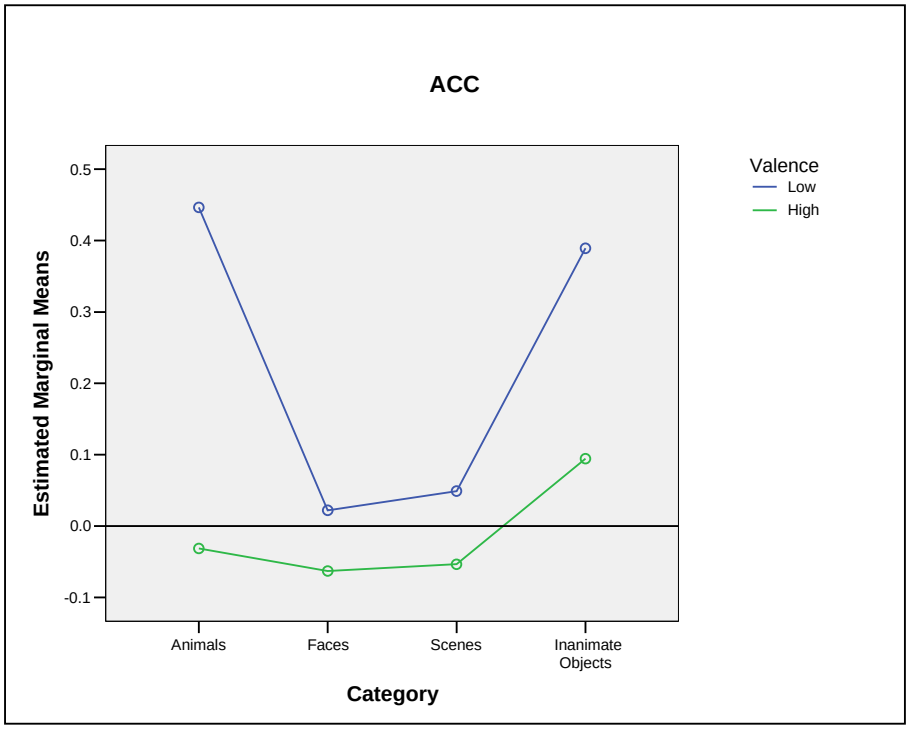


Figure 4.7 ACC estimated marginal means comparing low and high valence

The estimated marginal means in the line graphs represent the outputs of the ANOVAs. These were calculated from the effect sizes which are a measure of response magnitude (see Table 4.5).

Visual interpretation of the estimated marginal means line graph for valence x category (Figure 4.6 and 4.7) shows that low valence animals and inanimate objects tend to produce greater activation than control stimuli, whereas all high valence stimuli, plus low valence faces and scenes, produce activations similar to or smaller than control stimuli.

To conclude, the ACC was sensitive to the valence of stimuli, responding more strongly to low valence than to control or high valence stimuli (see Figure 4.7). The moderate effect sizes indicate that valence differences in overall activations for category depend on the particular category. This effect was found for both normally viewed presentations and brief, masked stimuli.

b) *Medial Prefrontal Cortex*

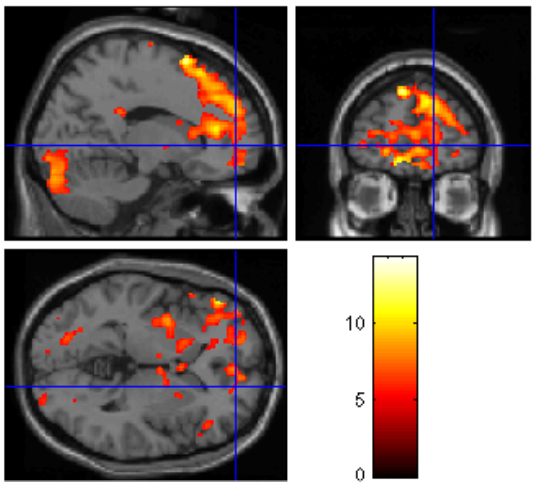


Figure 4.8 Significant cluster of activation in mPFC from an individual's data. The colorimeter scale displays the percentage intensity of voxels activated. The cross-hairs show activation in the mPFC right hemisphere for the significant effect of LV inanimate objects > control in the brief masked condition

A significant main effect of category was found but did not survive Bonferroni correction ($F(1,12) = 8.5$; $p=0.013$; partial eta squared = 0.414).

Partitioning the ANOVA matrix confirmed a main effect of category: in the brief, masked condition (Mauchly ($W=.223$, $p<.01$)), ($F(1,12) = 9.1$; $p<0.05$; partial eta squared = 0.431) (see Figure 4.8); in normally viewed condition (P) (Mauchly ($W=.097$, $p<0.0000005$)), ($F(1,12) = 7.0$; $p<0.05$; partial eta squared = 0.368); and in normally viewed condition (p) (Mauchly ($W=.196$, $p<0.005$)), ($F(1,12) = 6.3$; $p<0.05$; partial eta squared = 0.345).

There were no significant main effects of presentation condition, hemisphere, or valence.

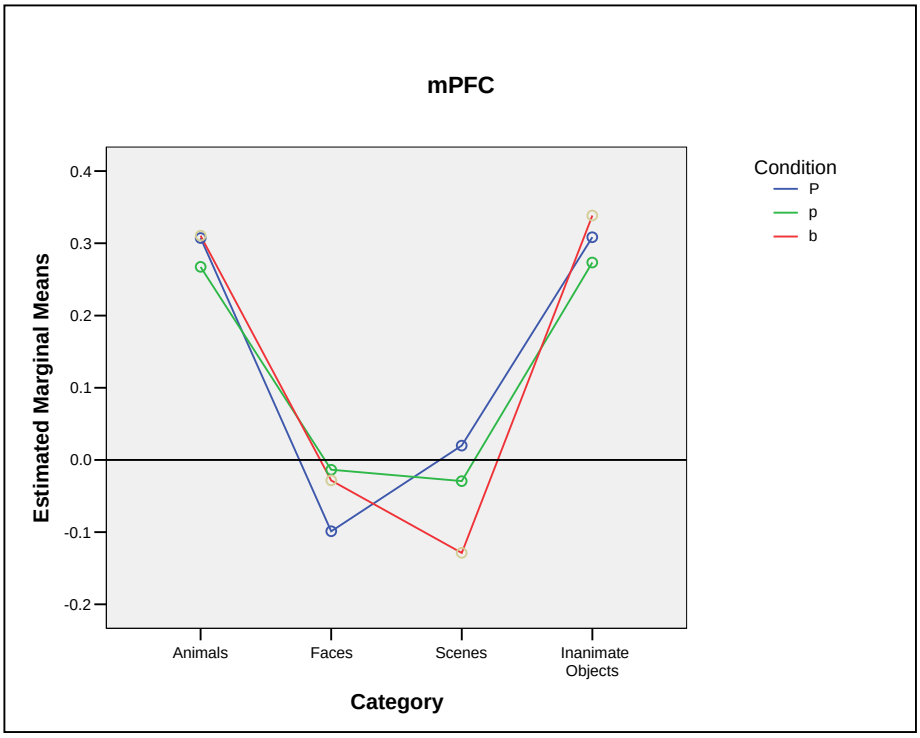


Figure 4.9 mPFC estimated marginal means comparing conditions
Key: b = brief masked; p = same image as brief masked presented under normal viewing; P = different image presented under normal viewing.

It can be seen from the plot of estimated marginal means for category x condition (Figure 4.9) that the strength of activations in the mPFC was greater for animals and inanimate objects (both low and high valence) than for controls. For faces and scenes these were lower than or similar to controls (both low and high valence).

To conclude, mPFC was sensitive to the category of stimuli for all three conditions.

c) Parahippocampus

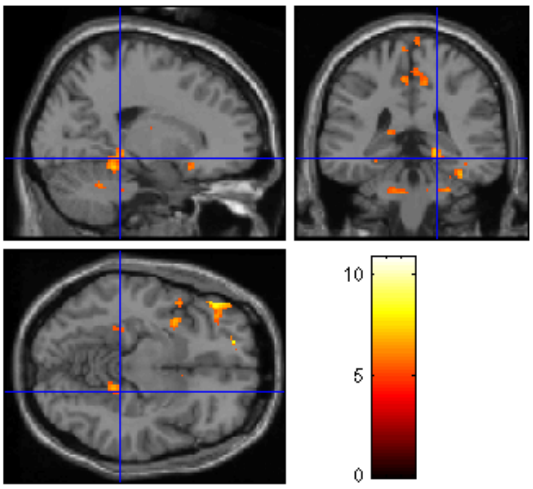


Figure 4.10 Significant cluster of activation in Parahippocampus from an individual's data. The colorimeter scale displays the percentage intensity of voxels activated. The cross-hairs show activation in the Parahippocampus right hemisphere for the significant effect of LV inanimate objects > control in the normally viewed condition

ANOVAs demonstrated significant main effect of presentation condition ($F(2,24) = 10.4$; $p<0.005$; partial eta squared = 0.465).

Partitioning the ANOVA showed that in normally viewed (P) there was a significant effect of category ($F(3,36) = 4.5$; $p<0.01$; partial eta squared = 0.274) (see Figure 4.10). There was no significant main effect of valence, and no hemispheric differences were found.

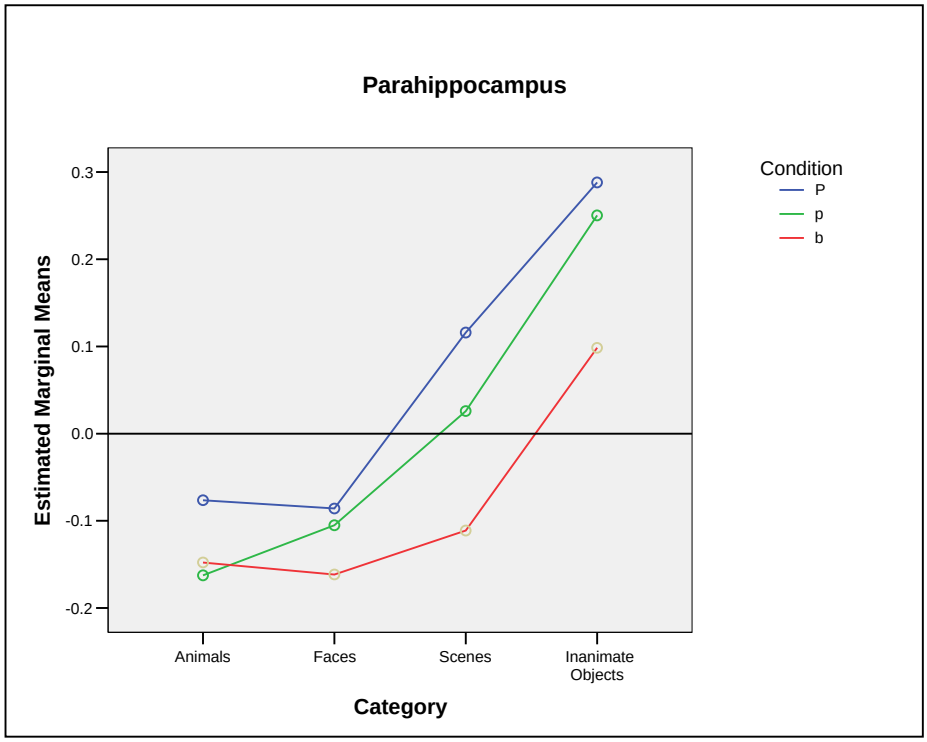


Figure 4.11 Parahippocampus estimated marginal means comparing category x condition, Key: b = brief masked; p = same image as brief masked presented under normal viewing; P = different image presented under normal viewing.

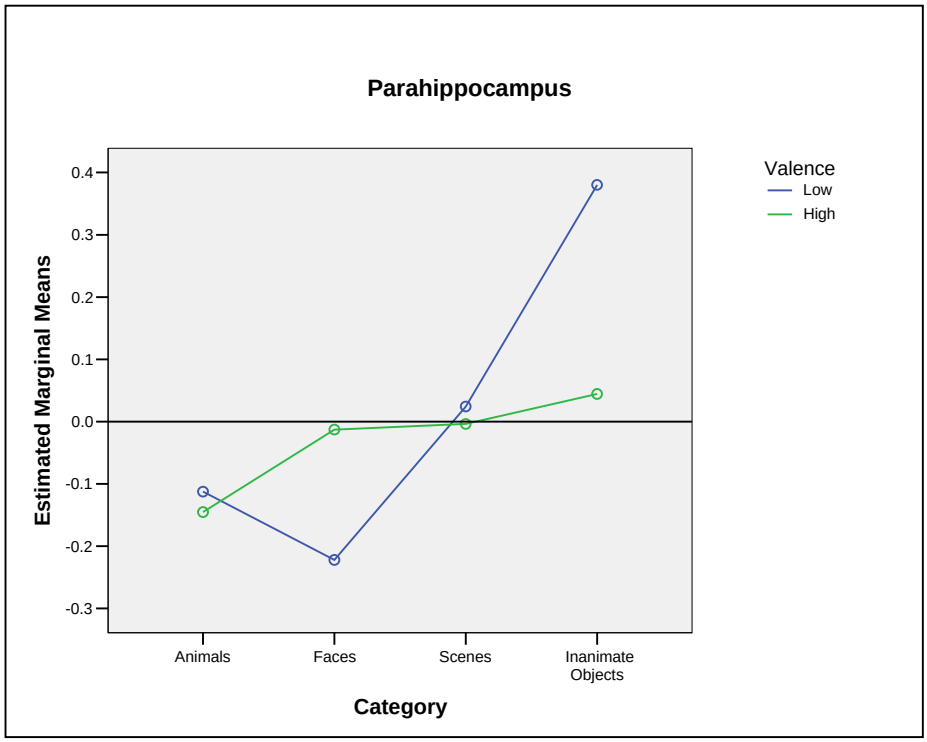


Figure 4.12 Parahippocampus estimated marginal means comparing low and high valence x categories (valence x category).

The greatest estimated marginal means in Figures 4.11 and 4.12 are evident when viewing LV inanimate objects in all three conditions with a marginal positive value for LV scenes under normal viewing.

Results support the view that the parahippocampal region is concerned with visual processing of high level properties, and indicates that this region is associated not only with 'places' (Epstein and Kanwisher, 1998, Epstein et al., 1999, O'Craven and Kanwisher, 2000), but also with inanimate objects. Activation is greater for normally viewed than brief, masked stimuli. It is not possible to say whether responsiveness to inanimate objects overlaps the parahippocampal place area (PPA). Greater mean activations were found when processing inanimate objects than animals or faces (Figure 4.11 and Figure 4.12). The inanimate stimuli could be defined as either arousing, surprising or novel, (e.g. dirty toilet, electric chair or fireworks) and, as such, would also support previous findings of the PPA being associated with surprise or novelty detection (Schroeder et al., 2004).

d) Amygdala

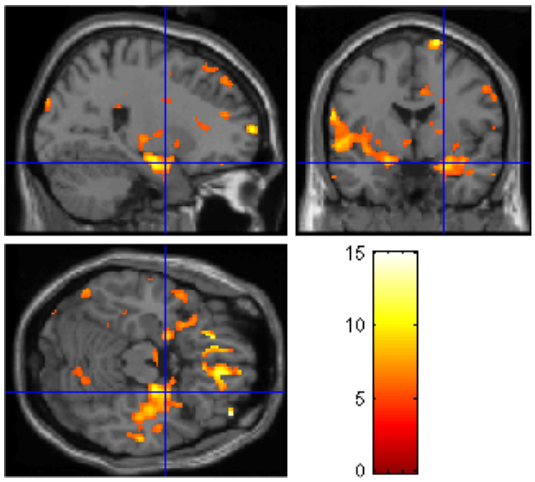


Figure 4.13 Significant cluster of activation in the amygdala from an individual's data. The colorimeter scale displays the percentage intensity of voxels activated. The cross-hairs show activation in the amygdala right hemisphere for the significant effect of LV inanimate objects > control in the normally viewed condition

A significant main effect of condition was found, (Mauchly (W=.481; p<.05)), ($F(1,12) = 5.1$; $p<0.05$; partial eta squared = 0.300).

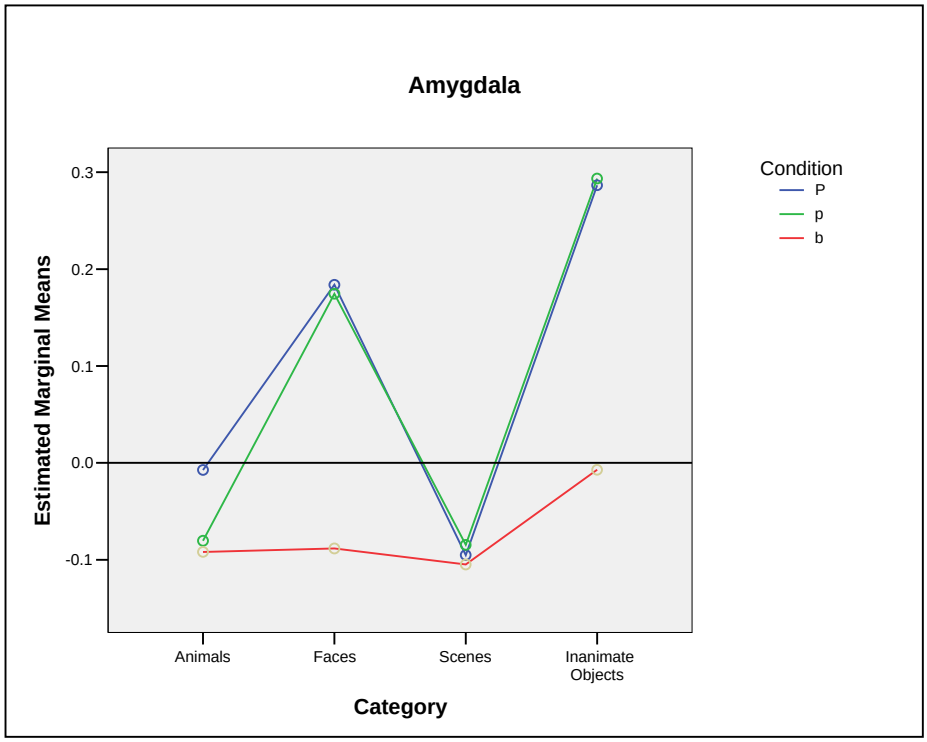


Figure 4.14 Amygdala estimated marginal means comparing category x condition.
Key: b = brief masked; p = same image as brief masked presented under normal viewing; P = different image presented under normal viewing.

Estimated marginal means for category x condition show means with positive values are evident only for inanimate objects and faces in the two normally viewed conditions (Figure 4.14). This is also evident in Figure 4.13 showing a significant effect of LV inanimate objects.

These results are surprising as the amygdala is associated with fast processing of fearful stimuli in particular and no evidence was found of either valence effects or brief, masked processing.

e) Superior Temporal Gyrus

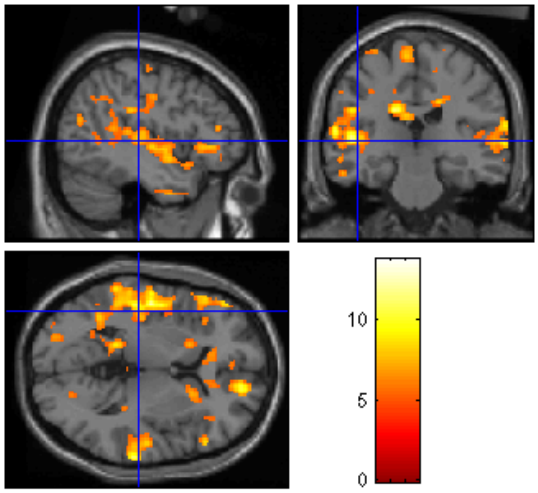


Figure 4.15 Significant cluster of activation in STG from an individual's data. The colorimeter scale displays the percentage intensity of voxels activated. The cross-hairs show activation in the STG left hemisphere for the significant effect of LV inanimate objects > control in the normally viewed condition

There was a significant main effect of valence ($F(1,12) = 19.3$; $p<0.001$; partial eta squared = 0.616). There was also a significant main effect of category ($F(3,36) = 7.7$; $p<0.0005$; partial eta squared = 0.392).

Partitioning showed a significant effect of category in all three conditions: brief, masked ($F(3,36) = 4.2$; $p<0.05$; partial eta squared = 0.261); normally viewed (P) ($F(3,36) = 5.6$; $p<0.005$; partial eta squared = 0.319); and normally viewed (p) (Mauchly ($W=.299$; $p<.05$)), ($F(1,12) = 5.1$; $p<0.05$; partial eta squared = 0.300). However, valence was not significant in the brief, masked condition, but was significant in normally viewed (P) ($F(1,12) = 23.2$; $p<0.0000005$; partial eta squared = 0.659) and normally viewed (p) ($F(1,12) = 19.1$; $p<0.001$; partial eta squared = 0.614).

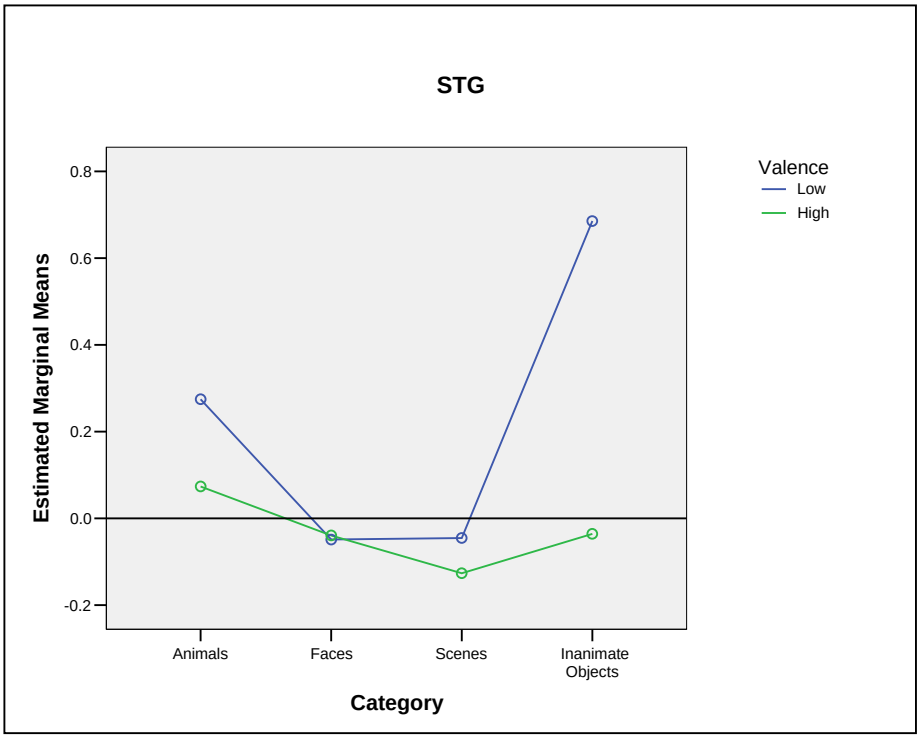


Figure 4.16 STG estimated marginal means comparing low and high valence x categories .

The valence effect displays some category specificity (Figure 4.16), showing positive values only with low valence animal and inanimate stimuli (see Figure 4.15). This was supported statistically when partitioning with a significant interaction between valence x category for normally viewed (P) ($F(3,36) = 3.8$; $p<0.05$; partial eta squared = 0.241) and normally viewed (p) ($F(3,36) = 4.0$; $p<0.05$; partial eta squared = 0.252).

A role for STG in the processing of emotional valence is indicated, with greater activations during the processing of LV animals and inanimate objects under normal viewing.

f) *Insula*

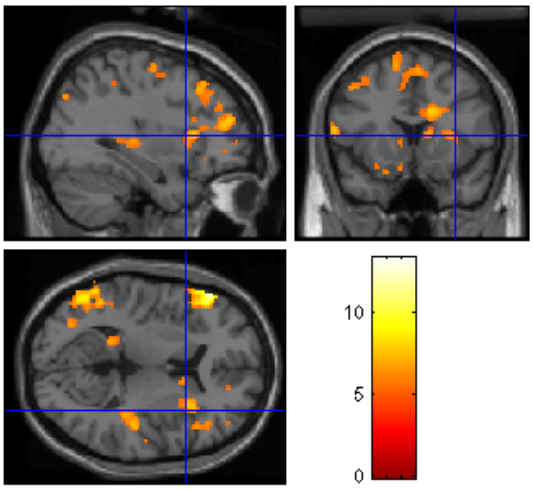


Figure 4.17 Significant cluster of activation in the Insula from an individual's data. The colorimeter scale displays the percentage intensity of voxels activated. The cross-hairs show activation in the insula right hemisphere for the significant effect of LV inanimate objects > control in the normally viewed condition

Significant interactions were found. Hemisphere x valence ($F(1,12) = 9.7$; $p<0.01$; partial eta squared = 0.446) and valence x category (Mauchly ($W=.341$; $p<0.05$)), ($F(3,36) = 7.8$; $p<0.0000005$; partial eta squared = 0.393).

Partitioning supported these findings across all three conditions: hemisphere x valence brief, masked ($F(1,12) = 8.0$; $p<0.05$; partial eta squared = 0.401); normally viewed (P) ($F(1,12) = 11.0$; $p<0.01$; partial eta squared = 0.478); and normally viewed (p) ($F(1,12) = 5.7$; $p<0.05$; partial eta squared = 0.323). Valence x category: in the brief, masked condition (Mauchly ($W=.260$; $p<.05$)), ($F(1,12) = 5.8$; $p<0.05$; partial eta squared = 0.325); in normally viewed condition (P) (Mauchly ($W=.310$; $p<.05$)), ($F(1,12) = 6.7$; $p<0.05$; partial eta squared = 0.359); and in normally viewed condition (p) ($F(3,36) = 6.2$; $p<0.005$; partial eta squared = 0.340).

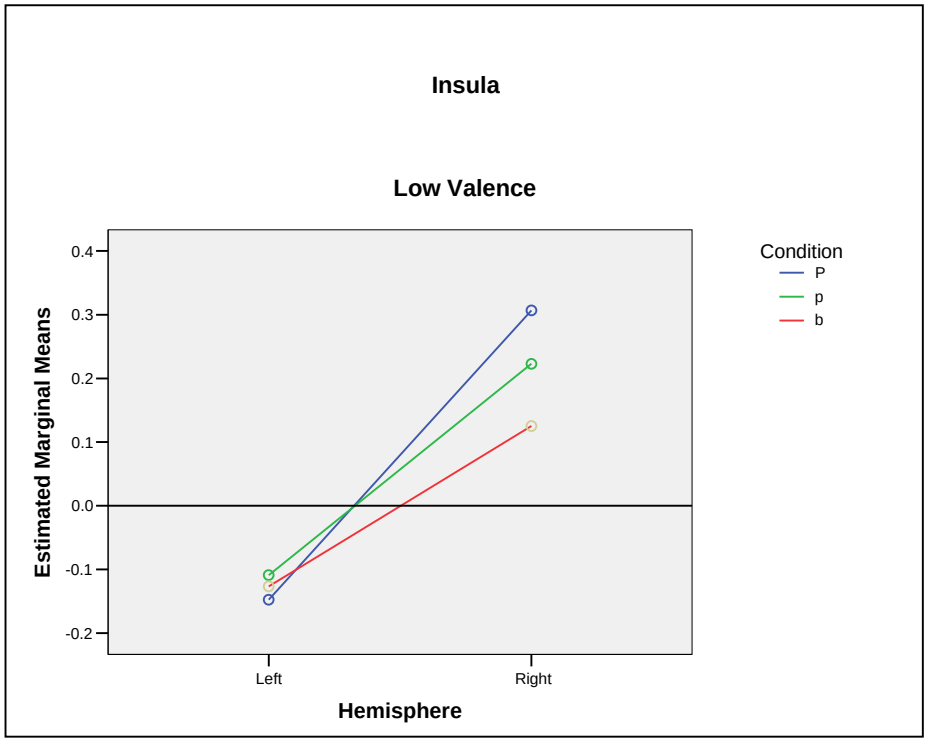


Figure 4.18 Insula estimated marginal means for low valence x hemisphere x condition. Key: b = brief masked; p = same image as brief masked presented under normal viewing; P = different image presented under normal viewing.

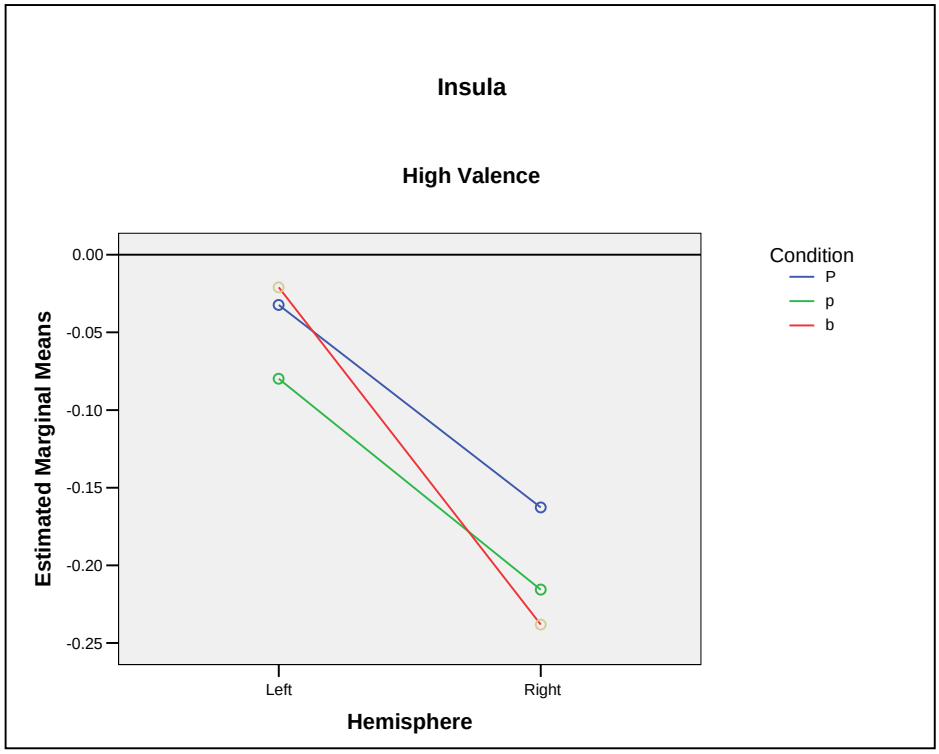


Figure 4.19 Insula estimated marginal means for high valence x hemisphere x condition. Key: b = brief masked; p = same image as brief masked presented under normal viewing; P = different image presented under normal viewing.

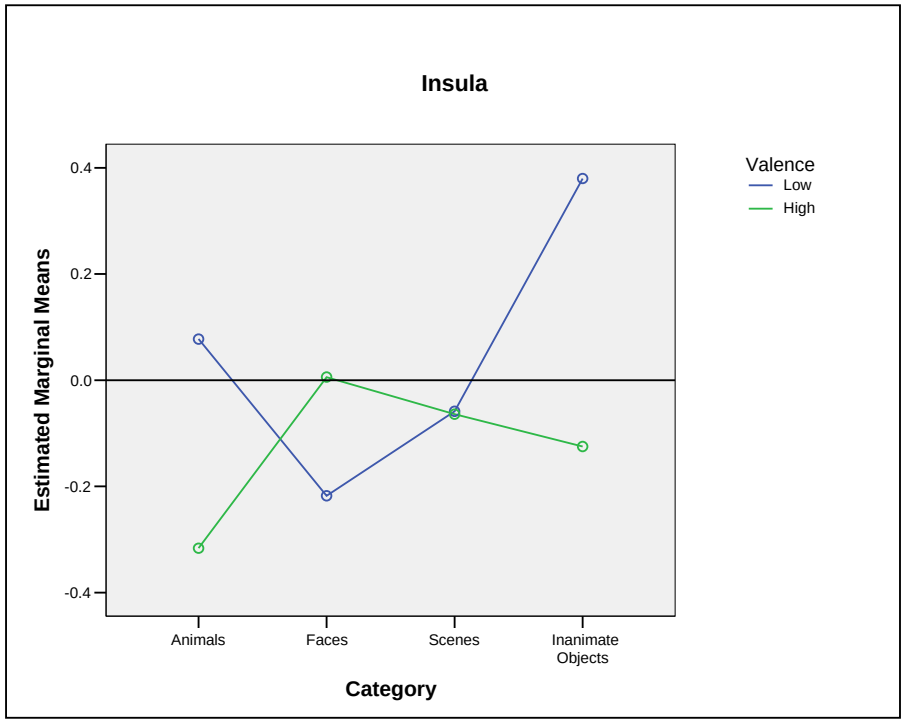


Figure 4.20 Insula: estimated marginal means for valence x category.

The line graphs Figures 4.18 and 4.19 show estimated marginal means for an interaction between hemisphere x valence with positive values found only for the RH whilst viewing LV stimuli. Figure 4.20 shows estimated marginal means for category x valence, where LV animals and LV inanimate objects display positive values. To conclude, the insula responded to stimuli of negative valence with the right insula specifically activated by low valence stimuli (in particular inanimate objects) (Figure 4.17).

g) *Fusiform Gyrus*

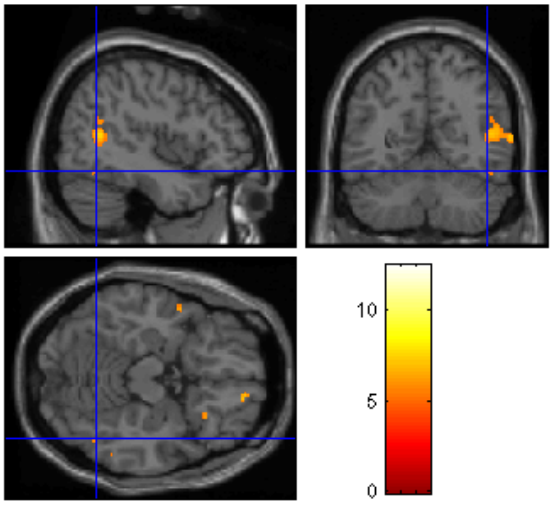


Figure 4.21 Significant cluster of activation in the Fusiform gyrus from an individual's data. The colorimeter scale displays the percentage intensity of voxels activated. The cross-hairs show activation in the Fusiform Gyrus right hemisphere for the significant effect of HV faces > control in the normally viewed condition

ANOVA showed main effect of presentation conditions ($F(2,24) = 14.2$; $p<0.001$; partial eta squared = 0.542). There was also a main effect of category ($F(3,36) = 3.9$; $p<0.0167$; partial eta squared = 0.244).

An effect of category was absent in the brief, masked condition when partitioning, but remained significant in one normally viewed presentation (P) ($F(3,36) = 4.7$; $p<0.01$; partial eta squared = 0.282).

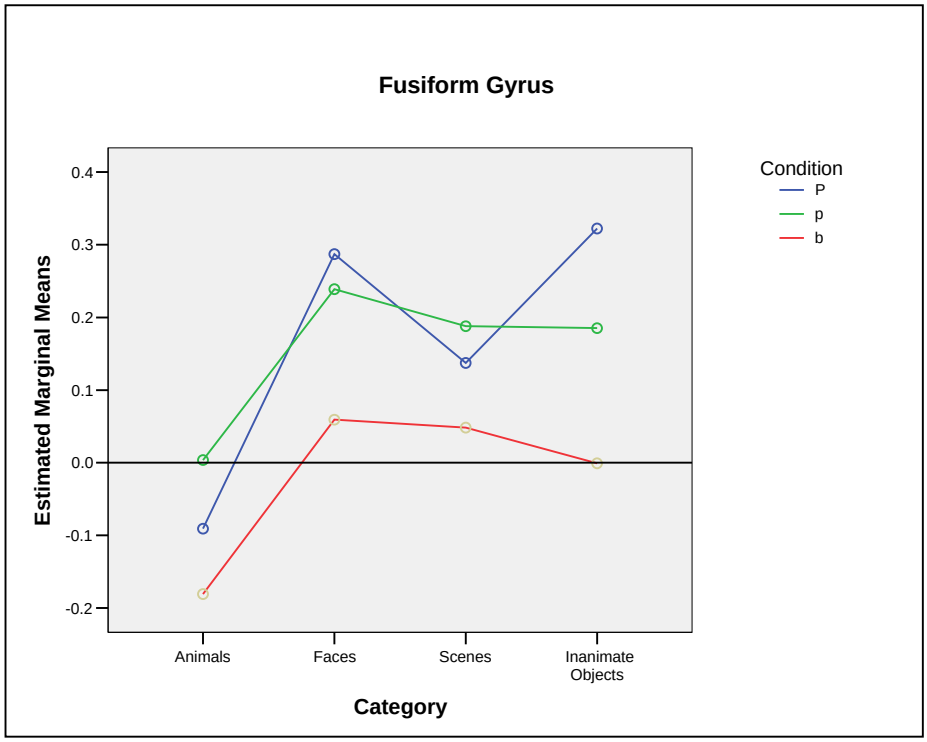


Figure 4.22 Fusiform gyrus estimated marginal means for condition x category.
Key: b = brief masked; p = same image as brief masked presented under normal viewing; P = different image presented under normal viewing.

Figure 4.22 shows estimated marginal means for category x condition. Values were positive for faces, scenes and inanimate objects in both normally viewed conditions.

A significant effect of category under normal viewing was not surprising in view of the literature that links the fusiform cortex with faces (see Figure 4.21), but there was also evidence of responsiveness to scenes and inanimate objects.

h) Dorsolateral Prefrontal Cortex

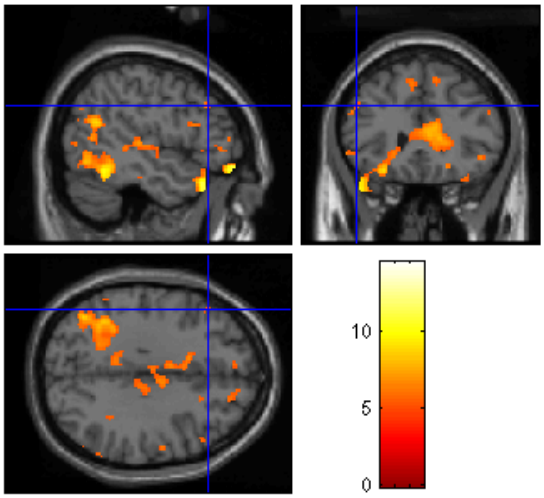


Figure 4.23 Significant cluster of activation in DLPFC from an individual's data. The colorimeter scale displays the percentage intensity of voxels activated. The cross-hairs show activation in the DLPFC left hemisphere for the significant effect of LV inanimate objects > control in the normally viewed condition

For the overall ANOVA, there was only a marginal significant main effect with an interaction between hemisphere and condition ($F(2,24) = 3.4$; $p = 0.05$). The other main effects did not survive Bonferroni corrections. Therefore caution must be applied to interpreting the subdivided ANOVA.

When partitioning, categories were significant with all three conditions: in the brief, masked condition (Mauchly ($W=.227$; $p<.01$)), ($F(1,12) = 5.3$; $p<0.05$; partial eta squared = 0.308); normally viewed (P) (Mauchly ($W=.274$; $p<.05$)), ($F(1,12) = 7.8$; $p<0.05$; partial eta squared = 0.394); and normally viewed (p) (Mauchly ($W=.188$; $p<.005$)), ($F(1,12) = 5.5$; $p<0.05$; partial eta squared = 0.313).

Equally, an interaction between valence x category was significant for the brief, masked condition (Mauchly ($W=.342$; $p<.05$)), ($F(1,12) = 5.1$; $p<0.05$; partial eta squared = 0.298) and one normally viewed presentation (p) ($F(3,36) = 7.2$; $p<0.001$; partial eta squared = 0.376) (Figure 4.23).

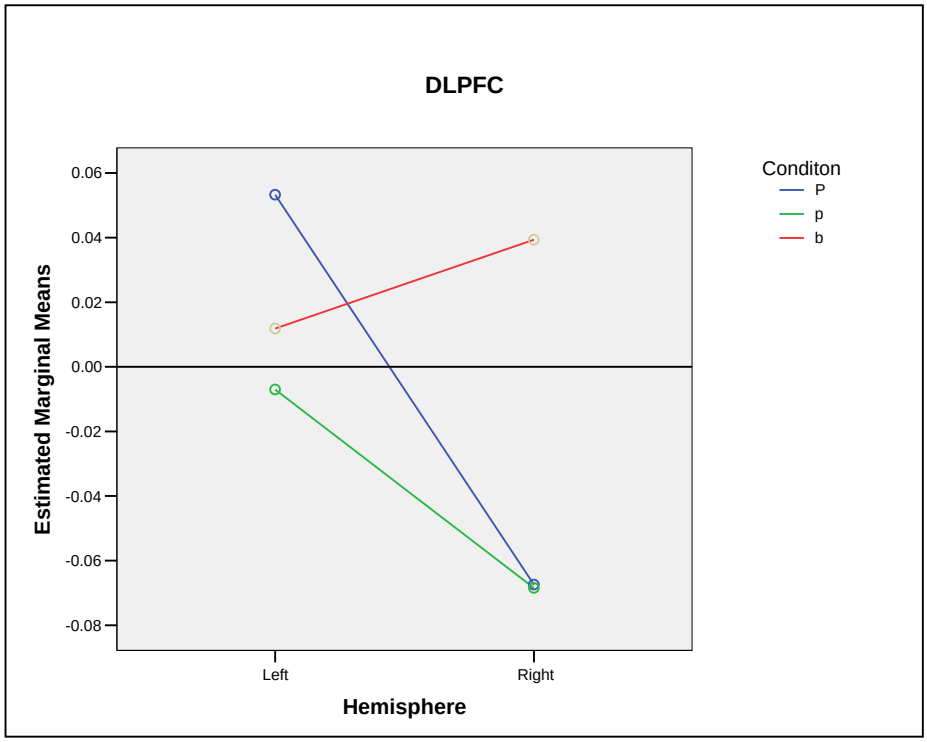


Figure 4.24 DLPFC estimated marginal means for condition x hemispheres
Key: b = brief masked; p = same image as brief masked presented under normal viewing; P = different image presented under normal viewing.

The estimated marginal means in Figure 4.24 show a significant interaction with hemisphere x condition. It would appear that the RH responds more strongly to brief, masked affective stimuli and the LH to normally viewed stimuli, but note the negative value for normally viewed stimuli in the RH (stronger response to control stimuli). Equally, the scale shows that these differences are very small.

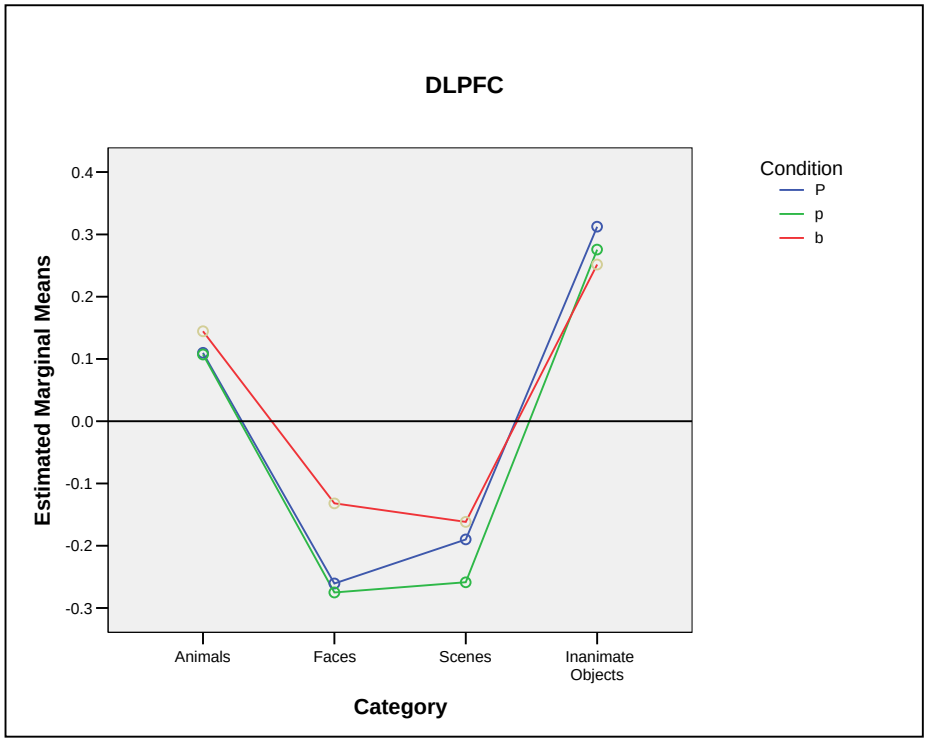


Figure 4.25 DLPFC estimated marginal means for condition x categories
Key: b = brief masked; p = same image as brief masked presented under normal viewing; P = different image presented under normal viewing.

Figure 4.25 shows estimated marginal means for category x condition. In all three conditions, the DLPFC responds more strongly to animals and inanimate objects.

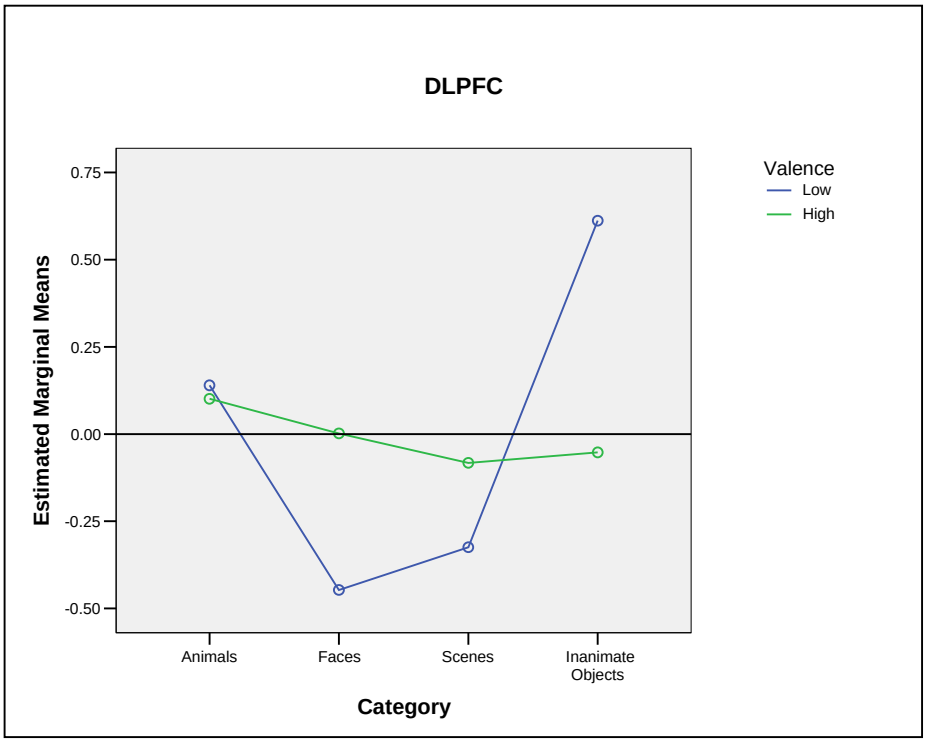


Figure 4.26 DLPFC estimated marginal means for category x valence.

Figure 4.26 shows estimated marginal means for category x valence. LV inanimate objects show a greater difference relative to stimuli in other categories or valence which are displayed in the DLPFC line graph and can be seen in the cluster of activation in Figure 4.23.

To conclude, the observations from ANOVA indicate that the DLPFC is more sensitive to LV inanimate objects in all three conditions. In addition, there was a marginal indication that the RH is dominant for processing brief, masked emotional stimuli, and the LH for normally viewed emotional stimuli.

i) Orbitofrontal Cortex

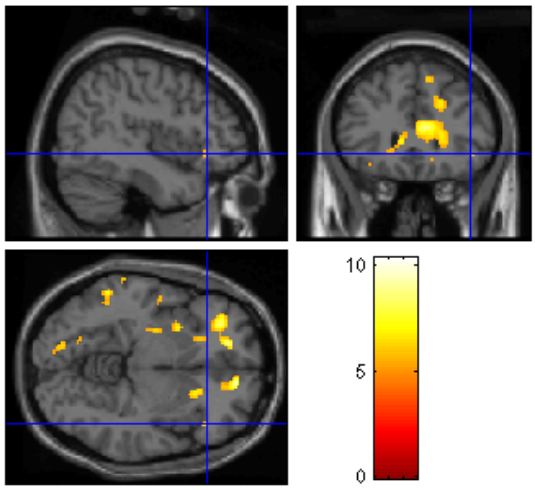


Figure 4.27 Significant cluster of activation in OFC from an individual's data. The colorimeter scale displays the percentage intensity of voxels activated. The cross-hairs show activation in the OFC right hemisphere for the significant effect of LV animals > control in the normally viewed condition

An interaction of valence x category was significant, (Mauchly (W=.227, $p<0.01$)), ($F(1,12) = 12.0$; $p<0.005$; partial eta squared = 0.499).

When partitioning the ANOVA, category effects were significant in one normally viewed condition (P) ($F(3,36) = 5.4$, $p<0.005$; partial eta squared = 0.309). Also a significant interaction between valence and category remained for: brief, masked (Mauchly (W=.304, $p<.05$)), ($F(1,12) = 7.2$, $p<0.05$; partial eta squared = 0.376); normally viewed (P) ($F(3,36) = 8.1$, $p<0.0000005$; partial eta squared = 0.404); and normally viewed (p) ($F(3,36) = 12.2$; $p<0.0005$; partial eta squared = 0.504) (Figure 4.27).

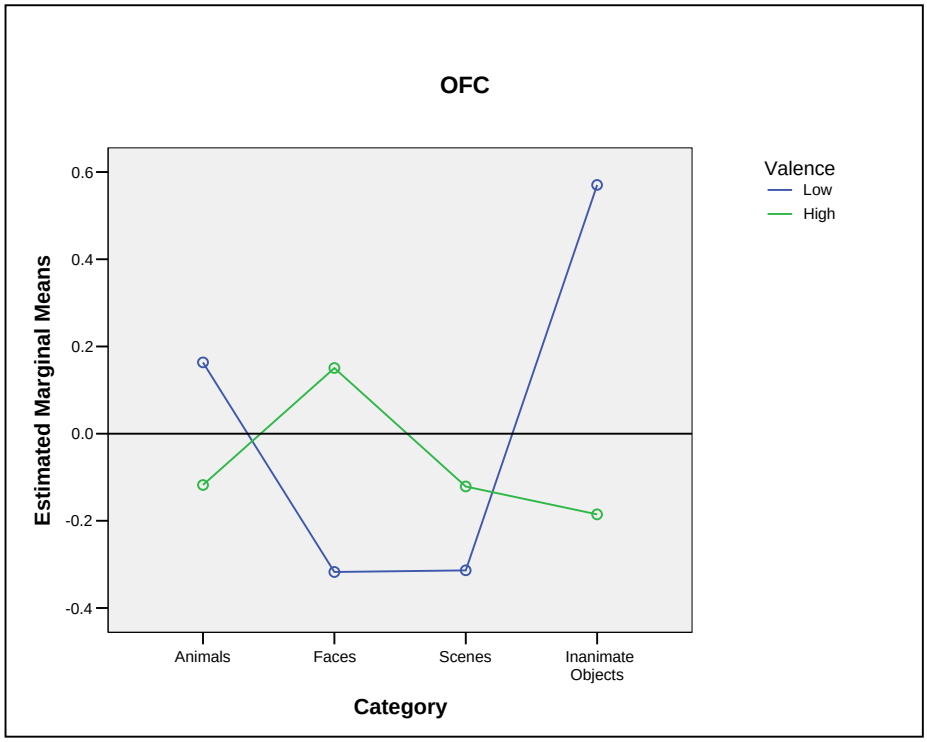


Figure 4.28 OFC estimated marginal means for high and low valence .

Figure 4.28 shows estimated marginal means for category x valence. OFC demonstrates positive values for LV inanimate objects with a clear similarity to the line graph for the DLPFC (Figure 4.26).

Based on the statistical evidence and values shown in the line graph, greater activations were evident in the OFC when viewing LV inanimate objects as in the DLPFC. However, there was no evidence of hemisphere specificity as there was in the DLPFC.

4:4:3 Summary

Significant effects from the fMRI experiment are summarised in table 4.6.

ROI	Significant effects of valence or category on response to brief masked presentations	Significant differences between responses to brief masked and normally viewed presentations	Significant effects of valence or category on response to normally viewed presentations	Other significant effects before partitioning
ACC	Val* Cat**	n.s.	P val:* p val:** P cat:** p cat:*	Main eff val:* Main eff cat:****
mPFC	Cat*	Con x cat*	P cat:* p cat:*	Main eff cat*
Para	n.s.	Main eff con:**	P cat:**	n.s.
Amy	n.s.	Main eff con:*	n.s.	n.s.
STG	Cat*	n.s.	P val:* p val:** P cat:** P cat:* P val x cat:* p val x cat*	Main eff val:** Main eff cat:****
Ins	Hem x Val* Val x Cat*	Hem x con*	P Hem x Val:** P Val x Cat:* p Hem x Val:* p Val x Cat:*	Hem x Val:** Val x Cat:*
Fusi	n.s.	Main eff con:***	P cat:**	Main eff cat:*
DLPFC	Cat* Val x Cat*	n.s.	P cat:* p cat:* p Val x Cat:**	Main eff cat* Val x Cat:*
OFC	Val x Cat*	n.s.	P cat:** P Val x Cat**** p Val x Cat***	Main eff cat:* Val x Cat:**

Table 4.6 Summary of significant effects
Key: * p<0.05; ** p<0.01; *** p<0.001; **** p<0.0001; n.s. = not significant; eff = effect; Val = Valence; Hem = Hemisphere; Con = condition; Cat = Category; P and p = Normally viewed; Para = Parahippocampal gyrus; Amy = Amygdala; Ins = Insula; Fusi = Fusiform gyrus.

4:5 Discussion

Participants were presented with complex visual pictures of animals, faces, scenes and inanimate objects employing a forward and backward masking paradigm.

The effects of valence, categories and experimental conditions varied between the selected nine ROIs. There was evidence of processing of briefly masked stimuli, especially for low valence presentations of animals and

inanimate objects. In order to discuss these issues coherently, each ROI is addressed in turn and in context with previous research. Some of the present findings are in agreement with previous research, other findings differ. It is important to bear in mind that a ROI as defined in this study is not a functional unit. A spherical ROI may include anatomically diverse structures of a smaller scale. It is also difficult to establish anatomical correspondences between different studies in the literature, or indeed, in different individual brains in the same study, because of the inherent variations of anatomy, and this may in large part account for differences in functional findings reported by different investigators. Thus the "typical" co-ordinates given for each ROI are only a statistical approximation to the location of a given structure.

4:5:1 Regions of Interest

a) Anterior Cingulate Cortex

The data show that the ACC was modulated by emotional valence both with brief, masked presentations and under normal viewing, thus supporting previous findings of the correlation between valence and ACC activations (Berthoz et al., 2002, Cunningham et al., 2004).

This may reflect the novelty (Downar et al., 2002) and complexity of IAPS pictures (Winston et al., 2003) depicting the premise of cognitive and emotion interactions. Equally, this experiment incorporated a valence categorisation task in which cognitive demands may have elicited greater neural activity in the ACC, as it is shown in previous studies that the ACC processes both cognitive and emotional tasks (Bush et al., 2000, Reiman et al., 1997, Whalen et al., 1998a). In emotional picture experiments, previous research found greater activations in the ACC during trials requiring subjective emotional responses (Hariri et al., 2003, Lane et al., 1997a). In addition, the valence categorisation tasks required greater attentional demands than experimental paradigms of passive viewing. The role of the ACC and attentional processing is well documented and is evidenced by an experiment comparing one condition that required emotional responses, (e.g. pleasant/unpleasant), and the other asking for contextual responses, (e.g. is

this scene indoors or outdoors) (Lane et al., 1997a). The former showed greater activation in the ACC when attentional resources were engaged in subjective emotional responses. The evidence from the present experiment supports this premise as modulation of the ACC due to valence categorisation was greater for the emotional experimental conditions than the non-emotional control condition.

Statistically significant differences were also found when processing stimuli of different categories in all three conditions, with greater activations for low valence animals and inanimate objects. Hitherto there is little evidence of ACC response to different categories in terms of emotional processing in the literature. Therefore, category specificity will be discussed at greater length in the general discussion below.

b) Medial Prefrontal Cortex

When examining the data, it was apparent that the mPFC was sensitive to processing of categories both with brief, masked presentations and under normal viewing. It has been hypothesised that the mPFC is involved in maintaining attention in order to assess and process information from other brain regions. However, it is also reported that activations in the mPFC decrease (as opposed to increase in the ACC and DLPFC) during an attentionally demanding cognitive task, thus suggesting that within this region there is an active relationship between cognition and emotion (Bush et al., 2000, Simpson et al., 2001a, Simpson et al., 2001b). As previously stated, this experiment did employ a valence categorisation task, which may have modulated emotional processing.

Equally, the role of the mPFC in emotional self awareness (Lane et al., 1997b) and the recurring feelings of emotional memories (Damasio, 1999), may explain mPFC activations based on associated personal experience. For instance, Phan et al. (2004) noted that activations in the vMPFC reflect the modulation of self association more than the value of emotional valence (Phan et al., 2004).

There was no evidence to suggest any significant difference in positive or negative valence processing. This complements previous findings in two

meta-analyses in that the mPFC is not valence specific, but has a more general role in emotion processing (Lane et al., 1997c, Murphy et al., 2003, Phan et al., 2002). This is also supported by a study using IAPS stimuli (Lane et al., 1997c) and lesion studies whereby damage to the mPFC resulted in changes in both positive and negative emotional experience (Damasio, 1994).

c) Parahippocampus

These findings support previous research that the parahippocampus is category specific (Epstein and Kanwisher, 1998, Epstein et al., 1999, Nakamura et al., 2000, O'Craven and Kanwisher, 2000). Response was greater when viewing inanimate objects as compared to scenes, faces and animals. In part, this is consistent with previous findings comparing objects relative to faces (Kanwisher et al., 1996). There were no effects of valence.

It was also evident that the parahippocampus was activated for normally viewed presentations only. There is no evidence to suggest that this region is activated below or close to the threshold of conscious awareness.

d) Amygdala

Previous data demonstrate a rapid response in the amygdala to the emotional content of stimuli (LeDoux, 2002), which is implicitly processed (Whalen et al., 1998b). Equally, the amygdala is known for rapid habituation of responses to affective faces (Breiter et al., 1996, Whalen et al., 1998b). According to these published views, positive activations to emotional stimuli (relative to control stimuli) were expected to be found with brief, masked presentations as well as under normal viewing, but this was not the case. Lateralisation of amygdala responses has been previously reported in neuroimaging studies. One such experiment used a backward masking paradigm with visual images of faces, and noted more neural activation in the RH for masked presentations and greater activations in the LH for unmasked presentations. They concluded that lateralisation varies in relation to conscious awareness of the target stimuli (Morris et al., 1998b). Again, the present study found no evidence of this.

Another unexpected negative finding is that there was no significant effect of valence - as the amygdala is well documented to be fear-related, one would have expected a difference in responses to high and low valence stimuli. Two possible explanations seem plausible. First, the content of many of the low valence IAPS face stimuli could be associated with disgust or sadness rather than fear, for instance a tumour on a baby's face, eye disease and battered female. The stimuli that could be associated with fear were mainly inanimate objects, (e.g. aimed gun), or animals, (e.g. attack dog). It is interesting, therefore, to note that the greatest value in the estimated marginal means was found with low valence inanimate objects. In support of this interpretation, Killgore and Yurgelun-Todd (2004) found zero activation in the amygdala when viewing nonconscious masked sad faces, hypothesising that sadness is not of immediate survival value whereas fear is (Killgore and Yurgelun-Todd, 2004). On the other hand, the amygdala has been reported to have a more generalised role in emotional processing than previously thought, (e.g. processing happy facial expressions) (Adolphs, 2002, Breiter et al., 1996, Britton et al., 2006b), sadness (Blair et al., 1999), and anger (Whalen et al., 2001). Therefore, an effect of valence would not necessarily be apparent using a positive and negative dissociation.

In addition, the authors listed above all reported affective results from face stimuli which are partly comparable to this experiment, in that faces incurred the second greatest value in the estimated marginal means in the amygdala. As an example of the varying results using different stimuli, Britton et al. (2006b) compared face stimuli with IAPS pictures of scenes and noted activation in the amygdala whilst viewing happy facial expressions, but not for positive IAPS scenes (Britton et al., 2006b). A similar study found greater amygdala response to fearful facial expressions than IAPS images of scenes evoking a fearful response (Hariri et al., 2002). These findings, in part, run counter to those studies using IAPS pictures demonstrating that positive and negative affect are both processed by the amygdala, thus concluding a more general role in emotional processing (Amaral et al., 2003, Liberzon et al., 2003). One point of view suggests that because the amygdala is part of the 'primitive' limbic brain, it is thought to be recruited for primary aversive detection, (e.g. danger). However, Liberzon argues that appetitive detection is

also of primary importance, as highlighted by 'positive' survival functions, (i.e. sustenance and reproduction) (Liberzon et al., 2003).

Secondly, the arousal ratings of the stimuli used were not of the highest score available in the IAPS set. As previously discussed, for ethical reasons it was decided not to use pictures of mutilated bodies (negative valence, very high arousal) or erotica (positive valence, very high arousal). Therefore, the small amygdala activations from this experiment may be due to the relative subtlety of the stimuli. The involvement of the amygdala in the evaluation of arousal dimension of affect has been previously documented (LaBar et al., 1998) and in particular the left amygdala is associated with the intensity of emotion (Cunningham et al., 2004). Others have reported that amygdala activations are correlated with arousal and not with valence (Heinzel et al., 2005).

Equally, this experiment employed a valence categorisation task and Pessoa et al. (2005b) found a reduction in amygdala activity to unattended affective stimuli during cognitive tasks, which suggested active suppression of the amygdala. This cognitive modulation hypothesis (Pessoa et al., 2005b) was drawn from evidence of reciprocal functional exchanges between cognitive and emotional systems (Mayberg et al., 1999). Cognitive evaluation attenuating amygdala activations suggesting involvement in emotional regulation is documented elsewhere (Hariri et al., 2003).

Moreover, although this experiment did not investigate functional interactions between ROIs, it is interesting to note that the absence of significant activations in the amygdala with regard to brief, masked and normally viewed conditions coexists with significant activations in the mPFC and DLPFC, which would be consistent with amygdala suppression from PFC. Prefrontal Cortices and amygdala interactions have been investigated with reference to emotional processing and cognitive evaluation (Keightley et al., 2003, Lange et al., 2003). One hypothesis is that a modulative integration serves to facilitate conscious evaluation to monitor primitive emotions (Hariri et al., 2003).

There is a third potential explanation for a negative finding regarding valence response. The amygdala is a small structure and an anatomical error is a possibility. This risk was minimised by following the preprocessing

procedure (section 2:1:4) and checking the activation patterns with coordinates for each participant. Equally an 8mm radius sphere centred on the coordinates for the amygdala in both hemispheres was a fair balance between sensitivity and accuracy. It should be noted that using the same procedures, significant activations in the amygdala were recorded in the next fMRI experiment.

e) Superior Temporal Gyrus

Using fMRI, Phillips et al. (1998) found significant activation in the STG for both facial images and vocal expressions of fear and disgust. They hypothesised that the STG responds to the emotional content of faces and vocal sounds suggesting a general role for the perception of emotional stimuli (Phillips et al., 1998). Other studies investigating the neural response of the STG with facial stimuli include an experiment conducted by Britton et al. (2006b), who compared low rated valence and arousal images of facial expressions with higher rated valence and arousal IAPS pictures. They found greater activations for face processing (Britton et al., 2006b). Greater response to faces than IAPS pictures can be partly explained by the hypothesis that the STG is involved in processing dynamic facial components, (e.g. mouth expression in relation to lip-reading). This is quite logical as the STG is a large structure that contains several functional units that are responsible for sound (e.g. primary auditory cortex and Wernicke's area) (Haxby et al., 2000).

On close inspection of the IAPS stimuli in the Britton experiment (Britton et al., 2006b), however, it would appear that the set of pictures used included faces, (e.g. babies), and that they were balanced in relation to target emotions and not to specific categories. Therefore, one could surmise that the imbalance of the percentage of face stimuli could bias the comparative result.

In the current study categories were evenly balanced in terms of category membership, valence and intensity, but activations for face stimuli were no greater than activations for other categories. It is interesting, however, that the greater significance of LV inanimate objects in the present experiment suggests category-related activity for negative stimuli, which

supports the significance of low valence images in the Britton et al. (2006b) experiment. Previous studies have drawn attention to greater STG activity when presented with LV stimuli such as fear and disgust (Phillips et al., 1998) and mutilations from the IAPS series (Kuniecki et al., 2003). Equally, a study using animals, faces, houses and tools found the STG to be category related, hypothesising a non-biological object motion association (Chao et al., 1999) based on topographical evidence that the temporal gyrus is in the proximity of the motion perception areas (V5) (Zeki et al., 1991). By the same token, damage to the occipital-temporal-parietal junction (V5) is reported to impair knowledge retrieval about tools (Tranel et al., 1997). However, to the best of my knowledge, no other study than this current research has examined a category x valence interaction in the STG and, as such, this is a topic for further research.

f) Insula

It was clearly evident that hemispheric specialisation was apparent in the insula. All significant activations were in the RH for LV stimuli across all conditions. These results concur with the valence lateralisation hypothesis, which postulates that negative emotions are lateralised towards the RH (Canli et al., 1998, Davidson and Irwin, 1999).

In addition, RH specialisation in the insula was reported in an explicit evaluation task of affective facial expressions (Britton et al., 2006b) and a correlation between the RH and valence has also been documented (Cunningham et al., 2004).

Moreover, the significance of LV stimuli supports previous research, in that the insula is associated with the emotion disgust (Calder et al., 2001, Phillips et al., 1997, Phillips et al., 2004). It is interesting to note that in the behavioural experiment in the present study the image of the dirty toilet evoked the greatest subjective reaction of disgust and in the present fMRI experiment LV inanimate objects showed the greatest activations. Furthermore, a meta-analysis on 65 studies investigating emotion using neuroimaging confirmed insula activations for negative stimuli (Wager et al.,

2003). Equally, recalling sadness whilst watching silent film clips demonstrated increased activations in the anterior insula (Lane et al., 1997b).

g) Fusiform Gyrus

In keeping with previous research, the fusiform gyrus did show a main effect of category. Looking at the estimated marginal means, it appears that inanimate objects showed marginally greater activations than the other categories, including faces. However, positive values were also apparent for low and high valence faces under normal viewing, which is consistent with previous reports implicating the fusiform gyrus in emotional processing of faces (Adolphs et al., 1996, Nakamura et al., 2000), and specifically, fearful faces (Vuilleumier et al., 2001). Nakamura and colleagues however demonstrated posterior fusiform gyrus activation non-selectively in both faces and scenes and concluded that, in complex images, this region is involved in extracting physical features (Nakamura et al., 2000).

Previous findings have shown that fusiform activations are modulated by valence (Paradiso et al., 1999, Vuilleumier et al., 2001), but present results did not reveal any significance of valence.

h) Dorsolateral Prefrontal Cortex

Hemispheric specialisation was marginally evident in the DLPFC, with significant activations in the LH with normally viewed stimuli and RH dominance when presented with brief, masked stimuli, although these effect sizes were small. It has been hypothesised that both hemispheres complement each other in terms of emotional processing. This theory suggests that the role of the RH is to subserve the subcortical limbic centres and the LH is involved in the control capacity of higher cortical structures (Gainotti et al., 1993).

Valence modulation was evident when viewing LV inanimate objects both in the brief, masked condition and under normal viewing. These findings demonstrate a) neural activity in the DLPFC close to or below the level of

conscious perception and b) that DLPFC shows greater activity for processing negative emotion than positive.

Previous studies have shown that the DLPFC is modulated by valence (Grimm et al., 2006) and in particular aversive stimuli, although the RH is implicated (Nitschke et al., 2006).

i) Orbitofrontal Cortex

There was no main effect of valence and this result is consistent with lesion studies noting that patients with damage to the OFC suffer from changes in both positive and negative emotion (Hornak et al., 1996, Hornak et al., 2003), thus suggesting a more general role in emotional processing (Drevets and Raichle, 1998, Murphy et al., 2003) and for processing of emotionally salient stimuli (Adolphs, 2002).

However, the present experiment found greater activation for LV inanimate objects, which may have been particularly noticeable (e.g. dirty toilet). This idea was reinforced by a significant main effect of category and significant interaction between valence x category.

The anatomical connections into autonomic centres in the limbic and paralimbic regions (Öngür et al., 1998), and the reported heavy connections with the intraprefrontal regions (e.g. DLPFC) (Cavada et al., 2000) support the hypothesis of the OFC's involvement in cognitive-emotion coalescence and top-down processing. However, significant activations were evident in the present experiments not only in normal viewing, but also for brief, masked stimuli close to and below conscious threshold.

4:5:2 General Discussion

The purpose of the present study was to examine the effect of valence both in normal viewing, and close to or below the threshold of conscious perception, whilst viewing four categories of natural images. Having discussed the results of each ROI separately, these findings in relation to the significance of valence, unconscious processing and category effects in general will now be considered.

Valence

There was evidence of significant overall effects of stimulus valence, bilaterally in the STG and ACC and in the right insula. This, in part, supports the hemispheric lateralisation valence hypothesis in that the RH is more likely to process emotion. This premise was originally based on behavioural and clinical studies (Ross, 1984, Sackheim et al., 1982), but remains controversial. Nevertheless, there is some indication in these results to support the hypothesis and, as such, there is evidence that right hemisphere dominance (RHD) in both near-threshold and suprathreshold emotional processing is extended to categories other than faces and scenes.

In support of this, LV stimuli elicited greater activations than HV in the RH for the insula, and bilaterally in general across most of the remaining ROIs.

It is clear that unpleasant stimuli activated both phylogenetically older (e.g. insula) and newer (e.g. DLPFC) systems. One would expect the former, as unpleasant pictures may elicit disgust derived from distaste associated with the danger of contaminated food (Rozin et al., 1994), but the latter is not so obvious as prefrontal cortices are associated with employing attentional systems to verify emotional content, which are obviously not exclusively unpleasant, and can be either pleasant or unpleasant (Berthoz et al., 2002). However, studies researching damage to the left DLPFC have highlighted that, as a result, patients suffer from depressive symptoms and have therefore reasoned that this region is associated with positive affect (Mineka et al., 1998); although other research has challenged this theory (Gainotti et al., 1997, House et al., 1990). Present results, however, show greater processing of unpleasant stimuli in areas associated with both cognition and affect.

Greater activations for normally viewed images than for brief, masked exposures were found in the parahippocampus, STG, amygdala and fusiform gyrus.

In the ACC, STG, insula, DLPFC and OFC the valence of stimuli was processed both in the brief, masked condition and under normal viewing this indicates that the level of conscious processing of the stimuli was not an overriding factor. It also tells us that the said regions are activated close to or

below the threshold of consciousness and suggests that the activations to such brief presentations must be relatively sustained in order to be detected reliably in a block-design fMRI experiment. Hemispheric differences were evident between normal viewing and brief, masked conditions in the DLPFC, which has been expanded upon above when discussing the DLPFC separately.

Categories

Some concerns were raised as a result of the behavioural experiment of Chapter 3 that the *a priori* stimulus categories (animals, faces, scenes and inanimate objects) might have low reliability due to variation between individual slides and the small number of slides per category. This issue was addressed in the current experiment by introducing a second set of stimuli, thus doubling the number of examples, and allowing a replication of category-specific effects. The results of the present fMRI study showed that the category-specific effects were indeed replicated, and that the two sets of normally-viewed stimuli gave similar results. Furthermore, the category-dependent effects seen in the present fMRI study did not follow the pattern expected, if they were due to a confounding variable such as detectability (see Chapter 3). There is thus some justification for interpreting the present results in terms of category-specificity.

Previous research examining the effect of categories has highlighted two different classifications of stimuli: 'natural objects' such as animals and fruit; and 'man-made objects' such as vehicles and tools (Moore and Price, 1999). These 'living' and 'non-living' dissociations are based on impairments in identification of stimuli from brain lesion studies (Warrington and Shallice, 1984). Two theories attempt to explain this tenet. First, man-made objects are identified by their functional attributes, (e.g. sports car is for driving); whereas identification of natural objects relies on perceptual features, (e.g. a lion has a mane, tail etc.) (Farah and McClelland, 1991, Warrington and Shallice, 1984). The second theory supports the differentiation between natural objects and man-made objects not because of their functional and perceptual features, but because identifying natural images places different neural demands due to their complexities and similarities, compared to the

more distinct man-made objects. Thus the differentiation is one of different demands due to levels of distinctiveness on shared neural systems (Durrant-Peatfield et al., 1997, Gelman, 1988).

It is not the remit of this thesis to further elucidate category membership, but it serves to illustrate category specificity in context of the present findings. As such, and in accordance with these classifications, the categories used in this thesis can be organised thus: animals – natural/living; faces – natural/living; inanimate objects – man-made/non-living; scenes – both natural/living, (e.g. skydiver, waterfall) and man-made/non-living, (e.g. car crash, atomic bomb). The relative ambiguity of scenes, that were also anomalous in the behavioural experiment, may account for the lack of significant valence effects compared to the other categories. In fact, the parahippocampus recorded the greatest activations when viewing scenes, albeit not significantly so, which is in keeping with previous research reporting this region's specialisation in processing places (Epstein and Kanwisher, 1998, Epstein et al., 1999, O'Craven and Kanwisher, 2000). By the same token, face processing in complex images was of marginally greater significance in the fusiform gyrus (RH) for both low and high valence, which again supports previous research in this region's recorded specialisation of processing faces (O'Craven and Kanwisher, 2000, Schultz et al., 2003). Even though this account, in part, concurs with those of previous authors, it is necessary to challenge why affective face stimuli were not of greater significance in general.

There has been considerable interest in comparing facial expressions with IAPS pictures as emotional probes, which has highlighted differential and common cortical areas in both conscious and unconscious processing (Britton et al., 2006b, de Gelder et al., 2002, Hariri et al., 2002). An experiment employing this comparison found greater amygdala activation for negative faces than negative IAPS scenes (Hariri et al., 2002). Most experiments investigating this comparison appear to have used simple face stimuli and not pictures of faces from the IAPS series. However, an interesting paper by Keightley et al. (2003) compared emotional faces with general emotional pictures, whereby all the images contained one or more people, including some (although it is not clear how many) with clear facial

expressions,. They found that affective faces were automatically processed in the limbic regions whereas the affective general pictures were effective only when attention was directed to emotional content (Keightley et al., 2003). The face stimuli in the current experiment were similar to at least some of the general pictures in Keightley's experiment, with a categorisation task specifically drawing attention to the emotional content of the images, but the results did not concur. To date there is little data on the effect of face stimuli when presented in the complex and variable context of everyday images, therefore the same facial expression stimuli need to be presented with different pictorial contexts to investigate the possible valence modulation of complex presentations.

Let us speculate at this point and suggest that the images of animals and inanimate objects were more prototypical stimuli (likely to have been seen before, e.g. dogs, toilets) whereas the scenes and faces were less prototypical (less likely to have been seen before, e.g. air crash, baby tumour). Of course, individual perceptual history will vary, but prototypicality effects are known to be robust. The concept of a prototypical category member is important in cognitive psychology as it can explain performance in categorisation tasks. The prototypical image is built up from cognitive and perceptual information rather than a memory or accurate picture (Rosch, 1975, Rosch and Mervis, 1975). This idea may explain why animals and inanimate objects showed greater neural activity than other categories in the majority of ROIs.

The Negative Estimated Marginal Means

A further aspect of these findings needs to be considered. Several of the brain regions showed negative estimated marginal means for varying stimuli which implies, in these instances, that there were greater activations for the control condition than experimental conditions. One possible explanation is that trying to categorise the emotional valence of a control stimulus is less straightforward than categorising the pleasant/unpleasant stimuli, in which case greater attentional demands would be required (as there is no obvious positive or negative answer). This idea is consistent with visual search

experiments whereby targets are processed in shorter reaction times than non-targets, as more time is needed for analysis (Treisman and Gelade, 1980).

Summary of results.

To summarise, these results show that when presenting affective complex stimuli, there are significant effects involving stimulus valence under normal viewing conditions, in ACC, STG, insula, DLPFC and OFC (H^1). When presented in brief, masked exposures, significant effects involving stimulus valence are found in ACC, insula, DLPFC and OFC (H^2). There are some differences between brief, masked and normally viewed presentations in mPFC, parahippocampus, amygdala, insula and fusiform gyrus (confirming H^3). The cause of these differences is uncertain. It is possible that the kinds of anomalous effects reported in Ch3 (i.e. reversal of apparent valence due to brief, masked exposure) contribute, but if these anomalies are effects of individual pictures, they are more likely to appear in higher order interaction terms of ANOVA (where cell size is small), and the only plausible confound of this kind is the condition x category interaction in mPFC (which should therefore be treated with caution). There are significant effects involving category (H^4) in ACC, mPFC, parahippocampus, STG, insula, fusiform gyrus, DLPFC and OFC. There is a marginal effect of valence in relation to hemispheric specificity in insula (H^5); and there are significant effects involving category under brief, masked conditions in ACC, mPFC, STG, insula, DLPFC and OFC (H^6).

If brief, masked presentations induced significant activations where normally viewed presentations did not, this would suggest that the chosen ROIs were activated for brief exposures only. This was not the case.

If normally viewed presentations were significant and brief, masked were not, this would suggest that particular region was not significantly activated close to or below conscious threshold. This pattern was evident in the fusiform gyrus, parahippocampus and OFC, where there was a category effect under normal viewing only, and in the STG for valence and valence x category.

However, without exception, we only witnessed significant activations to brief, masked stimuli when they were also significant for normally viewed presentations. This could suggest a graded process within a single mechanism/pathway, rather than a different mechanism/pathway.

4:6 Conclusion

Forward and backward masked stimuli presented for just 10 ms (see section 2:1:2) were shown (in Chapter 3) to allow discrimination of valence that was significantly different from control stimuli. These are stringent temporal parameters, and might be expected to generate little cortical activity. However it is shown in the present chapter that even under these conditions significant effects of stimulus valence and / or category were found for a high proportion of brief, masked presentations. Recent research has highlighted the rapid and efficient processing of complex natural images (Thorpe et al., 1996, Thorpe et al., 2001b, VanRullen and Thorpe, 2001c), and the present study supports, at least in part, the idea of apparent automatic processing that traditionally implies 'independence from top-down factors', (e.g. processing of coarse information) allowing categorisation in terms of valence and arousal.

The results of the present study have shown that a limited but significant level of processing of complex affective stimuli takes place in the near absence of conscious perception. Two avenues of interest arise. One is to revisit the view that perception without focal attention is severely limited and the other is to investigate the extent to which 'gist' information is processed in unattended images. To investigate further, an experiment was designed to present the same stimuli in conditions of attentional conflict between small stimuli presented at fixation, and larger, surrounding stimuli extending into the periphery of the visual field. Although there were no exact replications in procedures, a dual stimulus design (selective attention) was chosen in comparison with the masked experiment (non-selective attention) in order to discuss gist perception and capacity limitations in the next chapter.

Chapter 5 fMRI Dual-Image Experiment: An fMRI study comparing responses to large-field, small-field and dual affective stimuli

5:1 Abstract

One of the difficulties with using brief, masked stimuli for fMRI studies is that the stimuli are by definition weak. This in itself may reduce the likelihood of obtaining strong patterns of activation in the ROIs. The purpose of the present study is to determine whether similar patterns of sensitivity to IAPS stimulus valence and category can be obtained with a different paradigm. Rather than reducing the visibility of the target stimulus by brief presentation and masking, the intention here is to reduce conscious processing of a highly visible suprathreshold stimulus by providing a second competing image. This was achieved by introducing a 'dual image paradigm'[4], for a relatively long duration, using a small (foveal) image superimposed on a large (peripheral) image of opposite valence, thus exploiting the poverty of peripheral vision in order to explore demands on selective attention. The main question is whether 'to-be-ignored'[5] peripheral stimuli result in similar activations in the chosen ROIs to brief, masked stimuli, even though there is a difference in attentional demands.

The variables of interest were the same as those in the previous experiment: valence (low and high); category (animals, faces, scenes and inanimate objects) and hemispheric specificity. These findings are discussed in light of the results from the masked experiment in context of gist information and attentional capacity.

[4] **Dual image –** compound image consisting of the attended condition superimposed on the 'to-be-ignored' condition of opposite valence.
[5] **To-be-ignored condition –** instructed **t**o ignore large image, surrounding foveal image of the same category, but opposite valence.

5:2 Introduction

The density of cone receptor cells for processing photopic visual information is greatest in the fovea of the retina. The cone bipolar neurons and the ganglion cells that receive their signals, whose axons form the optic nerve, decrease in density moving away from the fovea. The LGN and primary visual cortex both have a strong magnification factor favouring the foveal input. All this means that visual acuity is keenest in the fovea and quickly declining in resolution, thus decaying, towards the periphery (Enns, 2004), hence the need for saccadic eye movements to bring a stimulus back into foveal vision for finer analysis (Liversedge and Findlay, 2000).

The technique to be adopted in the present experiment is a selective attention approach. Independent reports completed outside the scanner were able to confirm that the more peripheral stimulus in a dual array had a limited impact on valence judgments (see Section 5:4:1). The visual system has limited processing capacity and multiple objects in the visual field compete for neural representation. This competition can be biased by selective attention, which can adjust neural activity in the visual cortex (Desimone and Duncan, 1995). Existing data (Lavie, 1995, Pashler, 1998) suggest that the neural substrate of perception may be suppressed or even eliminated if attentional resources are diverted by contending tasks. Lavie's theory is that the importance of attention is to filter relevant and irrelevant information from 'noisy' visual scenes (Lavie and Tsal, 1994). For instance, when participants were engaged in a linguistic task, they were instructed to ignore a simultaneously competing visual task of moving stimuli; as a result motion-related fMRI activations in area MT were reduced (Rees et al., 1997). A possible exception to this selective mechanism is the processing of emotional stimuli, which as previously stated, is said to be automatic, therefore not needing attention. Calvo et al. (2007) briefly presented stimuli in the peripheral visual field and found greater selective orientation and preferential processing for emotional scenes than for neutral stimuli (Calvo et al., 2007).

To reiterate, it is further postulated that visual processing of facial expressions is not only automatic, but can also be processed without conscious awareness (Dimberg et al., 2000). This claim is supported only in

part by Vuilleumier et al (2001). Using a matching task of images of faces and houses presented at various locations in the visual field, they demonstrated that attention modulates fusiform activity especially for fearful faces, whereas amygdala response to fearful faces was consistent regardless of attentional demands (Vuilleumier et al., 2001). On the other hand, a study (Pessoa et al., 2002a) examining the neural correlates of faces with emotional content, including the amygdala, found that processing was not automatic and needed sufficient attentional mechanisms in order to process faces, and therefore under top-down control. In addition, it is argued that emotional (especially negative) stimuli can bias the competition for processing resources. Again, this means that emotionally valenced stimuli have a competitive advantage over neutral stimuli.

Developing on from this, it is possible to detect differences in 'attended'[6] (foveal) and 'to-be-ignored' (peripheral) perception of emotion of visual stimuli. For instance, previous studies have demonstrated that the advanced visual processing of foveal information suggests that it is easier to ignore stimuli presented in the low resolution periphery, where acuity of object recognition is too poor to be accurate (Beck and Lavie, 2005, Thorpe et al., 2001b). In order to bring objects into foveal vision, studies have demonstrated that both saccadic eye movements and selective attention are necessary (e.g. Liversedge and Findlay, 2000).

Although stimuli presented in the visual periphery are normally outside the focus of overt attention, a recognition study conducted by Calvo et al. (2005) presented complex images of affective scenes in the parafoveal visual field, and found the perception of emotional scenes had the advantage over neutral scenes. Interpretation of these results concluded that analysis by the cognitive system (i.e. recovery of semantic information) of affective scenes began covertly in parafoveal vision in advance of overt attention at foveal fixation, thus suggesting that the attentional field for emotional stimuli is broader than just the foveal spatial field (Calvo and Lang, 2005).

On the other hand, attention does not search out information by sweeping the visual field as the searchlight metaphor implies (Cave and

[6] **Attended condition –** instructed to voluntarily attend to a small image presented in the fovea superimposed on a large image of the same category, but opposite valence.

Bichot, 1999). Rather, Sperling and Weichselgartner argue a stage light analogy being more accurate in that it focuses on different actors in turn (Sperling and Weichselgartner, 1995). However, this implies a fast sequential process of which there is little evidence (Findlay and Gilchrist, 2003). In fact, the pursuit of understanding the selection of the next fixation attracts lively interpretation.

Studies have shown that it is also possible to covertly attend to items, (i.e. that attention can shift away from fixation without saccadic eye movements) (Thorpe et al., 2001b). Investigating spatial cueing, it was found that faster reaction times were achieved when the location of a target was cued even without eye movements (Posner, 1980, Posner et al., 1980). Later it was argued that covert perceptual attention precedes a saccade in order to facilitate saccades and improve identification of target (Kowler et al., 1995). On the other hand, the advantages of passive covert attention have mystified others when one considers the immediate advantages of active overt attention by means of a saccade bringing an item into fine detailed foveal vision (Findlay and Gilchrist, 2003).

Equally, there is evidence that attention can be directed to more than one item at once. Studies asking participants to identify peripheral targets whilst fixating on the fovea have shown convincing support of our ability to be visually aware outside the focus of attention if the target is salient enough (Braun, 1994, Braun and Sagi, 1990).

Research continues to explore the relationship between foveal and peripheral visual perception, with an increase in the use of natural images as stimuli. These include Li et al. (2002) who used natural images of scenes in an animal/vehicle categorisation go/no-go experiment, whereby images were randomly flashed in the periphery at around 6.1º eccentricity for, in effect, 80ms followed by a mask. They concluded that participants are highly efficient at categorising the 'gist' of natural scenes (Li et al., 2002).

Similar findings using an animal go/no-go task were found when two images were presented at the same time in the two hemifields with eccentricity of 3.6º left or right of fixation (Rousselet et al., 2002) and a study using one full image presented between two partial images, unmasked (Thorpe et al., 2001b), as well as presentations in the far periphery (Thorpe et

al., 1999). Equally, a study using a face-gender discrimination task presented stimuli at random locations of 8º x 10º of visual angle with SOA for faces at 133-160ms (Reddy et al., 2004). These studies, using a foveal peripheral paradigm, suggest that complex stimuli are processed rapidly in the near absence of attention.

Others have concluded that face processing depends on voluntary attention, as found in a matching task in peripherally presented faces and houses (Wojciulik et al., 1998), and that both pleasant and unpleasant images capture overt visual attention (Nummenmaa et al., 2006). These findings were supported in that affective perception occurs in the periphery at the cost of needing covert attentional resources (Calvo and Nummenmaa, 2007), and although coarse information may be extracted in the peripheral visual field, unless this advances selective attention, false alarms are likely (Calvo et al., 2008).

To further this line of enquiry, different methods were employed in the present experiment. For instance, Li and Reddy used extensive training procedures in order to coordinate motor demands (Li et al., 2002, Reddy et al., 2004), which could have affected the outcome. Motor responses were not part of the design for this experiment, so it was not necessary to include training procedures. Equally, Rousselet presented stimuli in the two hemifields (Rousselet et al., 2002), whereas this experiment employed a small image presented at fixation superimposed on a big image, thus presented in the periphery.

To take into account the duration of a saccade, with the intervals between saccades, it is estimated that 2 to 3 saccadic eye movements are made per second (Irwin and Brockmole, 2000, Koch, 2004). Therefore, in order to limit the effect of possible eye movements from one location to another, it is not uncommon for researchers to restrict the duration exposure of visual stimuli to <250ms (Li et al., 2002, Reddy et al., 2004, Rousselet et al., 2002). An example of this was a study by Prado and colleagues (2005) investigating cortical systems for reaching towards targets in fovea and peripheral vision, using three conditions. In the first, the target duration was 7s and therefore captured by the fovea. In the second, the target disappeared after 150ms thus interfering with fovea capture and therefore processed in the periphery; and in

the third the participants were ‘not allowed’ (Prado et al., 2005, p 850) to make a saccade during a 7s presentation. They concluded that reaching in the peripheral visual field activates more cortical regions than when reaching in central vision (Prado et al., 2005).

These parameters were considered when designing the present experiment. However, in order to address the possibility that the brief exposure duration of the stimuli in Chapter 4 did not allow for a time to peak for the BOLD signal, it was decided to display the stimuli for 1s. This is the minimum for time to peak for short stimuli (Jezzard et al., 2001). In light of this, three measures were undertaken to discourage saccades: a) the participants were instructed to attend to the foveal stimulus only - a separate behavioural study investigated the efficacy of this instruction; b) by continually positioning the foveal image centrally facilitating attention directed by expectation (Holm et al., 2008); and c) a categorisation task was employed to ensure fixation to target and to challenge attentional capacity/resource limitations, thus to reduce peripheral interference.

Nevertheless, these stimuli are not presented at or below the detection threshold, as in chapter 3 and 4, since it is obvious that the large-field surround is always present in the combined stimulus. The data will be examined to determine whether it can support findings from the masked experiment, and allow for comparisons of patterns of activations in the nine ROIs.

In sum, foveal stimuli were used as the voluntarily ‘attended’ target in order to measure the voluntarily ‘to-be-ignored’ peripheral stimuli, thus investigating the interaction between selective attention and emotional evaluation.

It was hypothesised that:

H^1 There are significant effects involving valence for ‘attended’ conditions.

H^2 There are significant effects involving valence for ‘to-be-ignored’ conditions.

H^3 Valence effect is different between ‘attended’ and ‘to be ignored’ conditions.

H^4 There are significant effects involving category for 'attended' condition.

H^5 There are significant effects involving category for 'to-be-ignored' stimuli

H^6 There are hemispheric differences between activations in paired (left and right) ROIs

5:3 Method

5:3:1 Participants

Eleven females and five males (age range 19 – 37 years, mean age 27.7) participated in the experiment. The same screening process and ethical considerations took place as in the masked experiment (see section 2:4:1).

Again, the only payment made to the participants was to those who travelled to the scanner independently where travel expenses were reimbursed.

5:3:2 Design

Each image (I) was shown for 1s within a block consisting of three images of the same emotional category (e.g. LV faces) and same condition (e.g. large-field), and three neutral (N) pictures in the same condition (e.g. large-field) to ensure that the participant's emotional response returned to baseline level. The baseline (neutral visual stimuli) was modelled implicitly, therefore modelling the neutral (baseline) condition as a separate regressor was not necessary.

Between each image there was a blank (B) screen lasting 1s with a 2s blank between each category, therefore each block lasted fourteen seconds (Figure 5.1).

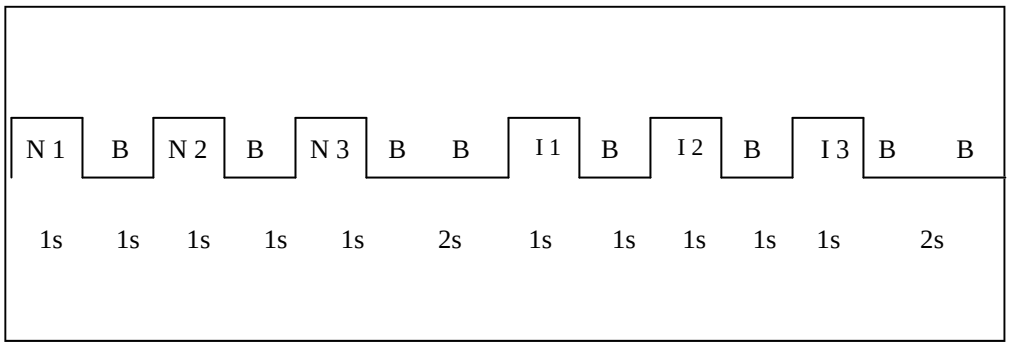


Figure 5.1 Block time sequence .
Key: N1-N3 = neutral images. B = blank. I1 - I3 = target images.

As the images were not masked, the neutral images and blank screens were of extra value in order to reduce any iconic representation after the target images disappeared.

The same stimuli were presented in three different ways. The first was control stimulus condition 1, a no-conflict condition whereby single large versions of the pictures were shown in the central and near-peripheral visual field. This 'large-field' single picture occupied a rectangle 16x10 deg (Figure 5.2). The second, control condition 2, consisted of small pictures presented at the fovea. The 'small-field' condition showed single pictures (3.75x2.5 deg) (Figure 5.3). The third stimulus type (condition 3), combined 'attended' (foveal) and 'to-be-ignored' (peripheral) pictures of opposite valence. This dual image consisted of small-field pictures superimposed centrally on large-field pictures of opposite valence and equivalent category (Figure 5.4). There were 24 blocks with the presentation order randomised for valence and category.

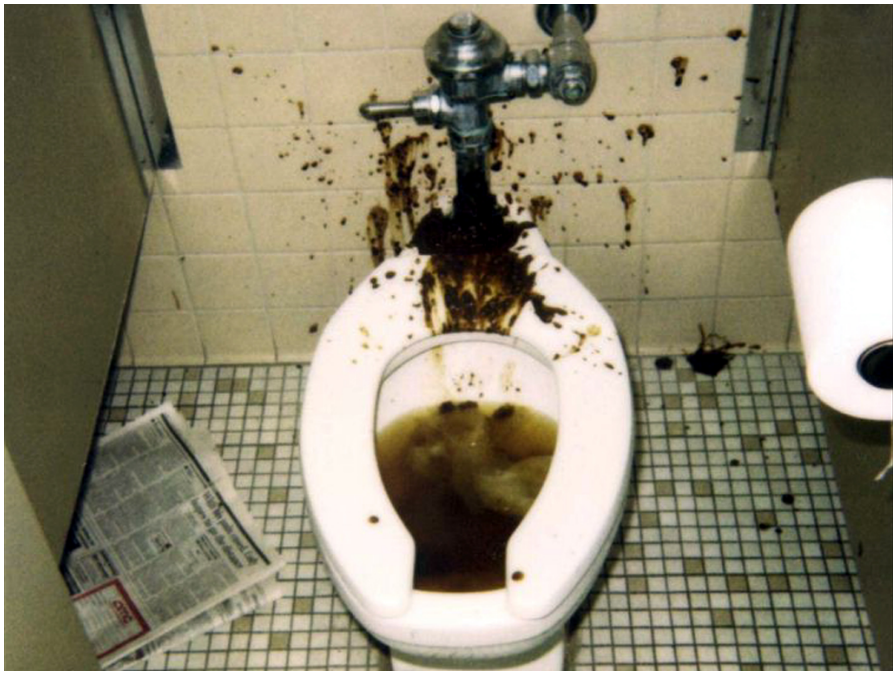


Figure 5.2 Large-field control condition one. LV inanimate slide number 9301

Figure 5.3 Small-field control condition two. HV face slide number 2071

Figure 5.4 Dual image consisting of LV foveal (voluntarily 'attended') animal slide number 1525; with HV peripheral ('to-be-ignored') animal slide number 1650.

5:3:3 Procedure

In keeping with the procedure of the first fMRI experiment, the participants carried out the same screening process (see section 4:2:4) and were thoroughly briefed in the control room, where they viewed a trial run on a laptop computer using different images to those in the actual experiment.

The instruction slide read as follows:

- Each picture will appear quickly.
- Please indicate whether the images are pleasant, unpleasant or neutral.
- Press the left button for pleasant, the right button for unpleasant and the middle button for neither.
- Some of the pictures are big. Some are small. Some are big with a small picture in the centre – when these appear please attend to the small central picture only.
- GET READY

Once again the button box was a dummy used for greater attention.

5:3:4 fMRI Data Acquisition

Data were acquired using procedures as outlined in section 2:1:2 and 2:1:4. Functional images were acquired using a T2-weighted gradient EPI sequence over 5.60 minutes (TR = 2000 ms, TE = 30 ms, FoV = 192 x 192mm, flip angle = 90°). 33 transversal (axial) planes were recorded with a thickness of 3mm. Voxel size 3 x 3 x 3, number of measurements = 168 volumes.

5:3:5 Data Analysis

a) Analysis of fMRI data

Again SPM2 (Friston and Wellcome Department of Imaging Neuroscience, 2003) (http://www.fil.ion.ac.uk/spm) was used for statistical processing which was implemented in MATLAB (MATLAB Inc, 2002) (http://www.mathworks.com/products/matlab). The same pre-processing was carried out prior to statistical analysis (see section 2:1:4).

As in the previous fMRI experiment a first level analysis was carried out as a preliminary investigation. In the second level analysis, taking into account the variability between participants, a significance level for differences in activations between experimental conditions of $p<0.05$ was applied. Using MarsBar toolbox for SPM2 (Brett et al., 2002) *http://marsbar.sourceforge.net* to analyse the processing of category and valence within each ROI, the means of the contrast values (effect sizes) were calculated for each of the 16 contrasts and entered into a data matrix (Table 5.3). These means are graphically displayed in Figures 5.7 - 5.28 for each ROI. The data analysis procedure was identical to that of the masked experiment (see section 2:1:4).

The overall purpose of this experiment was to ascertain if emotional processing occurs whilst viewing complex affective pictures presented in the 'to-be-ignored' periphery when selective attention is focused on an affective

Fig 5.5

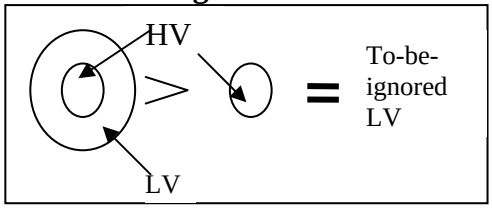
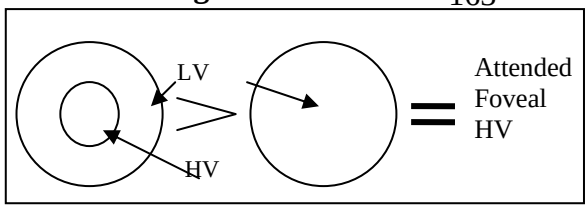


Fig 5.6



picture of opposite valence presented in the fovea. This was achieved by measuring the effect of valence and categories on specific contrasts between experimental conditions. Contrasts of high and low valence combined condition were compared with high and low valence small-field condition (this estimates the contribution of the 'to-be-ignored' large-field stimulus in the combined display: Figure 5.5). In addition, contrasts were computed between the combined display, and the single large-field stimulus (valence matched to the surround of the combined display). This estimates the effect of the 'attended', opposite-valence small-field stimulus in the combined display (Figure 5.6). In the first contrast (dual > small field), the valence of the fixated stimulus is the same. In the second contrast (dual > large field), the valence of the fixated stimulus is opposite. If the surround has no effect, the activations produced by these two stimuli should be zero for dual > small field. If the surround has an inhibitory effect on the centre, the activations should be negative for dual > small field. If the surround has an excitatory effect, activations should be positive for dual > small field. Activations should be non-zero (depending on a differential response to positive and negative valence) for dual > large field. The dual > large field contrast specifically assesses the effect of the small, central field in the dual stimulus. The two contrasts (dual > small field) and (dual > large field) will also be referred to as 'to-be-ignored' and 'attended' for the sake of brevity, because in the (dual > small field) 'to-be-ignored' contrast (Figure 5.5), the 'attended' part of the dual stimulus is physically approximated by the control stimulus. In the 'attended' contrast, the (dual > large field) (Figure 5.6), the 'to-be-ignored' part of the dual stimulus is physically approximated by the control stimulus. When referring to the valence of a contrast condition, this will be taken to indicate the valence of the ('to-be-ignored') large field part of the dual stimulus in the 'to-be-ignored' contrast, and of the ('attended') small field part of the dual stimulus in the 'attended' contrast.

Fig 5.5

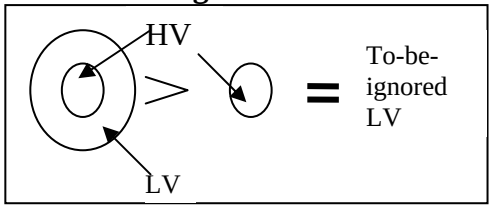
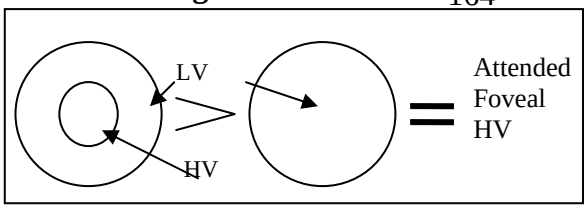


Fig 5.6



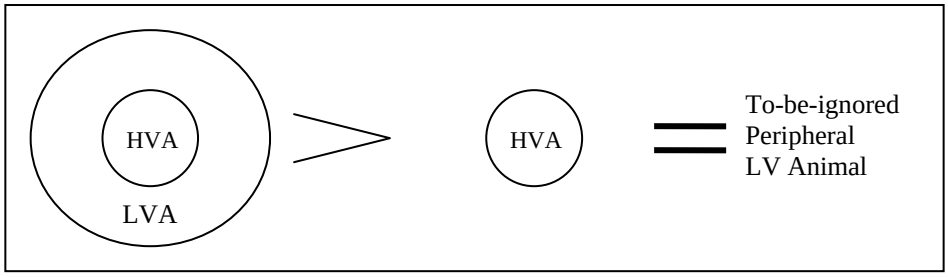


Figure 5.5 Example of the 'to-be-ignored' estimate (the combined animal condition minus the small-field control HV animal condition which shows the effect of 'to-be-ignored' LV animals).

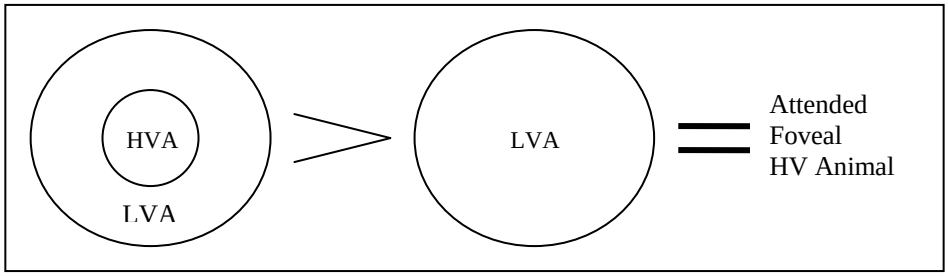


Figure 5.6 Example of the 'attended' estimate (the combined animal condition minus the large-field LV animal control condition which shows the effect of 'attended' HV animal

Versions of figures 5.5 and 5.6 have been copied into the footer of each page of this section whenever a reference is made to this paradigm. This is to ensure the reader can visualise the 'to-be-ignored' and 'attended' estimates while reading this chapter.

b) Analysis of Behavioural Data

Independent raters were engaged to complete subjective reports to further ascertain if the participants ever 'attended' the 'to-be-ignored' stimuli. A paired-samples t-test was carried out on these subjective reports monitoring correct responses (see section 5:4:1).

Fig 5.5

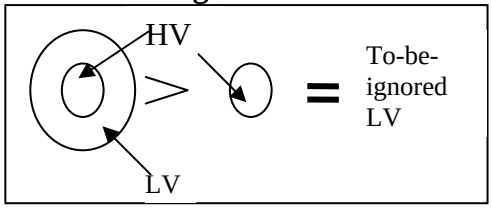
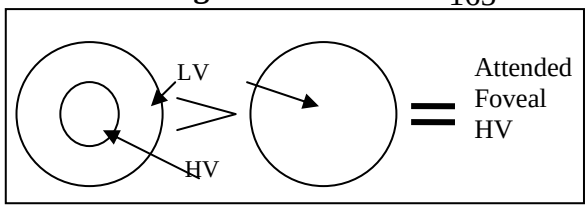


Fig 5.6



5:4 Results

The important contrasts for testing the experimental hypotheses are those that show the activation produced by the combined condition (3) versus condition (2) small field as a control condition. By matching the valence and category of the small-field stimulus in (3) and (2), the effect of the 'to-be-ignored' (peripheral) surround stimulus is shown by subtraction.

Initial subjective reports were analysed to determine concordance with IAPS ratings of the stimuli used in this experiment.

5:4:1 Subjective Reports

Subjective reports were completed under experimental conditions, similar to those of the fMRI study, and these reports monitored the concordance of pleasant/unpleasant responses to the stimuli of the MRI study with the published IAPS ratings of the component pictures. The questionnaires (Appendix XI) were completed by independent raters rather than the participants in the MRI study, because habituation might alter the valence and intensity of responses to a second viewing of these emotional stimuli (Breiter et al., 1996, Fischer et al., 2003). Whereas it cannot be proven that participants never attended to the 'to-be-ignored' peripheral stimuli, analysis of the responses of the independent raters did reveal a strong attentional bias for central stimuli.

A paired-samples t-test showed that the number of concordant responses was not significantly different for the 'large-field' single pictures and the dual task stimuli (t=0.257, df 23, p=0.799, two tailed); and there were no significant differences between the 'small-field' single pictures and the dual task images (t=0.182, df 23, p=0.857, two tailed) (Table 5.1). The means in Table 5.1 are the means of total concordant responses out of 48 (24 target images and 24 neutral images).

Fig 5.5

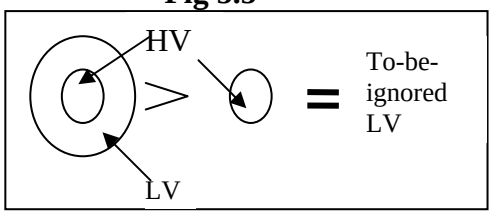
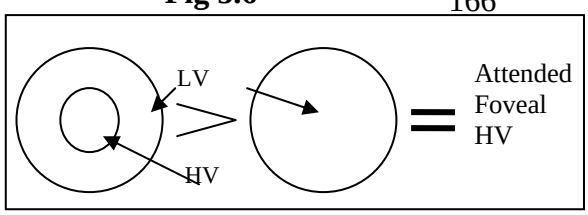


Fig 5.6



Descriptive Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Large-field	44.38	24	1.345	.275
	Attended foveal in dual image	44.25	24	1.894	.387
Pair 2	Small-field	44.33	24	2.014	.411
	Attended foveal in dual image	44.25	24	1.894	.387

Table 5.1 Descriptive statistics for small field and large field
Key: Mean = mean of concordant responses.

5:4:2 First Level Analysis

a) fMRI DATA

An initial first level group analysis was carried out in order to ascertain the quality of the data. In this analysis, the contrast of interest is the subtraction of the small-field (foveal 'attended') control stimulus from the dual (foveal 'attended' and peripheral 'to-be-ignored') stimulus. This contrast reflects the effect of the peripheral 'to-be-ignored' stimulus.

b) Effects of valence

Significant activation was found in the left amygdala when viewing 'to-be-ignored' LV stimuli across all four categories and the exact opposite occurred when presented with 'to-be-ignored' HV stimuli. This is a significant indication that the left and right amygdala subserve different functions in emotional processing. Bilateral activations in the ACC were evident for all four categories for 'to-be-ignored' peripheral HV, but the left ACC was only activated when processing 'to-be-ignored' peripheral LV scenes.

Fig 5.5

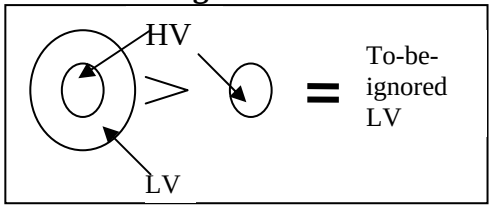
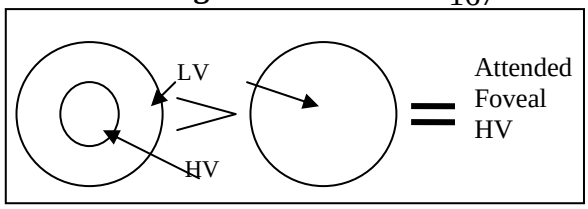


Fig 5.6



c) Effects of stimulus category

The fusiform gyrus, parahippocampus and insula were bilaterally activated by a 'to-be-ignored' peripheral HV and LV surround, and some of these effects were category specific. The fusiform gyrus did not respond only to 'to-be-ignored' peripheral faces, nor did the parahippocampus only react to to-be-ignored peripheral scenes, suggesting that these areas have only a broad categorical response to 'to-be-ignored' peripheral stimuli. STG was activated for all 'to-be-ignored' peripheral categories regardless of valence. (Table 5.2)

To-Be-Ignored Stimuli	Amy	ACC	mPFC	OFC	DLPFC	Para	Fusi	Ins	STG
LVA	R				L	L R	L R	R	L R
LVF	R				L	R	L R	R	L R
LVS	R	L				R	L R	L R	L R
LVI	R					R	R	R	L R
HVA	L	L R		R	L R	L R	L R	L	L R
HVF	L	L R	R	L R	L R	L R	L	L R	L R
HVS	L	L R	R	L	L R	L R	R	L R	L R
HVI	L	L R	L R	L R	L R	L R	L R	R	L R

Table 5.2 First level activations across all nine ROIs
Key: Amy = Amygdala; ACC = Anterior Cingulate Cortex; mPFC = medial Prefrontal Cortex; OFC = Orbital Prefrontal Cortex; DLPFC = Dorsolateral Prefrontal Cortex; Para = Parahippocampus; Fusi = Fusiform Gyrus; Ins = Insula; STG = Superior Temporal Gyrus.

d) Hemispheric differences.

The RH was dominant in the insula for both 'to-be-ignored' (dual > small field) LV and HV stimuli, providing evidence that this area is not specific to 'to-be-ignored' peripheral negative emotions. The RH was dominant across all conditions in the fusiform gyrus, parahippocampus and insula. The left ACC saw greater activations than the right, whilst the amygdala was activated on both left and right hemispheres equally according to valence. Overall, RHD for 'to-be-ignored' (dual > small field) emotional stimuli was recorded.

Fig 5.5

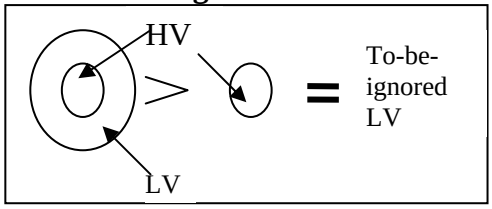
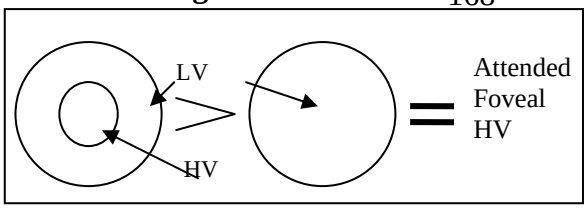


Fig 5.6



This first level analysis has shown that the quality of the data did yield interesting patterns of brain activation therefore justifying further investigation using second level analysis.

5:4:3 Second Level Analysis

For each pair of ROIs (left and right hemisphere), General Linear Model Repeated Measures ANOVA with four factors were entered (hemisphere: 2 levels, contrast condition: 2 levels, valence: 2 levels and categories: 4 levels). These data were entered into an SPSS spreadsheet (SPSS Inc, 2005-8) (https://www.spss.com). This analysis was conducted using a significance level for activations of p(crit) = 0.025. To establish the effect of emotional processing, *a priori* hypotheses maintained that there were significant main effects of valence and category. This was tested by partitioning of the ANOVA for dual > small field (Figure. 5.5) and dual > large field (Figure. 5.6) conditions with a p(crit) of $p<0.05$. Mauchly's test of sphericity was used and, where it was significant, degrees of freedom were adjusted according to Lower-Bound adjustment. Where required, further analysis was conducted by partitioning the ANOVAs.

It is clear from Table 5.3 that each ROI presents a distinctive pattern of responses across the nine ROIs and two hemispheric locations.

The nine bar charts that follow show the mean contrast values (effect sizes) of each ROI for all experimental conditions.

However, as the bar charts show, a negative contrast value means a greater response to the control stimuli than the target in the combined condition. A preference for 'attended', control small-field stimuli may account for this pattern.

Fig 5.5

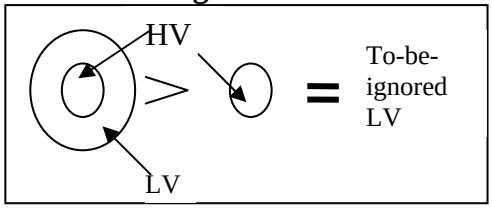
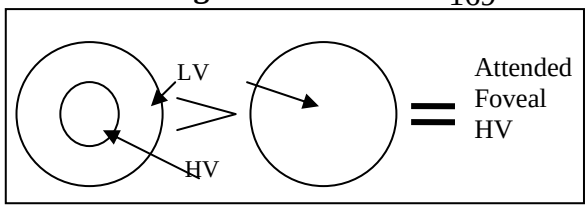


Fig 5.6



2nd Level Random Effects Group Analysis Mean Contrast Values

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
LVA Att	-0.09	-0.16	-0.30	-0.25	0.19	-0.11	-0.19	0.12	0.02	-0.17	-0.01	-0.41	0.20	0.16	-0.06	0.19	0.06	0.22
LVF Att	-0.02	-0.11	-0.12	-0.24	0.25	0.03	-0.01	-0.04	-0.03	0.03	0.00	-0.31	0.39	0.21	0.44	0.37	-0.05	0.04
LVS Att	-0.03	0.04	-0.07	-0.07	0.31	0.06	0.03	-0.38	-0.13	0.06	-0.02	-0.35	0.54	0.12	0.29	0.71	0.25	0.12
LVI Att	0.03	-0.08	-0.35	-0.09	0.27	-0.16	-0.02	-0.18	0.02	0.10	-0.03	-0.28	0.48	0.23	0.16	0.66	0.08	0.13
HVA Att	0.21	0.35	1.19	0.18	-0.47	0.31	0.99	0.71	0.20	0.48	-0.01	1.37	0.09	0.55	0.30	-0.54	0.60	0.30
HVF Att	-0.16	0.12	0.90	0.38	-0.25	0.15	1.26	0.55	0.19	0.03	-0.13	1.16	-0.12	0.20	-0.10	-0.34	0.79	0.64
HVS Att	-0.04	0.16	0.73	0.51	-0.63	0.04	0.90	0.48	-0.11	0.04	-0.01	0.98	-0.20	-0.18	-0.09	-0.58	0.42	0.11
HVI Att	0.01	0.06	0.78	0.58	-0.85	0.04	0.79	0.52	-0.01	0.04	-0.04	1.16	-0.22	-0.37	-0.35	-0.28	0.53	0.08
LVA TBI	-0.18	-0.27	-0.45	-0.49	0.55	-0.10	-0.10	-0.16	-0.04	-0.20	-0.19	-0.39	0.14	0.23	0.09	0.55	-0.39	-0.08
LVF TBI	-0.15	-0.19	-0.36	-0.31	0.40	-0.06	0.05	-0.04	0.03	-0.24	-0.18	-0.40	0.43	0.43	0.19	0.73	-0.15	0.00
LVS TBI	-0.21	-0.14	-0.48	-0.14	0.48	-0.09	0.08	-0.45	-0.17	-0.31	-0.34	-0.31	0.54	0.39	0.17	1.09	-0.12	0.03
LVI TBI	-0.15	-0.11	-0.46	-0.18	0.38	-0.25	-0.09	-0.27	-0.09	-0.12	-0.20	0.07	0.89	0.30	0.13	0.99	-0.11	-0.04
HVA TBI	-0.40	-0.38	0.67	0.19	-1.01	-0.20	0.84	0.20	-0.33	-0.33	-0.36	1.10	-0.85	-0.68	-0.66	-0.07	0.13	-0.15
HVF TBI	-0.17	-0.15	0.69	0.33	-1.00	-0.17	0.70	0.33	-0.22	-0.05	-0.07	0.96	-0.86	-0.76	-0.71	0.02	0.33	-0.06
HVS TBI	-0.15	-0.05	0.79	0.38	-1.21	-0.26	0.55	0.55	-0.10	0.00	-0.04	0.91	-0.59	-0.79	-0.69	-0.11	0.59	0.11
HVI TBI	-0.05	0.12	0.60	0.36	-0.92	-0.22	0.53	0.46	-0.04	0.14	0.18	0.43	-0.63	-0.77	-0.56	-0.38	0.57	0.11

Table 5.3 Mean contrast values for effect sizes in ROIs – dual image experiment

Key: Att = 'attended' (dual > large field). TBI = 'to-be-ignored' (dual > small field). ROIs 1 – Left Anterior Cingulate Cortex; 2 – Left medial Prefrontal Cortex; 3 – Left Parahippocampus; 4 – Left Amygdala; 5 – Left Superior Temporal Gyrus; 6 – Left Insula; 7 – Left Fusiform Gyrus; 8 – Left Dorsolateral Prefrontal Cortex; 9 – Left Orbitofrontal Cortex; 10 – Right Anterior Cingulate Cortex; 11 – Right medial Prefrontal Cortex; 12 Right Parahippocampus; 13 – Right Amygdala; 14 – Right Superior Temporal Gyrus;15 – Right Insula; 16 – Right Fusiform Gyrus; 17 – Right Dorsolateral Prefrontal Cortex; 18 – Right Orbitofrontal Cortex.

Nn = +ve means

a) Anterior Cingulate Cortex

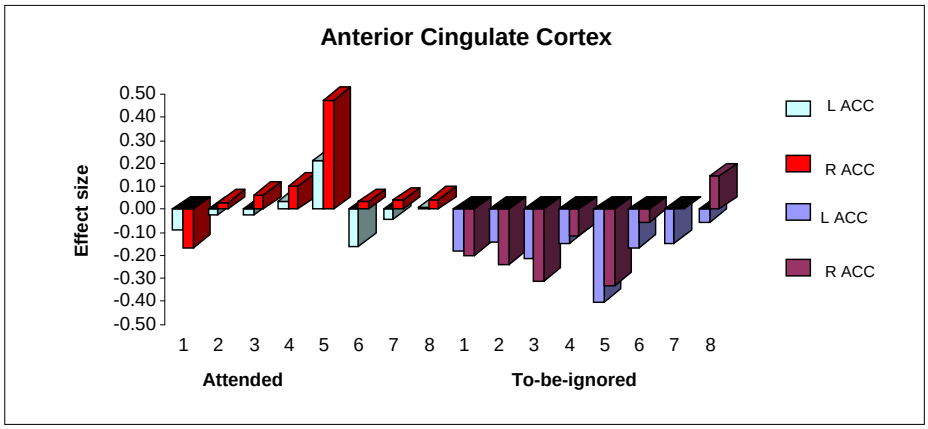


Figure 5.7 ACC effect sizes.
Key: 1 LV animals 2 LV faces 3 LV scenes 4 LV inanimate objects
5 HV animals 6 HV faces 7 HV scenes 8 HV inanimate objects

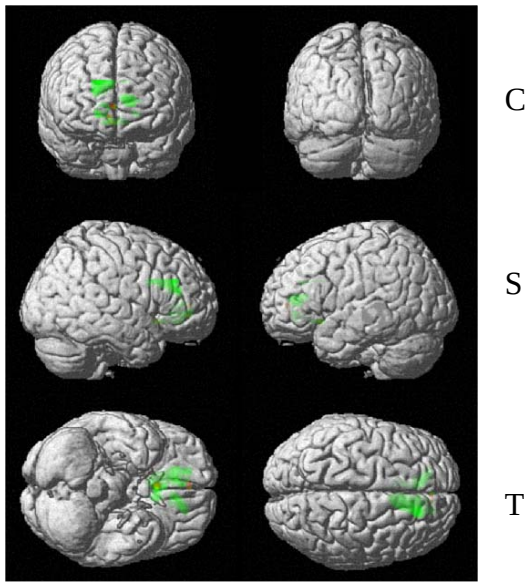


Figure 5.8 Images of the ACC displaying the significant effect of condition, contrasting 'attended' and 'to-be-ignored' .
Key: Green = 'Attended' images; Red = 'To-be-ignored' images; C = Coronal; S = Sagittal; T = Transverse.

Figure 5.7 shows that there is a difference in activations between 'attended' (dual > large field) (Figure 5.6) and 'to-be-ignored' (dual > small field) (Figure 5.5) stimuli in the ACC, with 'attended' (dual > large field) (Figure 5.6) HV animals having the greatest effect size in the RH. This is

Fig 5.5

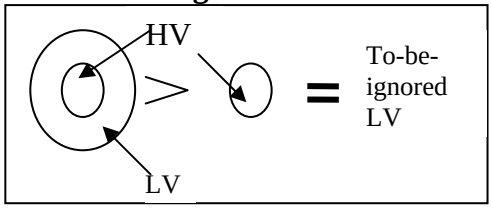
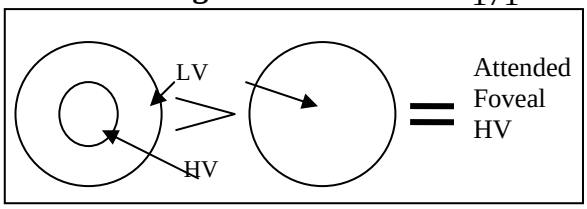


Fig 5.6



demonstrated in Figure 5.8 showing greater activation in the RH with very little activation for the 'to-be-ignored' (dual > small field) (Figure 5.5) condition.

ANOVAs confirmed a significant main effect of contrast condition ($F(1,15) = 12.7$; $p<0.005$), which suggests that the ACC responded differently to the stimulus conditions (Figures 5.5 and 5.6).

When partitioning the ANOVA matrix, a significant effect of category was found in the 'to-be-ignored' condition (dual > small field) ($F(3,45) = 6.4$; $p<0.005$) and a significant interaction between valence x category in the 'attended' condition (dual > large field) ($F(3,45) = 5.6$; $p<0.005$).

To conclude, these results support previous findings in the masked experiment (Chapter 4) in that the ACC is category specific across both conditions, but this specificity is dependent upon valence in the 'attended' condition (dual > large field). Valence modulation in the ACC has been highlighted in previous research (Berthoz et al., 2002, Cunningham et al., 2004) and visually it is evident that response is greatest for HV animals in the 'attended' condition (dual > large field).

b) Medial Prefrontal Cortex

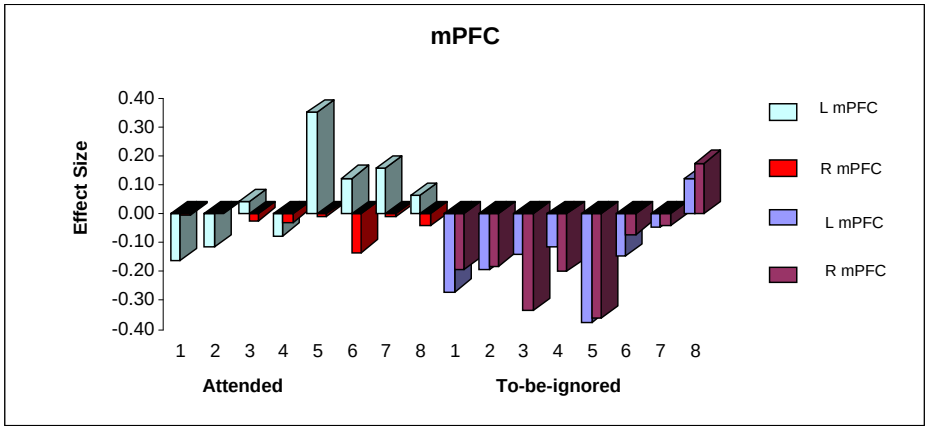


Figure 5.9 mPFC effect sizes.
Key: 1 LV animals 2 LV faces 3 LV scenes 4 LV inanimate objects
5 HV animals 6 HV faces 7 HV scenes 8 HV inanimate objects

Fig 5.5

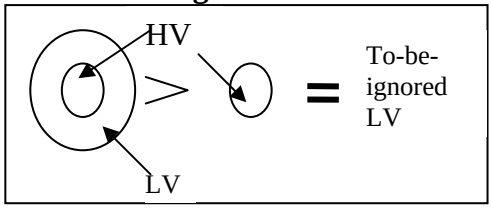
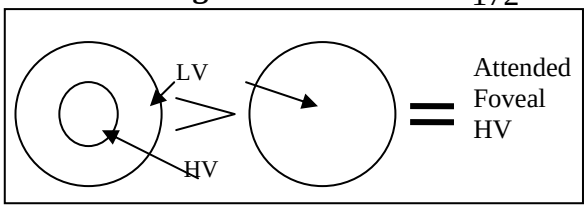


Fig 5.6



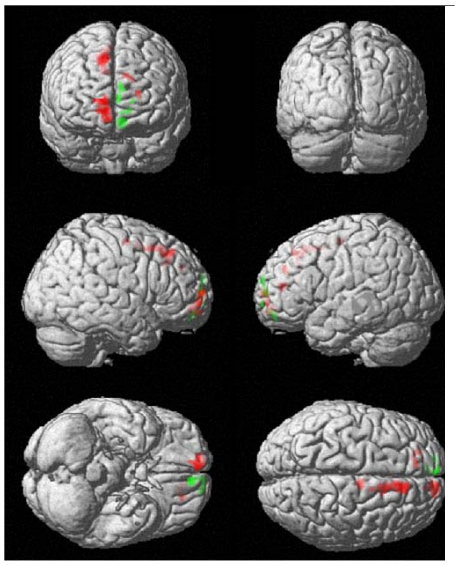


Figure 5.10 Images of the mPFC displaying the significant effect of valence (HVI>LVI) for 'to-be-ignored' condition.
Key: Red = HVI; Green = LVI; C = Coronal; S = Sagittal; T = Transverse.

In Figure 5.9 there is a distinction between 'attended' (dual > large field) (Figure 5.6) and 'to-be-ignored' (dual > small field) (Figure 5.5) stimuli with positive activations whilst processing HV stimuli in the LH in the 'attended' condition (dual > large field); with very little activation in the 'to-be-ignored' condition (dual > small field) with the exception of HV inanimate objects as evidenced in Figure 5.10.

A significant main effect of condition was found ($F(1,15) = 5.2$; $p<0.05$ and a significant interaction between condition x category ($F(3,45) = 7.0$; $p<0.001$. The trend seems similar to that found in ACC, with negative contrast values for the dual > small field contrast.

Partitioning showed a significant main effect of category in the 'to-be-ignored' condition (dual > small field) ($F(3,45) = 4.5$; $p<0.01$).

There was no evidence to suggest an effect of valence, thus supporting the supposition that valence modulation is not associated with the mPFC as evidenced in the masked experiment and relevant literature (Damasio, 1994, Lane et al., 1997c, Murphy et al., 2003, Phan et al., 2002).

Fig 5.5

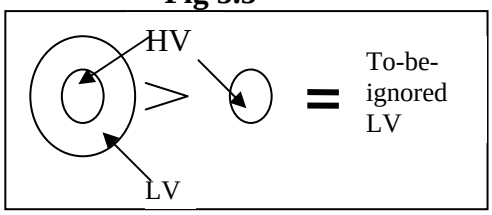
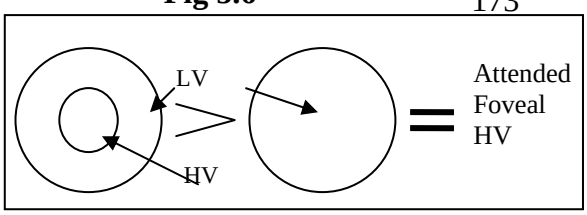


Fig 5.6



c) Parahippocampal Gyrus

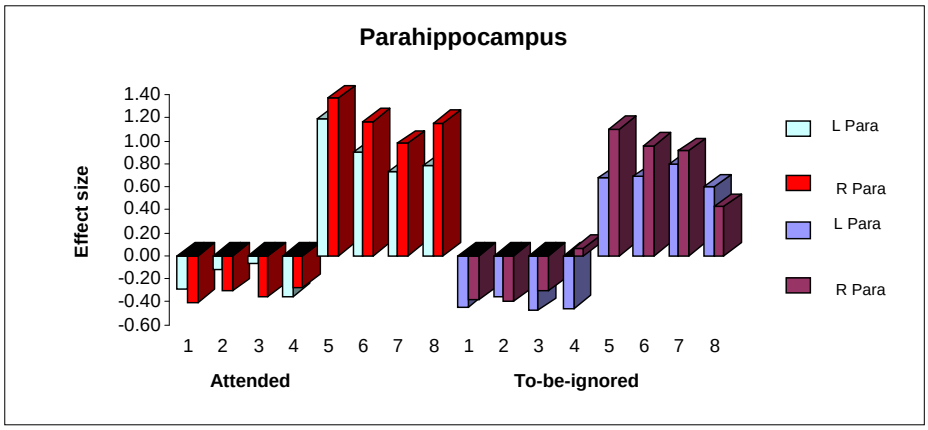


Figure 5.11 Parahippocampal gyrus effect sizes.
Key: 1 LV animals 2 LV faces 3 LV scenes 4 LV inanimate objects
5 HV animals 6 HV faces 7 HV scenes 8 HV inanimate objects

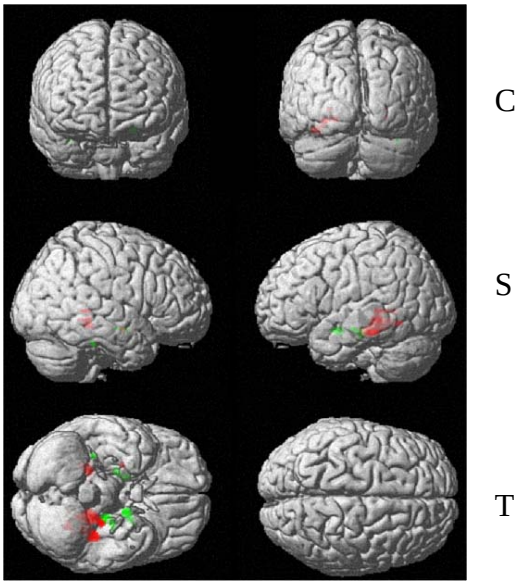


Figure 5.12 Images of the Parahippocampal gyrus displaying the significant effect of condition in the LH, contrasting 'attended' and 'to-be-ignored'.
Key: Red = Attended; Green = To-be-ignored; C = Coronal; S = Sagittal; T = Transverse.

Fig 5.5

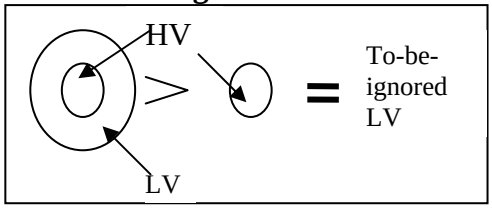
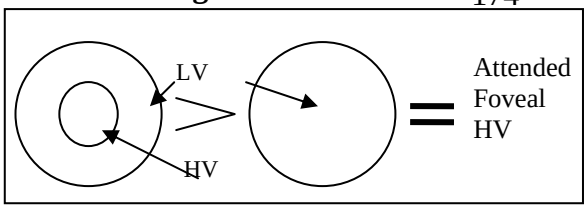


Fig 5.6



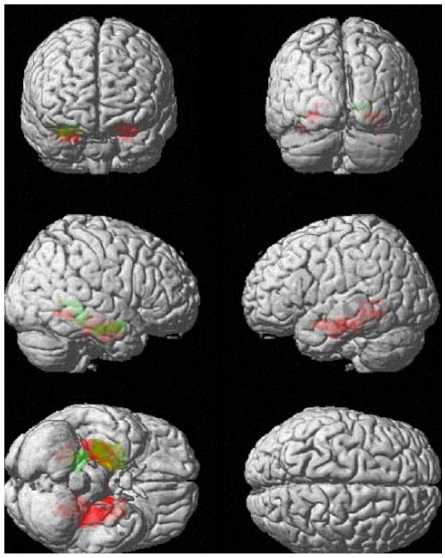


Figure 5.13 Images of the Parahippocampal gyrus displaying the significant effect of valence in the LH for 'attended' condition.
Key: Red = LVS; Green = HVS; C = Coronal; S = Sagittal; T = Transverse.

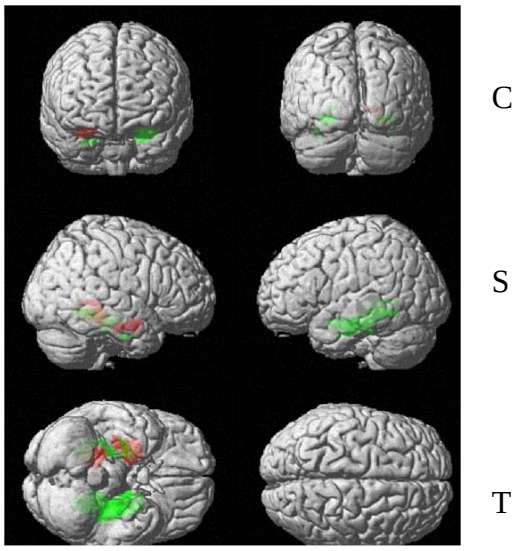


Figure 5.14 Images of the Parahippocampal gyrus displaying the signıtıcant effect of valence in the LH for 'to-be-ignored' condition .
Key: Red = LVS; Green = HVS; C = Coronal; S = Sagittal; T = Transverse.

In Figure 5.11 the obvious pattern in the parahippocampus is a clear indication of a valence effect which is the same in both conditions.

Again, a variation in response to the 'attended' (dual > large field) (Figure 5.6) and 'to-be-ignored' (dual > small field) (Figure 5.5) conditions was found as ANOVA revealed a main effect of condition (F(1,15) = 7.6;

Fig 5.5

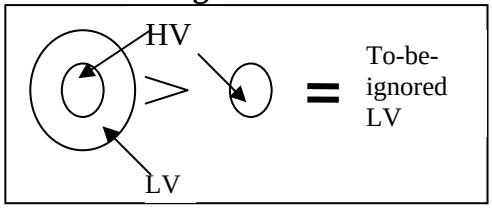
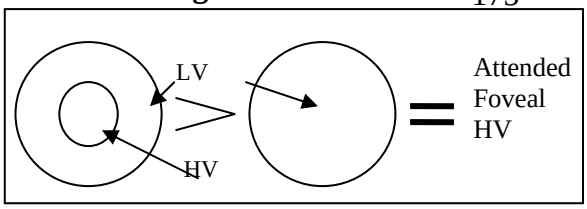


Fig 5.6



p<0.025) (e.g. Figure 5.12, sagittal view). A main effect of valence (F(1,15) = 9.4); p<0.01) and valence x category (F(3,45) = 2.9; p<0.05) was also evident.

Partitioning the ANOVAs showed that valence was significant across both conditions 'attended' (dual > large field) (F(1,15) = 10.1; p<0.01) (Figure 5.13), and 'to-be-ignored' (dual > small field) (F(1,15) = 8.2; p<0.05) (Figure 5.14). In the 'to-be-ignored' condition (dual > small field), there was a significant interaction between valence and category (Mauchly (W=.289; p<.01)), (F(1,15) = 4.8; p<0.05).

To summarise, when examining the statistics and graph it is evident that the parahippocampus responds to HV stimuli more than LV stimuli in both the 'attended' (dual > large field) and 'to-be-ignored' (dual > small field) conditions. There was some evidence of category specificity in the 'to-be-ignored' condition (dual > small field).

d) Amygdala

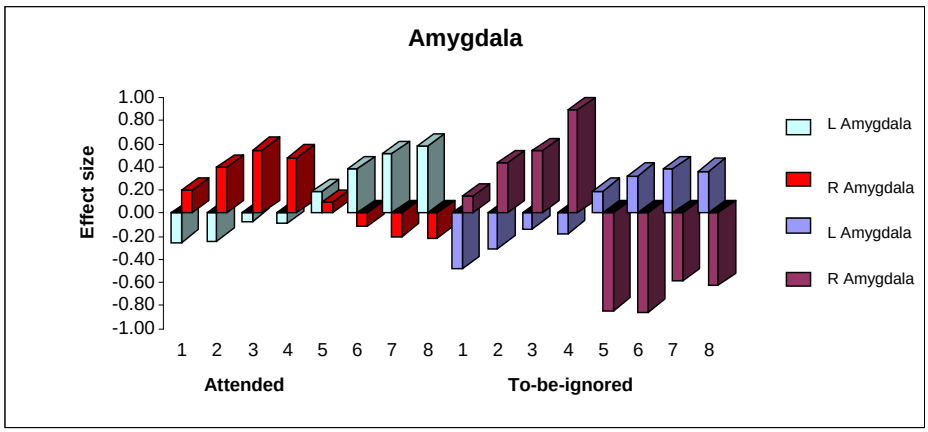


Figure 5.15 Amygdala effect sizes.
Key: 1 LV animals 2 LV faces 3 LV scenes 4 LV inanimate objects
5 HV animals 6 HV faces 7 HV scenes 8 HV inanimate objects

Fig 5.5

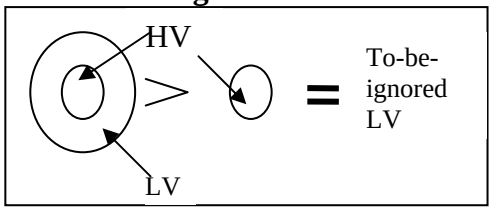
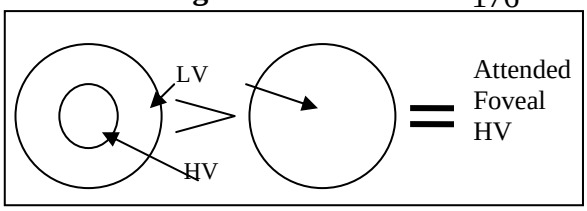


Fig 5.6



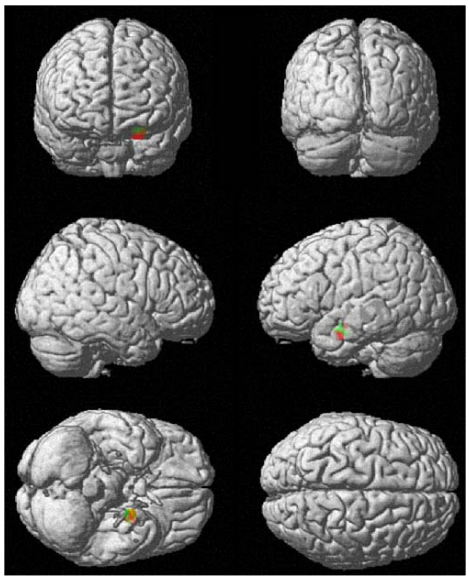


Figure 5.16 Images of the Amygdala displaying the significant effect of valence in the LH .
Key: Red = LVI; Green = HVI; C = Coronal; S = Sagittal; T = Transverse.

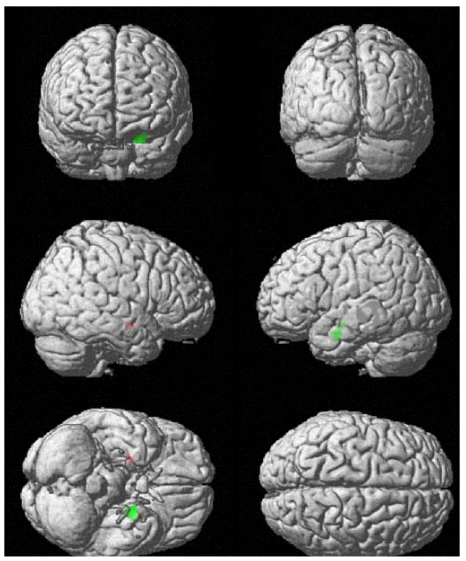


Figure 5.17 Images of the Amygdala displaying the significant effect of category in the LH for 'to-be-ignored' condition .
Key: Red = Inanimate; Green = Animals; C = Coronal; S = Sagittal; T = Transverse.

In the bar chart (Figure 5.15), there is a very distinctive pattern which indicates that the amygdala can apparently respond differentially to stimuli according to valence across both 'attended' (dual > large field) (Figure 5.6) and 'to-be-ignored' (dual > small field) (Figure 5.5) conditions. Greater effect sizes are found for LV stimuli in the RH and greater effect sizes for HV stimuli in the LH in both conditions. This pattern concurs with the valence

Fig 5.5

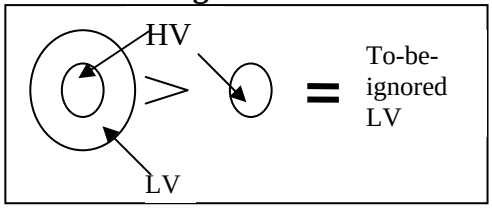
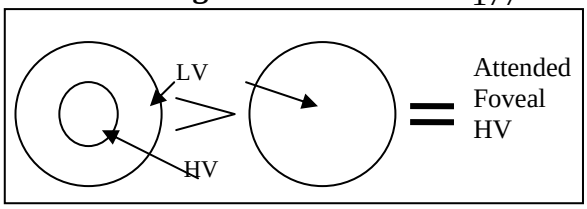


Fig 5.6



lateralisation hypothesis (Canli et al., 1998, Davidson and Irwin, 1999). It is necessary first to consider whether these differences are statistically significant.

In part, this observation was supported statistically as ANOVAs showed a significant interaction between hemisphere and valence ($F(1,15) = 6.9$; $p<0.025$) (Figure 5.16).

Partitioning the ANOVAs revealed a significant main effect of category in the 'to-be-ignored' condition (dual > small field) ($F(3,45) = 6.7$; $p<0.005$) (Figure 5.17) and a significant interaction between hemisphere x valence ($F(1,15) = 8.7$; $p<0.05$). There were no significant activations in the 'attended' condition (dual > large field).

The involvement of the amygdala in rapid processing (LeDoux, 2002, Whalen et al., 1998b) is supported with these findings as the only significant activations were found in the 'to-be-ignored' condition (dual > small field). However, there was no main effect of condition. This will be addressed in the general discussion.

To summarise, these results support the view that the left and right amygdala subserve different functions (Morris et al., 1998b): category effects and valence effects are dependent upon hemisphere. These results bear little resemblance to those of the masked experiment. The validity of comparing the two fMRI experimental designs will be discussed in Chapter 6.

Fig 5.5

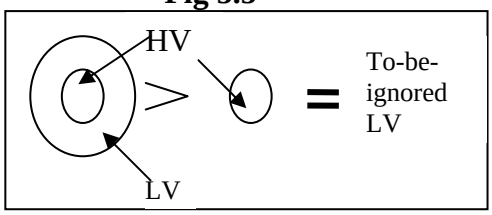
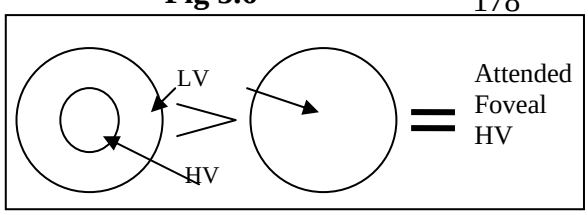


Fig 5.6



e) *Superior Temporal Gyrus*

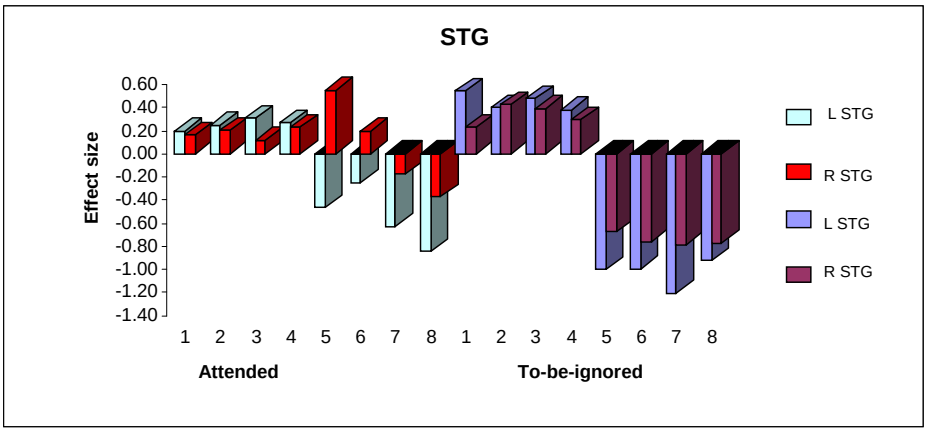


Figure 5.18 STG effect sizes.
Key: 1 LV animals 2 LV faces 3 LV scenes 4 LV inanimate objects
5 HV animals 6 HV faces 7 HV scenes 8 HV inanimate objects

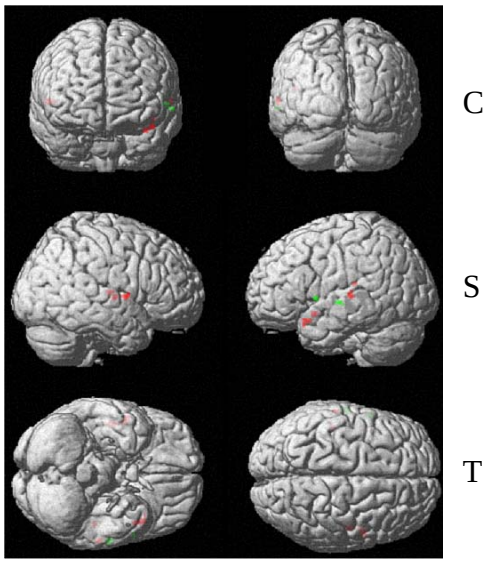


Figure 5.19 Images of the STG displaying the significant effect of condition in the LH .
Key: Red = To-be-ignored HV; Green = Attended HV; C = Coronal; S = Sagittal;
T = Transverse.

In the STG Figure 5.18 displays differences in 'attended' (dual > large field) (Figure 5.6) and 'to-be-ignored' (dual > small field) (Figure 5.5), with unilateral effect in HV faces and animals in the attended condition (dual > large field), and bilateral effect in all LV 'attended' (dual > large field) and 'to-be-ignored' (dual > small field).

Fig 5.5

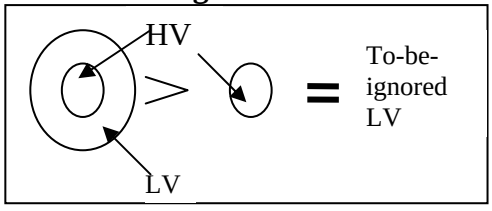
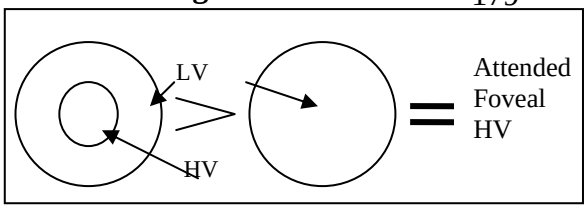


Fig 5.6



ANOVAs revealed a significant main effect of condition ($F(1,15) = 10.7$; $p<0.01$); a significant main effect of valence ($F(1,15) = 10.3$; $p<0.01$); plus a significant interaction between condition x valence ($F(1,15) = 33.6$; $p<0.001$) (Figure 5.19); and condition x category ($F(3,45) = 3.4$; $p<0.05$).

In the 'to-be-ignored' condition (dual > small field), partitioning showed a significant main effect of valence ($F(1,15) = 19.7$; $p<0.0000005$), and in the 'attended' condition (dual > large field) there was a significant main effect of category, (Mauchly ($W=.389$; $p<.05$)), ($F(1,15) = 4.6$; $p<0.05$). There was also a significant interaction between valence x category in the 'attended' condition (dual > large field) ($F(3,45) = 5.5$; $p<0.005$).

As the results indicated in the masked experiment, the role of the STG in processing emotional valence is again evident with greater emphasis in the 'to-be-ignored' condition (dual > small field), although the bar chart shows consistent positive activations when viewing LV stimuli as opposed to HV stimuli in both conditions. There was also a category effect in the 'attended' condition (dual > large field).

f) *Insula*

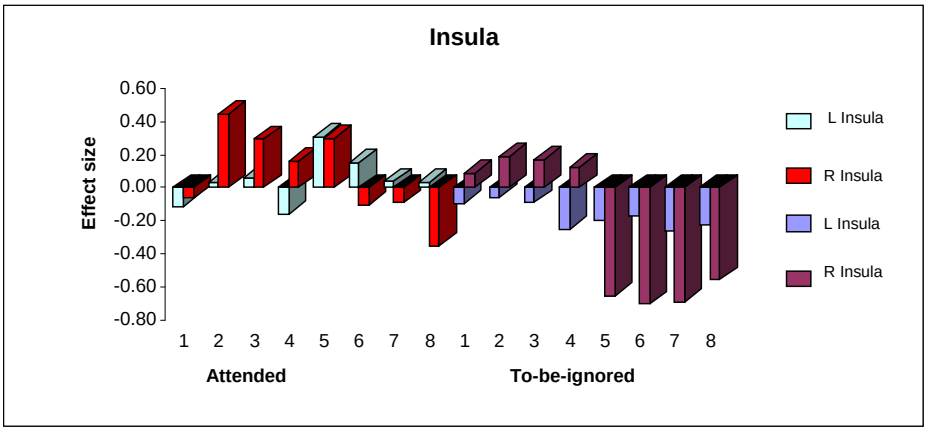


Figure 5.20 Insula effect sizes.
Key: 1 LV animals 2 LV faces 3 LV scenes 4 LV inanimate objects
5 HV animals 6 HV faces 7 HV scenes 8 HV inanimate objects

Fig 5.5

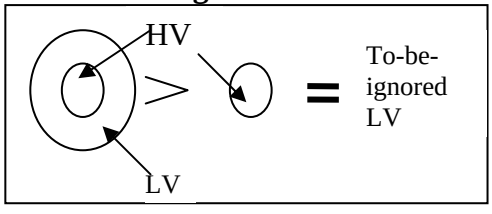
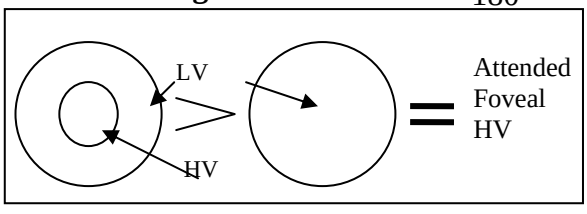


Fig 5.6



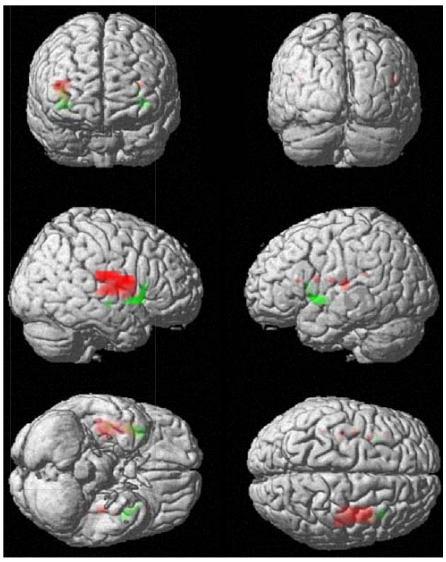


Figure 5.21 Images of the Insula displaying the significant effect of condition when viewing LV animals.
Key: Red = Attended; Green = To-be-ignored; C = Coronal; S = Sagittal; T = Transverse.

In Figure 5.20 the insula shows a valence effect when viewing to-be ignored (dual > small field) (Figure 5.5) stimuli, particularly for low valence in the RH. This is also evident in Figure 5.21. However, this was not supported statistically.

ANOVAs revealed a significant main effect of condition ($F(1,15) = 17.4$; $p<0.005$) and significant interactions between condition x valence ($F(1,15) = 7.3$; $p<0.05$) and valence x category ($F(3,45) = 2.9$; p<o.05.

Only an interaction between valence x category remained significant in the 'attended' condition (dual > large field) (Figure 5.6) after partitioning ($F(3,45) = 5.2$; $p<0.005$). ANOVA revealed no significant results in the 'to-be-ignored' condition.

The involvement of the insula in processing LV stimuli is well documented and these findings support this hypothesis, particularly in the RH in the 'attended' condition (dual > large field) for certain categories. These results are in accordance with the masked experiment and also confirm the lateralisation hypothesis in that the RH responds more to LV stimuli (Canli et al., 1998, Davidson and Irwin, 1999).

Fig 5.5

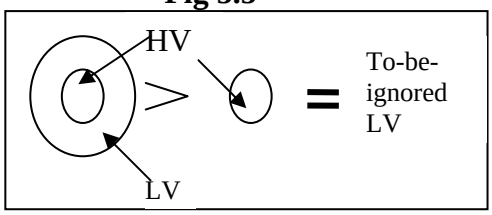
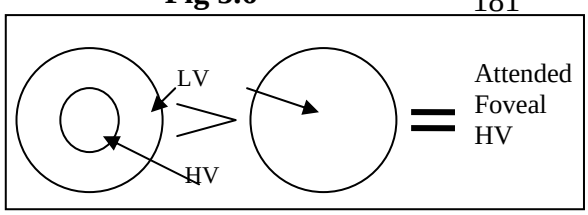


Fig 5.6



g) *Fusiform Gyrus*

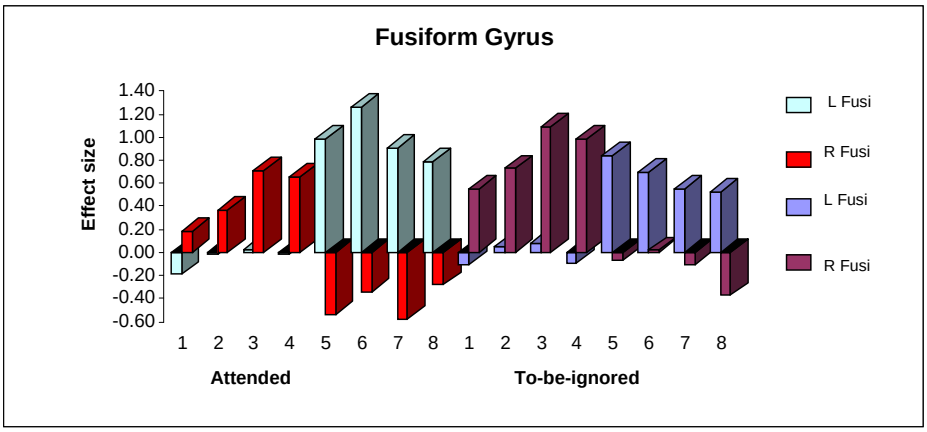


Figure 5.22 Fusiform gyrus effect sizes.
Key: 1 LV animals 2 LV faces 3 LV scenes 4 LV inanimate objects
5 HV animals 6 HV faces 7 HV scenes 8 HV inanimate objects

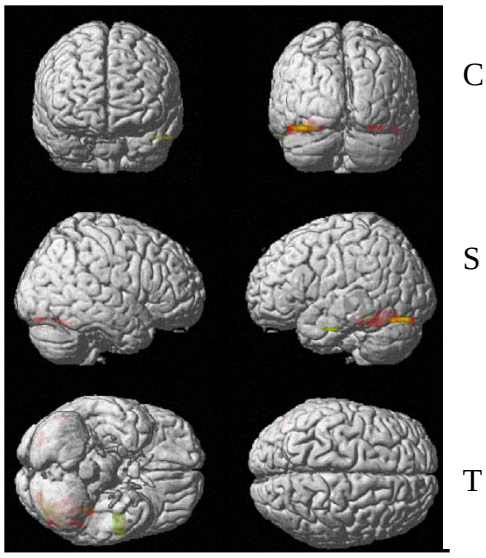


Figure 5.23 Images of the Fusiform gyrus displaying the significant effect of category for the 'attended' condition.
Key: Red = LVF; Green = LVI; C = Coronal; S = Sagittal; T = Transverse.

Fig 5.5

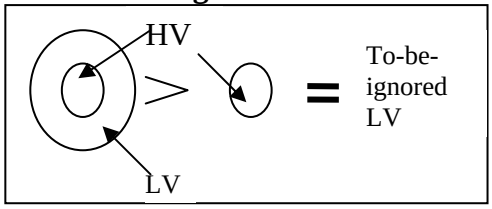
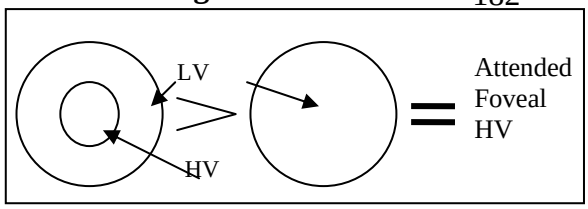


Fig 5.6



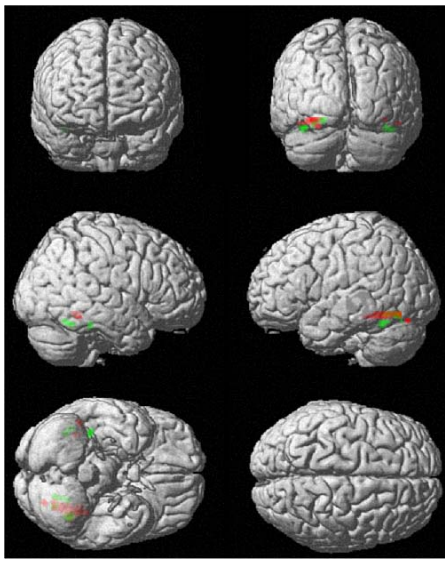


Figure 5.24 Images of the Fusiform gyrus displaying the significant effect of valence for 'to-be-ignored' condition.
Key: Red = HVF; Green = LVF; C = Coronal; S = Sagittal; T = Transverse.

Visually, in Figure 5.22, there is a valence and hemisphere interaction, with the RH processing LV and the LH processing HV in both experimental conditions, although this was not supported statistically. In Figures 5.23 and 5.24 differences can be seen in category and valence processing.

There were no main effects when examining the ANOVAs, but there were significant interactions between hemisphere x category ($F(3,45) = 3.4$; $p<0.05$) and valence x category ($F(3,45) = 3.3$; $p<0.05$).

After partitioning, a significant valence x category interaction was found in the 'to-be-ignored' condition ($F(3,45) = 4.0$; $p<0.05$).

In this instance, the valence effect was modulated by effect of category in the fusiform gyrus which has been previously documented associating fearful faces with the RH (Paradiso et al., 1999, Vuilleumier et al., 2001). These results also confirmed category modulation of fusiform gyrus activity, although processing faces specifically more than other stimuli was not evident in the present study. An effect of valence has also been found bilaterally in the fusiform gyrus when presented with LV stimuli (Paradiso et al., 1999).

Evidence presented in the bar chart supports the valence lateralisation hypothesis with an obvious valence x hemisphere interaction, but in the

Fig 5.5

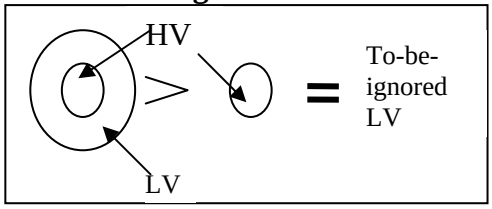
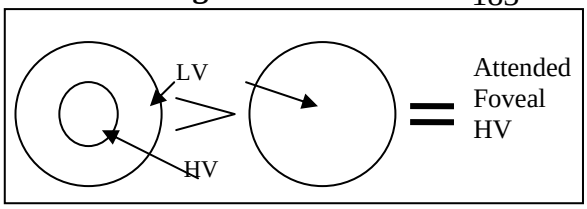


Fig 5.6



ANOVA only a category x hemisphere interaction was evident. While the ANOVA did not reveal a statistically significant valence x hemisphere interaction, the plots (Figures 5.25 and 5.26) thereof support the bar chart.

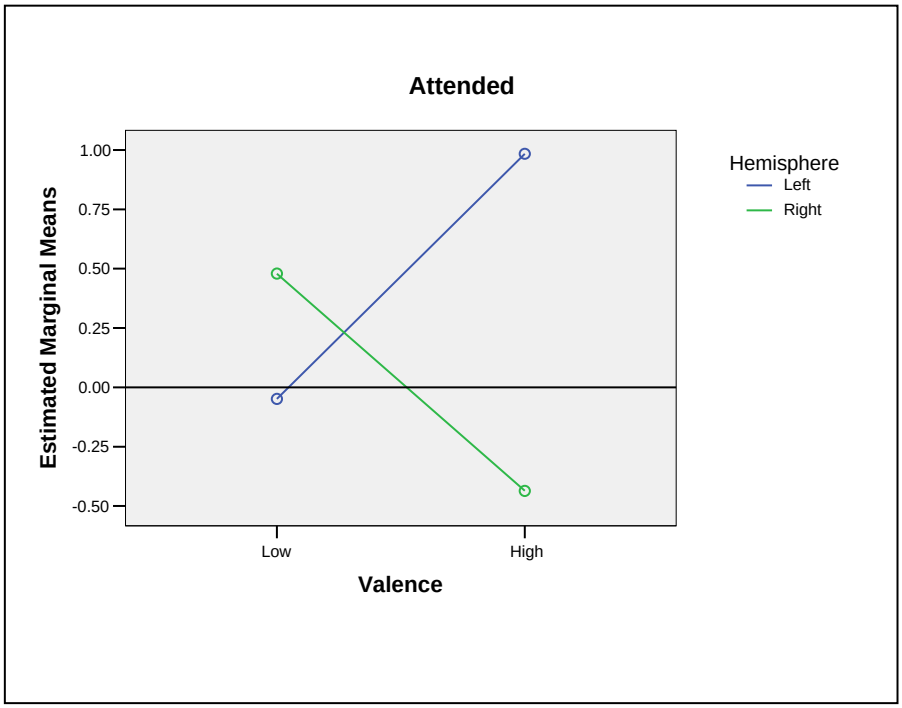


Figure 5.25 Fusiform gyrus estimated marginal means comparing valence x hemisphere for 'attended' condition.

Fig 5.5

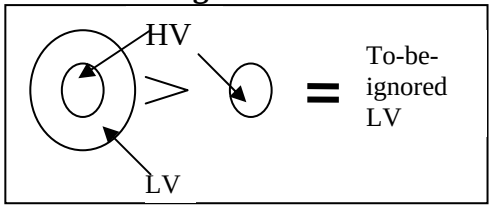
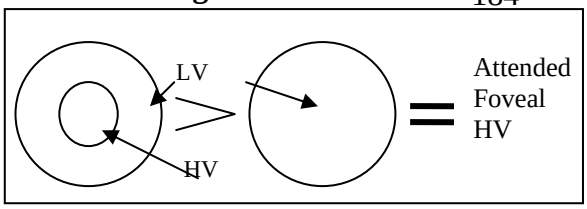


Fig 5.6



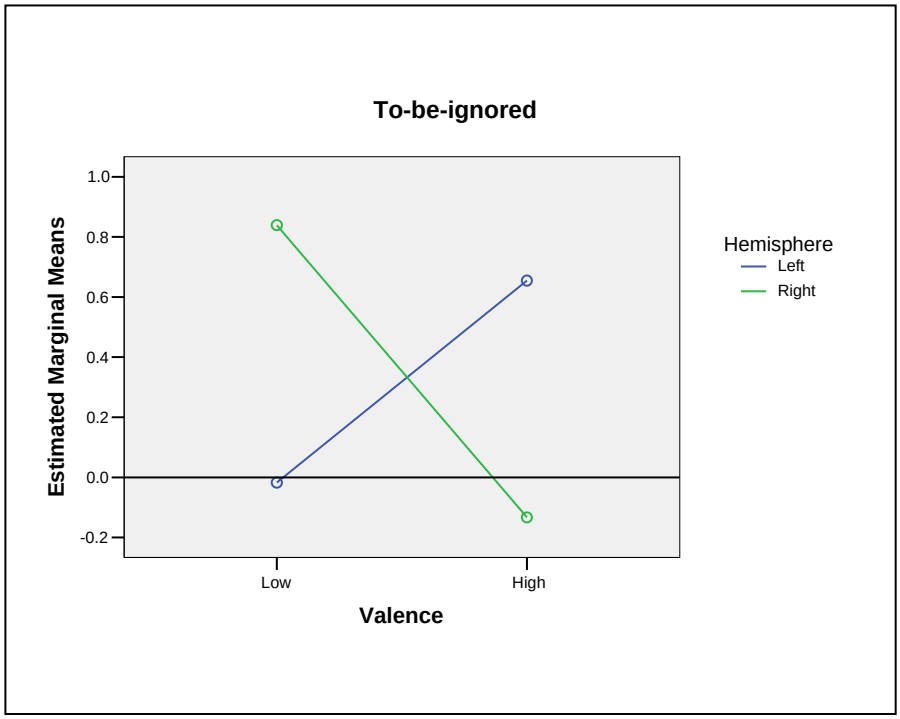


Figure 5.26 Fusiform gyrus estimated marginal means comparing valence x hemisphere for 'to-be-ignored' condition.

h) Dorsolateral Prefrontal Cortex

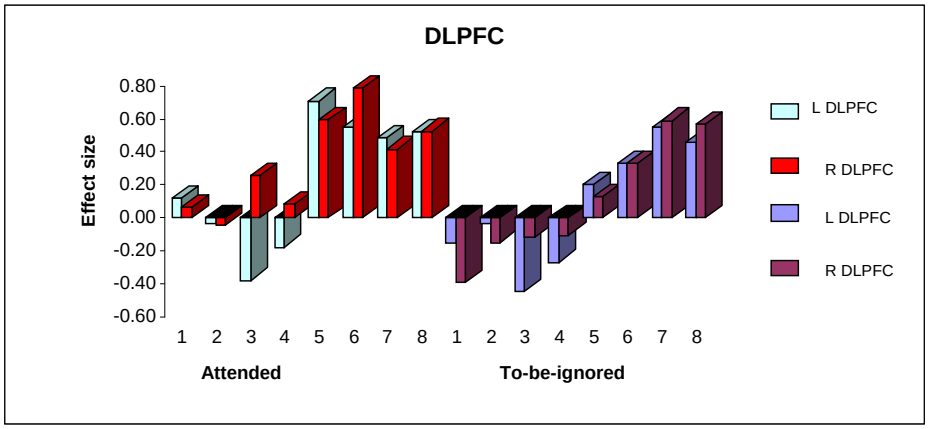


Figure 5.27 DLPFC effect sizes.
Key: 1 LV animals 2 LV faces 3 LV scenes 4 LV inanimate objects
5 HV animals 6 HV faces 7 HV scenes 8 HV inanimate objects

Fig 5.5

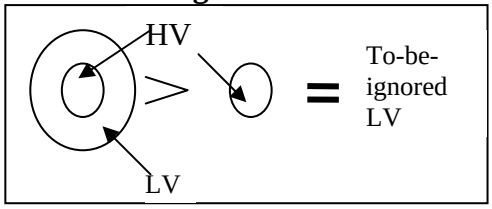
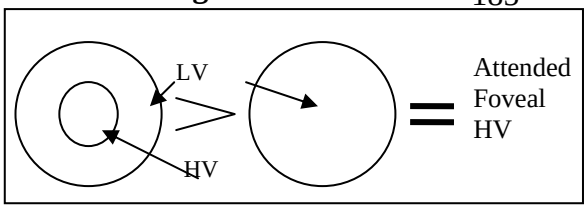


Fig 5.6



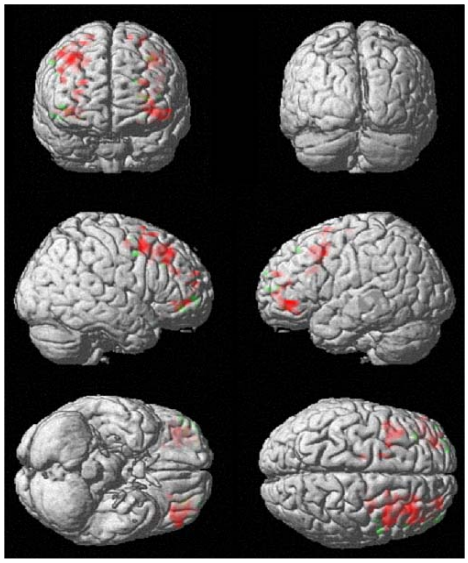


Figure 5.28 Images of the DLPFC displaying the significant bilateral effect of valence for 'to-be-ignored' condition .
Key: Red = HVS; Green = LVS; C = Coronal; S = Sagittal; T = Transverse.

In the DLPFC, Figure 5.27 shows a difference in valence effect for both 'attended' (dual > large field) (Figure 5.6) and 'to-be-ignored' (dual > small field) stimuli (Figure 5.5) with bilateral activations for HV stimuli (Figure 5.28).

A significant main effect of condition was found using ANOVA ($F(1,15) = 6.5$; $p<0.05$) and main effect of valence ($F(1,15) = 4.6$; $p<0.05$). Plus a significant interaction between condition x category, (Mauchly ($W=.338$; $p<.05$)), ($F(1,15) = 6.1$; $p<0.05$).

After partitioning, it was only in the 'to-be-ignored' condition (dual > small field) that significant effects of valence ($F(1,15) = 5.0$; $p<0.05$) and category ($F(3,45) = 3.0$; $p<0.05$) were found.

Statistically, valence effect and category effect were significant, as they were in the masked experiment, the difference being that in this experiment, significant effects were only found in the 'to-be-ignored' (dual > small field) condition. Previous research has argued that the DLPFC is modulated by valence (Grimm et al., 2006).

Fig 5.5

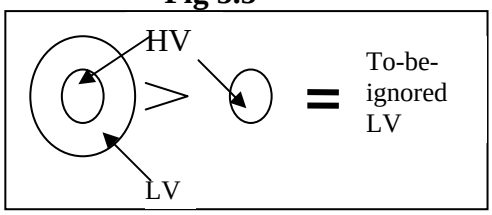
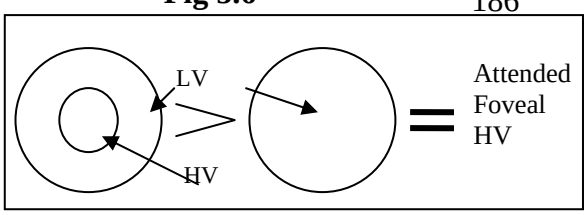


Fig 5.6



i) Orbitofrontal Cortex

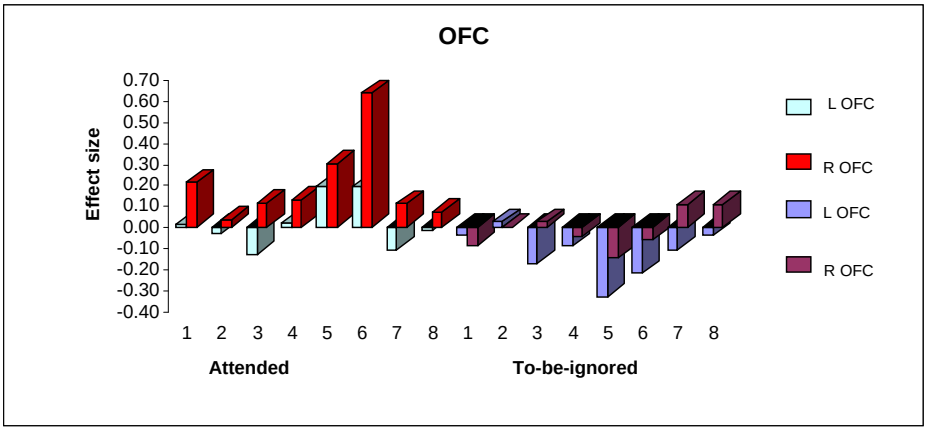


Figure 5.29 OFC effect sizes.
Key: 1 LV animals 2 LV faces 3 LV scenes 4 LV inanimate objects
5 HV animals 6 HV faces 7 HV scenes 8 HV inanimate objects

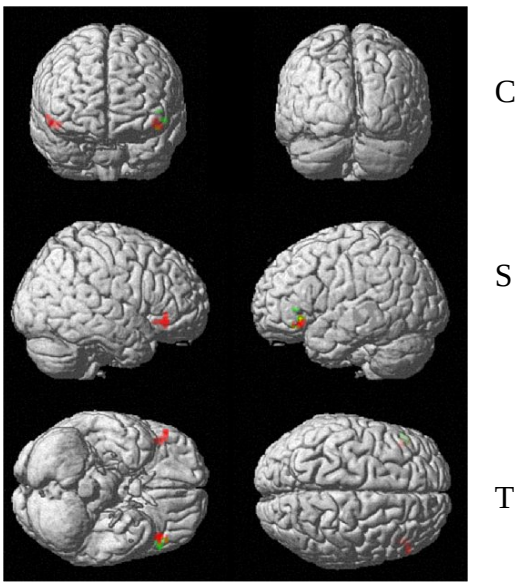
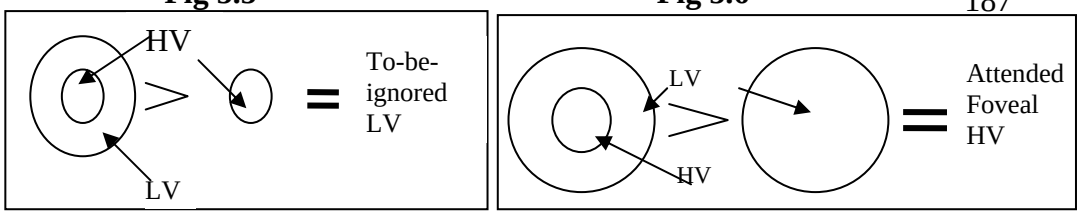


Figure 5.30 Images of the OFC displaying the significant effect of condition contrasting HV faces in the 'attended' and 'to-be-ignored' conditions.
Key: Red = HVF 'attended'; Green = HVF 'to-be-ignored'; C = Coronal; S = Sagittal; T = Transverse.

Figure 5.29 shows little disparity in activations for 'to-be-ignored' (dual > small field) (Figure 5.5) stimuli, but greater activations for the 'attended' condition (dual > large field) (Figure 5.6). Figure 5.30 compares 'attended' (dual > large field) HVF and 'to-be-ignored' (dual > small field) HVF. There appears to be an overall difference in valence and category.

Fig 5.5 **Fig 5.6**



A significant main effect of condition ($F(1,15) = 4.9$; $p<0.05$) and significant interaction between condition x category ($F(3,45) = 3.5$; $p<0.05$) were evident.

There were no significant effects or interactions when partitioning the ANOVA matrix.

Looking at the bar chart alone, it would appear that there is a distinction between categories, dependent on experimental conditions, with greater activity evident when processing HV animals and faces, whereas the emphasis in the masked experiment was on LV inanimate objects, but this was not supported statistically. There was no evidence, therefore, of valence modulation, thus supporting a more general role in emotional processing (Drevets and Raichle, 1998, Murphy et al., 2003), which was also found in the masked experiment.

Fig 5.5

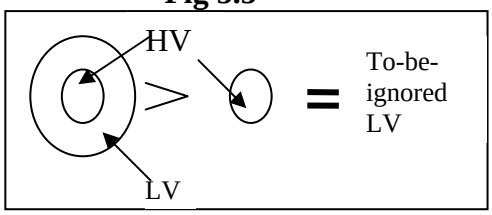
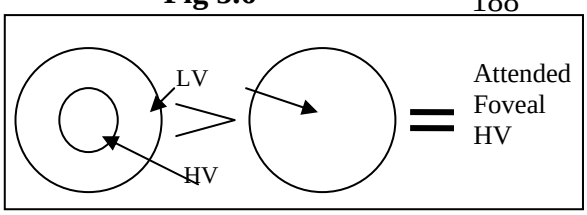


Fig 5.6



5:4:4 Summary

ROI	Significant effects of valence or category on response to to-be-ignored presentations	Significant differences between responses to to-be-ignored and attended presentations	Sig effects of valence or category on response to attended presentations	Other significant effects before partitioning
ACC	Cat**	Main eff con**	Att Val x cat**	n.s.
mPFC	Cat**	Main eff con* Con x cat***	n.s.	n.s.
Para	Val* Val x cat*	Main eff con*	Att val**	Main eff val** Val x cat*
Amy	Cat** Hem x val**	n.s.	n.s.	Hem x val*
STG	Val****	Main eff con** Con x val*** Con x cat*	Att cat* Att Val x Cat**	Main eff val**
Ins	n.s.	Main eff con** Con x val*	Att Val x cat**	Val x cat*
Fusi	Val x cat*	n.s.	n.s.	Hem x cat* Val x cat*
DLPFC	Val* Cat*	Main eff con* Con x cat*	n.s.	Main eff val*
OFC	n.s.	Main eff con* Con x cat*	n.s.	n.s.

Table 5.4 Summary of results for the dual image experiment
Key: * p<0.05; ** p<0.01; *** p<0.001; **** p<0.0001; n.s. = not significant; eff = effect; Val = Valence; Hem = Hemisphere; con = condition; Cat = Category; Att = 'Attended' (dual > large field); Para = Parahippocampal gyrus; Amy = Amygdala; Ins = Insula; Fusi = Fusiform gyrus.

Table 5.4 summarises the results for the dual-image experiment.

5:5 Discussion

The main focus of this experiment was to ascertain if there was a difference in activations when processing in the 'attended' (dual > large field) condition compared with the 'to-be-ignored' (dual > small field) condition. Indeed, a main effect of condition was found in the ACC, mPFC, parahippocampus, STG, insula, DLPFC and OFC. To further elucidate, effects will now be addressed in terms of valence, category effect and hemispheric asymmetry.

Fig 5.5

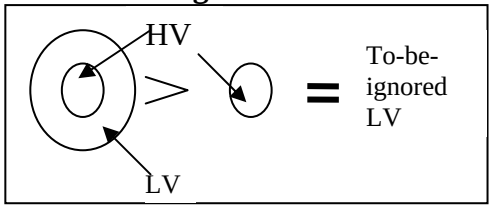
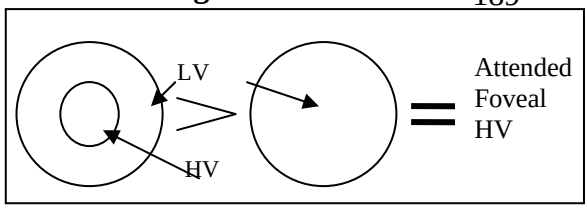


Fig 5.6



5:5:1 Valence and Category Effects

Valence and category effects in relation to each of the 9 ROIs have been discussed at length in chapter 4, and as such, will not be repeated in this section. There are interesting highlights to re-emphasise, however, and will now be addressed when summarising the present results in this discussion.

Significant effects involving valence for 'attended' conditions (H^1) were found for ACC, parahippocampus, STG and insula (Table 5.4, column 4). In the 'to-be-ignored' condition (H^2) significant effects for valence were found for parahippocampus, amygdala, STG, fusiform gyrus and DLPFC (Table 5.4, column 2). The valence effect was significantly different between 'attended' and 'to be ignored' conditions (H^3) for STG and insula (Table 5.4, column 3). This means that all areas except mPFC and OFC showed some differential response to valence. A point of interest is that it has been consistently shown that the mPFC is not modulated by valence in both the current fMRI experiments and previous research, commented upon in section 4:5:1 (b) (Damasio, 1994, Lane et al., 1997c, Murphy et al., 2003, Phan et al., 2002).

Significant effects involving category were found for the 'attended' condition (H^4) in ACC, STG and insula (Table 5.4, column 4). There were significant effects involving category for 'to-be-ignored' stimuli (H^5) in ACC, mPFC, parahippocampus, amygdala, fusiform gyrus and DLPFC (Table 5.4, column 2). Although there is little evidence that there is a category effect on the ACC, the results from both the fMRI experiments in this document do suggest that the ACC is modulated by category and is therefore a topic for further investigation.

The use of dual stimuli has revealed several distinctive qualitative differences in the responses of ROIs to differences in stimulus valence and category. The parahippocampal gyrus gave positive activations when the 'attended' part of the dual stimulus was high in valence (dual > large field) but also when the 'to-be-ignored' part of the dual stimulus was high in

Fig 5.5

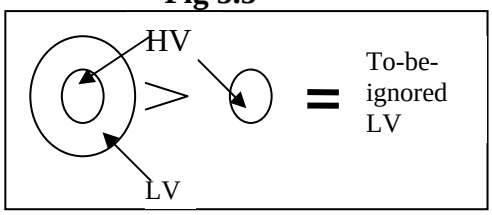
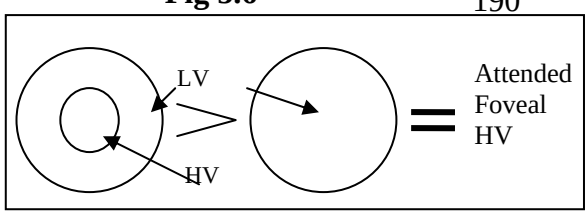


Fig 5.6



valence (dual > small field). Low valence produced negative activations in the two instances. Valence was also a main effect and significant in the 'to-be-ignored' (dual > small field) condition (Figure 5.5) in the STG (in particular for low valence) and DLPFC for high valence. Stronger activations in the STG were also found for low valence stimuli in the masked experiment in the present study and this finding is consistent with the work of Britton et al (2006) reported in chapter 4 (Britton et al., 2006b).

Equally, in the 'to-be-ignored' (dual > small field) condition (Figure 5.5) there was a valence and category interaction in the parahippocampus and fusiform gyrus. Both these ROIs are said to be category specific, but evidence here suggests that category activations are modulated by valence. One of the predictions for this chapter was that there was a difference in HV and LV for 'to-be-ignored' (dual > small field) stimuli (H^2). This was partly confirmed when valence effect was category dependent. In the 'attended' (dual > large field) condition (Figure 5.6), a valence and category interaction was also found in the fusiform gyrus, ACC, STG and insula. Again, although I found no evidence of category x valence interation in the STG when reviewing previous studies, the two current fMRI experiments in this study found significant evidence of this and is therefore worth revisiting in future work.

An interesting question arises when interpreting these results. Why should some ROIs show valence effects only in one condition whereas others show valence effects in both conditions? This will be addressed in the general discussion.

5:5:2 Hemisphere Specificity

Significant hemispheric differences were found only in fusiform gyrus and amygdala (H^6).

A significant interaction was found between hemisphere and category in the fusiform gyrus, indicating that the different hemispheres are modulated by category membership. Category specificity particularly in the RH has been

Fig 5.5

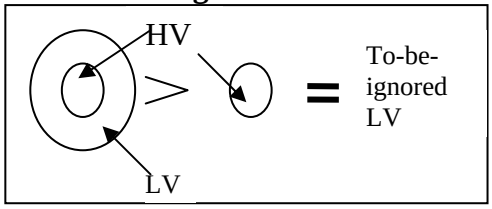
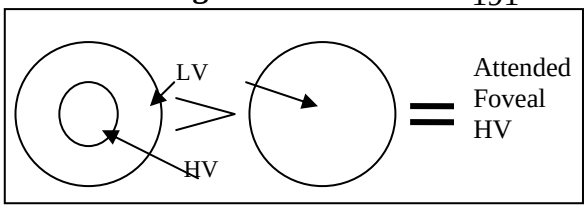


Fig 5.6



previously reported (Rees et al., 2000). Although the graphs indicated an interaction between hemisphere and valence, statistically this was not substantiated with ANOVAs.

In the 'to-be-ignored' (dual > small field) condition (Figure 5.5) an interaction between hemisphere and valence was found in the amygdala. Visual evidence in the graph indicated that the RH was dominant when processing LV stimuli and the LH dominant when processing HV stimuli, which means that in this instance hemispheric specialisation was modulated by valence in the amygdala. Several authors have discussed the asymmetry of amygdala functions. Some support the traditional model of lateralisation of emotion hypothesis (Adolphs et al., 2001, Canli et al., 1998), others have suggested that amygdala lateralisation involves the RH in memory modulation of emotion (Kilpatrick and Cahill, 2003) whilst others claim that the LH shows greater activations for conscious awareness of target and the RH greater for unconscious awareness of stimuli (Morris et al., 1998b). The present results are quite clear in their support of the valence lateralisation hypothesis in relation to the amygdala.

Statistical and visual evidence of effect sizes in the graphs indicate evidence of RHD in the fusiform gyrus and insula when processing negative emotional content. Previous research has indicated RHD in the fusiform gyrus when processing fearful facial expressions (Sprengelmeyer et al., 1998) along with other supporters of the preferential role of the RH (Adolphs et al., 1996, Adolphs et al., 2001, Kimura et al., 2004, Smith and Bulman-Fleming, 2004), however a meta-analysis by Murphy et al. (2003) found no evidence of RHD for emotional processing. Looking at 106 studies using PET and fMRI, Murphy and colleagues (2003) reported greater LH activations for appetitive stimuli, but symmetrical activations for withdrawal stimuli (Murphy et al., 2003). However, their research encompassed studies using a wide variety of stimuli in the five sensory modalities and, as such, it is difficult to assess the validity of the comparisons. For instance, RH dominance may be specific to certain stimuli and/or particular modality(ies) (Calvo and Nummenmaa,

Fig 5.5

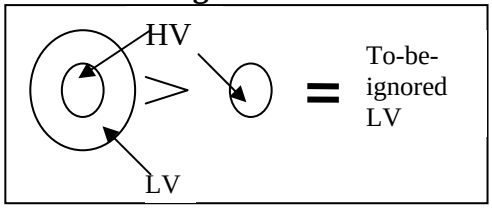
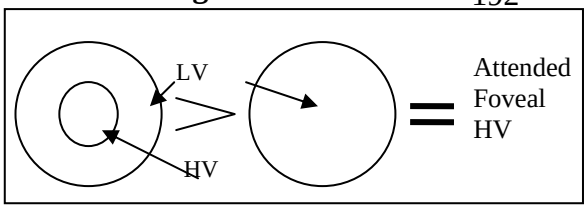


Fig 5.6



2007). The present results confirm H^3 for some of the ROIs with a clear indication of hemispheric specificity dependent upon valence.

5:5:3 General Discussion

A significant main effect of condition in seven out of nine ROIs demonstrates a difference in activations between the 'to-be-ignored' and 'attended' conditions. Equally, the valence effects (Section 5:5:1) and hemispheric differences (Section 5:5:2) are highly noteworthy, and of particular interest is why some ROIs reveal valence and hemispheric differences in both or one condition, whereas others do not. Why should the ROIs respond so differently in terms of valence to the presentation conditions?

An obvious answer is that these results do suggest that the foveal and peripheral images were processed differently by the majority of ROIs, but what does this actually mean?

The first point to make is that the large-field stimulus when presented on its own as a control condition, was just as 'attended' as the small-field stimulus. Therefore, when subtracting a control condition from the combined condition, the 'attended' contrast is actually measuring the difference between the large-field homogeneous 'attended' stimuli with the combined, centrally 'attended' small-field stimuli i.e. the difference between homogenous and combined stimuli, irrespective of attention. After subtraction two types of 'residue' remained. One was labelled 'to-be-ignored' and the other 'attended'.

Regardless of the chosen label, highly distinct patterns were evident in some of the ROIs when looking at bar charts in the results section. The most interesting to note are those where, regardless of orientation of target valence (e.g. HV 'attended' or LV 'attended'), the same valence still modulates certain ROIs. In both the 'attended' and 'to-be-ignored' conditions, valence modulation was found in the amygdala (Figure 5.15) and fusiform gyrus (Figure 5.22) – the RH was activated for LV and the LH activated for HV;

Fig 5.5

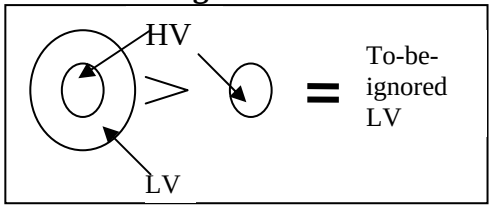
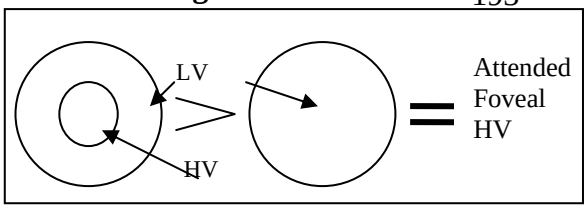


Fig 5.6



parahippocampus (Figure 5.11) – bilateral activations were evident for HV but no significant activation for LV; STG (Figure 5.18) – bilateral activations for LV; and DLPFC (Figure 5.27) – bilateral activations for HV. Therefore, the effect of valence was strongly evident after taking into account the difference between the homogeneous and combined stimuli, regardless of which condition was subtracted.

To discuss this further, attentional modulation will now be addressed. It is hypothesised that 'to-be-ignored' images (dual > small field), may be actively inhibited. However, the 1s stimulus duration period meant that the participants had time to fixate on both the 'attended' (dual > large field) (Figure 5.6) and 'to-be-ignored' (dual > small field) (Figure 5.5) stimuli. After all, a normal fixation pause is 250ms (Liversedge and Findlay, 2000, Reddy et al., 2004), a saccadic eye movement 30-70ms (Koch, 2004) and spatial cuing studies have shown that spatial attentional shifts can happen even without saccades (Posner, 1980). By the same token, automatic saccades can happen regardless of the efforts of the participants to focus solely on the 'attended' (dual > large field) (Figure 5.6) presentations. This was demonstrated in a study by Calvo and Lange (2004), presenting one emotional stimulus and one neutral stimulus at the same time in the periphery. Part of Calvo and Lange's experiment was to instruct the participants to look only at the neutral stimulus. As processing is biased towards emotional stimuli (Calvo and Lang, 2004), not only was the emotional stimulus fixated upon first, but it has been found that it takes participants 460 - 490ms to comply with instructions and take control over fixation (Nummenmaa et al., 2006). Of course, the current study presented two emotional stimuli at the same time, so emotional versus neutral competition was not an issue, however it follows that late selective orienting would have at least ensured fixation foveally as instructed.

One of the goals of this experimental design was to tax attentional load with a categorisation task in order to suppress the processing of 'to-be-ignored' peripheral stimuli. Requesting specific semantic information (i.e.

Fig 5.5

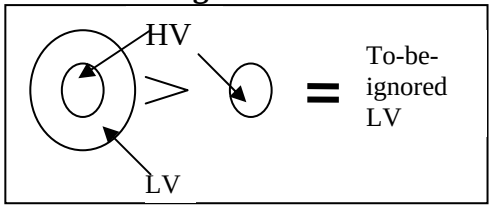
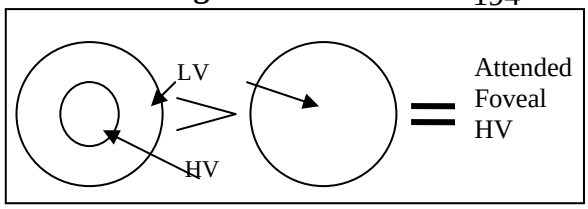


Fig 5.6



pleasant or unpleasant) would have required overt attention to the foveal component of the dual image. It is probable, therefore, that 1s presentation time may have still led to degraded processing in the periphery, that was limited to coarse or gist information. It is argued that the amygdala processes gist information fast and globally (LeDoux, 1998, Zald, 2003). In the present study, the only significant activations in the amygdala were found for the 'to-be-ignored' (dual > small field) (Figure 5.5) condition, suggesting that coarse processing did occur in the periphery, although as already highlighted, the effect sizes showed strong patterns of activation for both conditions.

Supporting evidence comes from studies of change blindness and inattentional blindness which have highlighted gist perception or processing global information of an image without being aware of the detail. It is concluded that focal attention is not a requirement for gist perception and coarse information, such as category or spatial structure, can be processed without awareness (Mack and Rock, 1998, Rousselet et al., 2005). As emotion-laden stimuli are also said to be processed automatically (Vuilleumier et al., 2001), it is quite probable that the recovery of the gist of the peripheral part of the dual image is sufficient to allow the affective content to have been processed.

There is a large body of evidence that demonstrates our ability to be aware of visual stimuli outside focal attention. For instance, Braun has conducted many dual-task experiments demonstrating the effectiveness of salient distractors in the periphery, even when performing demanding tasks at fixation (Braun, 1994, Braun and Sagi, 1990). According to Braun, if a stimuli is salient enough and attention is focussed on fixation, some attention may still be involuntarily allocated by the simple act of presenting a stimulus in the peripheral visual field, thus 'capturing' attention (Braun, 2003). Traditionally, this research is based on artificial stimuli such as the letters T and L. However, more recent experiments using natural images have demonstrated that focal attention is needed even less than previously thought (Li et al., 2002, Li et al., 2005, Rousselet et al., 2002). The possibilities of

Fig 5.5

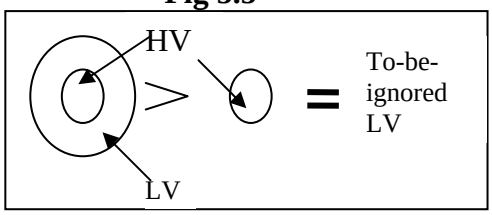
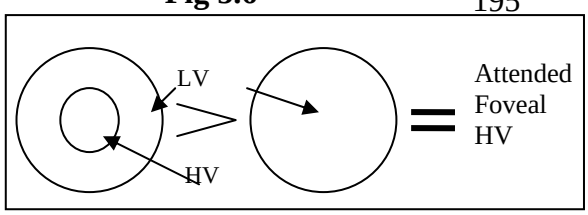


Fig 5.6



peripheral processing have been discussed, but it is not possible to accurately assess by what degree the peripheral information modulated the ROIs. That said, there are, three relevant outcomes from these results:

a) There was strong evidence of significant activations that differed in response to 'attended' (dual > large field) (Figure 5.6) and 'to-be-ignored' (dual > small field) (Figure 5.5) contrasts. These differences were supported statistically in the ACC, mPFC, parahippocampus, STG, insula, DLPFC and OFC (main effect of condition Table 5.4, column 3).
b) The bar charts of effect sizes demonstrate strong patterns of valence modulation regardless of experimental condition, which supports the premise that the processing of affect is extremely robust, the most obvious being the parahippocampus, amygdala, STG, fusiform gyrus and DLPFC.
c) ANOVAs showed significant differences in experimental conditions for valence in the STG and insula.

5:6 Conclusion

In order to modulate conscious registration of the target stimuli presented in the fovea and periphery, a selective attention paradigm was employed (Mack and Rock, 1998). Significant results were obtained supporting the efficacy of the 'attended' (dual > large field) and 'to-be-ignored' (dual > small field) contrasts in isolating differential effects of conscious registration of emotional stimuli as well as patterns of effect sizes reflecting the automatic nature of affective processing.

To attempt a coherent overall perspective of these findings, Chapter 6 will draw together the results of all three experiments in context of the rewards and challenges of employing complex everyday visual stimuli.

Fig 5.5

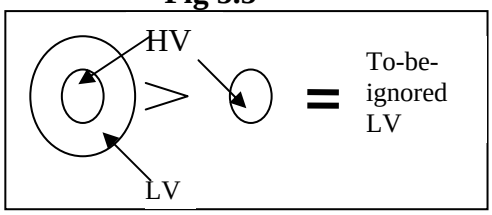
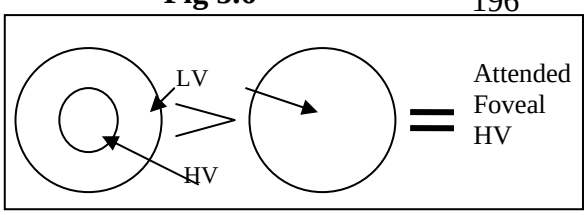


Fig 5.6



Chapter 6 General Discussion

6:1 Overview and Summary

The behavioural experiment in Chapter 3 determined that the valence of certain natural images can be perceived below the level of conscious awareness, concordantly with valence ratings. Using forced-choice discrimination tasks for detection of the target and discrimination of its valence, together with ratings of the confidence in detection and confidence in valence impression, levels of consciously perceived valence response were indexed. Valence discrimination frequencies were compensated for response bias, which was assessed by the valence response to control stimuli (neutral masks only, target absent). It was demonstrated that a large proportion of IAPS stimuli can be successfully discriminated for affect even whilst the presence of those images is undetected. However, six anomalous stimuli (giving significant discrimination in the opposite direction to that predicted by the IAPS valence rating) were identified and possible explanations were offered for these exceptions.

The stimuli were then grouped by category membership to investigate the neural correlates of affect in natural images presented below or close to the threshold of conscious awareness. It was clear that valence discrimination in brief, masked stimuli was not limited to stimuli of a certain category (i.e. faces) but could occur with animals, scenes and inanimate objects as well. An fMRI experiment was conducted in order to identify differential responses to stimulus valence in brief exposures and natural images. To increase the reliability of the stimulus set as a measure of key variables (valence and category), a second set of images was chosen to present under normal viewing conditions in addition to the original stimulus set. The second set of images was matched with the first set in valence and category, providing a basis for replication of fMRI results. Both the normally-viewed sets of stimuli revealed very similar activations. This therefore provided a standard for the assessment of valence and category effects.

The critical finding in this experiment was that if a given experimental factor (such as valence, category or cerebral hemisphere) yielded significant differences in activations of a ROI in the brief, masked condition, they were also significant in the normal viewing conditions. In the normal viewing condition only, different categories produced significantly different activations in the parahippocampus and fusiform gyrus, which supports the importance of these two regions for previously reported category specificity (Epstein and Kanwisher, 1998, Epstein et al., 1999, O'Craven and Kanwisher, 2000, Schultz et al., 2003). High and low valence produced significantly different activations in the STG (Ochsner et al., 2004a, Ochsner et al., 2004b).

On the basis that processing of brief, masked stimuli only took place when the same stimuli were processed under normal viewing, it was argued that there was no qualitative difference in conscious and unconscious processing. This is validation of a threshold-based account of unconscious processing and signifies a one-way dissociation between conscious and unconscious processing. This tenet is derived from the assumption that if unconscious processing is sensitive to the same information as that which is consciously processed, perception without awareness is indicated. By the same token, if unconscious processing takes place without conscious processing of the same stimuli, this would imply insensitivity to the stimuli at above the level of conscious awareness (Reingold, 1992, Reingold and Merikle, 1990), but this was not the case.

In order to distinguish between neural responses to conscious events under instruction to-be-ignored the dual image experiment was carried out. Using the same stimuli, the difference in activations in ROIs comparing affective 'attended' (dual > large field) processing and 'to-be-ignored' stimuli (dual > small field) were examined. Even though there were differences in attentional demands between the masked experiment and the dual image experiment, some of the key results were the same and are supported by previous research. These were the significant main effects of valence and categories in the STG , ACC (Berthoz et al., 2002, Killgore and Yurgelun-Todd, 2004) and DLPFC (Grimm et al., 2006).

One possible unifying proposal that would tie together the findings of the three experimental chapters of this thesis is the concept of a tripartite taxonomy. Dehaene and colleagues (2006) argue a distinction between subliminal, preconscious and conscious processing. They hypothesise that early, bottom-up activation is necessary, but not adequate enough for conscious processing. Top-down amplification is also required (e.g. prefrontal, parietal cortices), to achieve conscious access. However, these joint processes may still not be sufficient for conscious processing, as highlighted in studies investigating inattentional blindness. Subliminal processing is defined as weak activation that dies out before achieving activation in a global neuronal network (bottom-up), whilst preconscious processing is described as activation being accessible, but not accessed (i.e. not consciously reported as stimuli are not seen due to inattention) due to insufficient or interrupted top-down attentional amplification (Dehaene et al., 2006). Therefore, the differences in the (dual > large field) and (dual > small field) conditions in the dual-image experiment could possibly be explained in terms of preconscious (having the potential to be consciously reported, but not consciously accessed due to top-down attention being temporarily diverted) and conscious processing, whereas the differences in the behavioural study and the masked fMRI study could be explained in terms of a continuum (not a single, abrupt discontinuity) between subliminal and conscious processing. Thus, visual processing becomes more conscious with increasing viewing time, because a stronger feedback signal propagates through more synapses. Also, persisting neural activity at all stages of the visual pathway signals continuity (and therefore importance, compared to fleeting impressions and background noise) of the new stimulus. For the eye-movement control system, early fixations of a novel stimulus are necessarily driven by bottom up salience: the second and subsequent fixations can be influenced by information gathered and analysed from the first fixation, thus feedback and top-down influences strengthen the conscious percept.

The tripartite model concurs with the view that conscious perception cannot materialise without attention. Others also argue that some attention resources are needed for processing natural images and are, therefore, not

processed as automatically as recently reported. For instance, the ultra-rapid categorisation (URC) experiments previously referred to in this thesis (e.g. Li et al., 2002, Thorpe et al., 2001b, VanRullen and Thorpe, 2001a) have been criticised by Walker et al. (2008) as not taxing enough, in terms of simplicity of task and simple saliency of stimuli, to truly test for attention dependency. Even though a URC experiment simultaneously presented four scenes, and demonstrated capacity limitations for multiple categorisation (Rousselet et al., 2004c), criticism for lack of clarity regarding the results strengthened the resolve of Walker and colleagues (2008) to challenge the claims of ultra-rapid processing of complex images. Using a categorisation task of four objects within a scene in a dual-task paradigm, it was found that even at presentations of 500ms, only relatively primary visual properties can be processed under such conditions. These findings support conventional visual studies in that some attentional resources are needed for the processing of both traditional and natural images and as such Walker et al's criticisms can be applied to all claims for non-attentive processing (Walker et al., 2008).

It has been discussed that even in the amygdala, attention resources are still needed to process affective faces compared to nonfaces, although Pessoa et al. (2002b) did acknowledge that humans can respond to aversive stimuli outside focal attention (Pessoa et al., 2002b). Others, on the other hand, have demonstrated automatic processing of emotion both involuntarily and without attention, where activity in the amygdala depended upon valence rather than selective attention (Öhman, 2002, Vuilleumier et al., 2001).

In order to reconcile these opposing views, we can argue that voluntary attention is not necessary for a stimulus to have an effect on the brain, through feedforward mechanisms. It could be argued that there is never a complete absence of attention in masking experiments; the observer must be looking in the general direction of the stimulus in order to get a retinal image. A conscious impression seems to require both a certain stimulus strength (so that the stimulus can be distinguished from noise) and a certain amount or resource level of attention.

The issue of stimulus strength is thus important to the discussion. Detectability of a visual stimulus is one measure of strength, and presumably depends on low level visual properties (spatial and temporal luminance contrast, etc.). However, there is another measure of stimulus strength that was used in the present study, and that is IAPS arousal rating, which in this instance estimates the strength of an emotional stimulus as defined in the circumplex model. Arousal can indicate importance and, as such, guide attention in addition to the influence of valence (Barrett et al., 2005). It is hypothesised that in the real world, unpleasant influences prompt relevant motor responses for protection and survival. If an aversive event is not arousing enough, the effect is minimised. Correspondingly, low arousal appetitive stimuli can induce pleasure, such as a meadow (Bradley and Lang, 1999). Thus the effect of arousal may not be equivalent for high and low valence stimuli. To equate valence ratings with aversive pictures of both low and high arousal is unrealistic in the natural world (Bradley and Lang, 1999). In the present study, this problem (which may indicate a failing of the circumplex model) was avoided by using stimuli with moderately high arousal ratings.

Having provided operational definitions, it is possible to ask how conscious and unconscious processing differs. Are there qualitative differences? It has been established that this may be the case in the two fMRI experiments, but no overall valence bias appeared in the MRI data that seemed to explain the pleasantness bias observed in the behavioural study.

In the IAPS series, variations in physical properties such as spatial frequency in terms of size and luminance have been highlighted as a potential problem. A recent study examining the whole IAPS series, found that differences in the energy of spatial frequencies was not of particular significance; however, when inspecting physical properties of selected subsets potential confounds were evident (Delplanque et al., 2007). This is of a particular concern for studies investigating emotional processing for it is hypothesised that the parvocellular pathway conveys high spatial frequency information to the visual cortices with slow responses and the magnocellular pathway transmits coarse low spatial frequency information rapidly to the subcortical areas such as the amygdala

(Vuilleumier et al., 2003b). However, the magno/parvocellular interaction (see Section 1:5) has recently been attacked partly because the grating contrast-sensitivity measurements are too narrow for the range of overlapping stimuli that activate both these pathways. Skottun and Skoyles (2006) have argued that magno and parvocellular pathways are not as dichotomous as previously suggested because there is a large overlap in spatiotemporal properties. Therefore, the difference between the information the amygdala receives and that of the fusiform gyrus for instance, is probably more of a graded difference. Hence, discussions about the functions of these pathways are inconclusive (Skottun and Skoyles, 2006).

Despite possible spatial frequency effects on detection and discrimination, ANOVA (Section 3:5:6) did confirm that high and low valence stimuli for the chosen categories in the present study were matched for detectability, and as such, valence and category were not confounds with detectability. Equally, in the masked fMRI experiment (Chapter 4) a replication of the normal viewing condition with different slides was included and differences in valence effects were negligible.

It is very difficult to control for local properties systematically using natural images. A huge majority of previous studies examining affect in fast detection and discrimination paradigms have used highly homogeneous stimuli often centrally presented and of the same size. This makes it difficult to compare those results with the results from real life images used in this thesis (Rousselet et al., 2004b). However, even when considering these difficulties, some of the results presented here support previous findings.

The effect of apparent size on salience of images has been explained in terms of an evolutionary benefit, in that retinal size may determine relevance for survival and correlate with distance of the point of interest (Codispoti et al., 2006a). Equally, as an object moves further away, fine details in terms of high spatial frequency are progressively lost (Loftus and Harley, 2005). Based on this fact, it was hypothesised that ERP correlates of early stages of perceptual analysis would be modulated by size, in contrast with the LPP which is a long-latency ERP

implicated in recognition processes. Indeed it was found that physical properties such as size did modulate early ERP components, whereas the LPP was not modulated by physical properties. These results led to the hypothesis that at the LPP stage, stimulus interpretation has been achieved regardless of size (Codispoti et al., 2006a). Top-down influences are evident in visual tasks where the difficulty of the task requires the integration of visual information over time.

The evidence presented here, however, demonstrates that modulation of the neural response to IAPS stimuli by brief, masked presentation (Chapter 4) or by a dual stimulus paradigm (Chapter 5) does not eliminate valence or category specific responses. On the other hand, the magnitude of these responses may be altered. In Chapter 4, any modulation of neural activity in the masked condition is most likely due to bottom-up processes, since there is a drastic reduction in the spatiotemporal energy in the stimulus due to brief, masked presentation. The preservation of responses suggests that higher levels in the processing hierarchy (represented by the ROIs) must be receiving some information from the stimulus and may to some extent be compensating for the impoverished input. These findings support the work of Codispoti et al explained above (Codispoti et al., 2006a). Likewise, in the behavioural experiment (Chapter 3), discrimination of valence was achieved in the absence of detection, thus suggesting a degree of automatic, unconscious processing of affect. Contrariwise, in Chapter 5, differences in response to the 'to-be-ignored' and the 'attended' contrast are likely to be due to top-down modulation of activities by attention circuits.

In summary, together the present results indicate that affective natural images of a wide range of categories are effective tools in measuring valence using behavioural and fMRI designs.

6:2 Conclusions

The following conclusions can be drawn:

1) Do people give consistent valence responses to complex stimuli? Clearly they do because IAPS has been rated. What is the minimum visual information they need in order to do this? Very little – below the detection threshold in some cases.
2) If people can do this, then their brain must be able to register differences in valence even when we provide only these minimal, brief, masked presentations. fMRI shows us that the responses are very small for brief, masked exposures. Nevertheless, in certain ROIs there were significant main effects of valence or interactions including valence for the masked stimuli.
3) Brief, masked exposures are one way of limiting visual information pickup. Another method is to direct attention away from stimuli. Using dual pictures, valence-specific effects were found in an fMRI experiment. In some ROIs, the valence effect was modulated by whether the stimulus was 'attended' or 'to-be-ignored'.
4) In all these experiments, there were strong effects of 'category'. However, 'category' is an a priori way of classifying the stimuli. Variation within category may be as large as variation between categories because of variation in image properties between members of a category, so it is unwise to conclude that a significant effect of 'category' within an ROI indicates that the ROI is category-specific.
5) It has been suggested that faces are special stimuli. We might therefore expect that if subliminal effects or effects of to-be-ignored stimuli occur, it will be for faces. The results suggest otherwise. In fact, in some cases the valence responses are stronger for other categories of stimuli.
6) Valence specific effects were found to be widespread across the nine ROIs sampled, suggesting that the analysis of emotional valence is carried out by a large cortical and subcortical network.
7) There was some evidence of hemisphere modulation which supported previous findings.

Even taking into account the methodological differences between the studies in this thesis, these results demonstrate a marked consistency of ROI activation near or below conscious awareness when presented with many of the images.

It is evident that several regions respond to affect, categories and experimental conditions. Other regions are activated for one or two of these factors. Further investigation is needed to expand, validate and explore these results using natural everyday images. The principle contribution of this thesis is to demonstrate new evidence that it is possible to employ a wide range of natural images to study affect close to the threshold of conscious perception using fMRI.

6:3 Limitations

A criticism of the behavioural experiment and response bias is that the control condition consisted of neutral stimuli and it can be argued that a forced choice of pleasant or unpleasant did not allow for accuracy, as a picture of an iron, cup or plate etc were not at all unpleasant, and as such would have been scored as pleasant. This effect, however, was negated with the neuroimaging studies. On the other hand, the neutral images could be described as boring, which is negative valence with low arousal (Posner et al., 2005). Potentially, this may have distorted the fMRI results using the subtraction method.

Equally, the behavioural experiment was displayed on either a laptop or projector screen. This introduces an inconsistency in the sizes that the images were viewed.

As stated in section 2:1:2 although the presentations of the images were 10ms in the masked experiments, the technical demands of the equipment used meant that the actual display time may have been as long as 16.6ms. However, 16.6ms is still considered to be near or below conscious awareness and as such fulfilled the experimental objectives.

Another concern over design was in the dual-image experiment. The small-field image was superimposed on the large-field image and as such would sometimes mask out a proportion of relevant information in the large-field image.

When displaying the large-field control image, a better design may have been to 'blank out' the area that the small-field image masked in the combined condition. Thus the to-be-ignored image and the large-field control image would have supplied the same comparative information. Although this may be considered to be a flaw in the design of this experiment, it should be noted that some of the results were highly significant, but what was actually measured is a subject of debate. Therefore, this experiment asked more questions than it answered and will be pursued to peer review publication.

Another note to be made is that when participants became aware of the nature and design of an experiment, deliberate and strategic responses may have contaminated the results. Although it has been argued that expectation can facilitate fixation (Holm et al., 2008).

One of the criticisms of fMRI is that it is not a direct measure of physiological correlates of rapid synaptic and spiking events, but a secondary measure of blood flow and blood oxygenation correlating with local changes in neural activity which has a slower time course (see section 1:7:4). Equally, an fMRI signal is a fractional measure of local neuronal activity that has been averaged over time and space, which is also a limiting factor. These two limitations are acknowledged here, but using fMRI is still a tenable, objective tool to approximate what is going on in regions of the brain. In addition, fMRI takes static images of the brain, which does not facilitate investigations into neuronal networks or distribution of the workings of the brain. This, however, was not an issue in the present experiments as these were ROI analyses.

6:4 Related Ideas and Future Research

Finally, this last section projects ideas for future research and gives consideration to two related theories.

The cognitive neuroscientific approach is to empirically examine the function of brain regions and the interaction of neural networks and how they give rise to psychological functioning. The use of methodological reductionism allows

for bite sized questions and answers to build foundations for the bigger questions and the biggest question of all is, of course, how the mind and body relate. Therefore, to gain a broader perspective of the neuronal and behavioural data presented in this thesis, we will now consider two recent developments in functionalism: homuncular functionalism and teleological functionalism.

Traditionally known as a 'little man in the head', the fallacy of the homunculus is an illusion of the conscious self in the mind that observes and initiates all operations (Solms and Turnbull, 2002). The idea of the "mind" as the perceiving, thinking and feeling entity inside a person, was dismissed by Ryle (1949) as a redundant metaphor that simply transfers tasks to a smaller self, which in turn moves to another even smaller self inside the initial observer ad infinitum. This infinite regression, he argued, proves that the Cartesian idea of mind as a thinking entity is illogical as it does not explain anything (Ryle, 1949).

The idea, however, that the brain contains anatomical modules interconnected to form functional systems, each with a particular cognitive or behavioural function, is deeply embedded in neuropsychological thinking. This 'homuncular functionalism' (Attneave, 1961, Dennett, 1978, Lycan, 1981) with many little semi-knowledgeable homunculi which are both autonomous and interact as an organised group create a whole system giving rise to sophisticated emergent properties. The little homunculi can be broken down into smaller and smaller subunits until each component is responsible for the simplest task. This hierarchy becomes less intelligent at lower and lower levels in terms of function and physical composition; until it is possible to explain how subjective mental properties (subunits) can be transmitted via material action potentials, thus explaining how the mind and body relate without becoming trapped in an infinite regress (Rose, 2006).

This model not only facilitates the study of one subunit at a time, but also accommodates research into multiple levels of brain function further up the hierarchy (e.g. perception of valence and the amygdala, perception of valence and the limbic system, perception of valence and the PFC). Homuncular functionalism is therefore an ideal model to discuss cerebral mechanisms (Rose, 2006).

Of course there are criticisms of homuncular functionalism. It does not explain qualia, for instance, and it also assumes a rather neat hierarchy with each module defined in terms of function, but this top-down method, runs counter to scientific enquiry as traditionally understood, where often a system is investigated which generates hypotheses as to the functions of those systems (bottom-up). Equally, modules may be flexible and serve different functions; therefore attributing functional specificity is not possible (Rose, 2006). In fact, a problem with homuncular functionalism is that homunculi are identified as components of neuroanatomical structures, independent of functional deliberation, which is not ideal from a neuroscientific point of view (Mundale and Bechtel, 1996). It is also argued that the number of modules is limited and does not account for the infinite capacity of the mind (Fodor, 2000). The difficulty in accepting homuncular functionalism as a complete account of conscious experience is that it does not answer the "why" question. What is this intricate hierarchy for? What is it about the system that makes its owner conscious, and why does he/she need to be conscious? Nor does it altogether answer the "how" question. How does the system generate conscious experience? Is the degree of consciousness a correlate of the internal connectivity state of the system (which could perhaps be defined mathematically), thus of any hypothetical system that has this kind of connectivity? Is it correct to think of consciousness as somehow residing in the system, or does it reside in the relationship or connectivity between the system and the world?

For the purposes of this thesis, although there are unsolved problems with the theory of homuncular functionalism, it is still a useful analogy to understand multilevel systems in the brain and how they relate to mental states. In fact, it has been suggested that this potent metaphor may turn out to be an indication in how the brain is organised in general (Crick and Koch, 2004).

Both homuncular and teleological functionalism are compatible in terms of multi-level functions and modularity. The difference between the two theories is that teleological functionalism postulates phenomenal experience as the same as biological functions. Just as the biological function of the heart is to pump blood

and thus subserve the whole body, the biological function of the brain is to "subserve consciousness, or just to be conscious" (Rose, 2006, p 123). This tenet eliminates the brain/mind distinction and provides a very good template to explain its origins and purposes. As such, it provides an answer to a shortfall in homuncular functionalism in that brain mapping is bound in functional considerations and is therefore teleological (Mundale and Bechtel, 1996), which goes some way to explain how and why conscious experience has evolved. It makes the reasonable assumption that consciousness must have a biological function.

Following evolutionary principles, a functional role or goal is adaptive to the environment for survival of the organism. Historically, human evolution has undergone constant, if random, fluctuations in genetic recombinations. Hence, systems can be inefficient due to forced premature abandoned development or rendered redundant (Millikan, 1993). Thus the visual system has been shaped by mutation and natural selection. Accordingly, we should not be surprised that our visual systems are subject to visual illusions, since illusions are representative of individual visual mechanisms that have been adapted and 'usually work'. To take an example from the present study, when the input signal is weak in a masked presentation, we might expect the visual system to use context and expectancies to generate a plausible percept, leading to the misrepresentation of some of the IAPS stimuli (e.g. the negative image of flies on pie interpreted as positive valence because it looked like currants on a pie).

Both theories are useful for the neuroscientist. Lots of little homunculi in a hierarchical modulatory series of increasingly more stupid levels the lower down the hierarchy one goes, which also generates new emergent properties as a whole, is a useful analogy in the pursuit of understanding the mechanisms of the brain. Teleological functionalism accommodates a frame of reference to integrate neuroscience, psychology and evolutionary biology, thus bringing into account the origins and purposes of cerebral mechanisms.

It is beyond the scope of this thesis to further elucidate on these two functionalist theories, but this does highlight the valuable relationship between

cognitive neuroscience and philosophy of mind. These two disciplines are traditionally juxtaposed, but to integrate their ideas can be extremely beneficial and inspiring for future research.

In the present study a category effect on the ACC was evident in both the fMRI experiments. Equally, a category x valence interaction was found in the STG, again in both exeriments. Neither of these findings are supported in the literature, but as they are evident in two different fMRI paradigms, it warrants further investigation in future research.

Future studies should also further investigate natural images by using finer grain analysis such as a multi-modal neuroimaging technique where EEG and fMRI data are recorded simultaneously. The advantages of the high spatial resolution of fMRI and the added benefits of the high temporal resolution of EEG are an excellent combination for studies investigating brain responses to rapidly presented natural images. This simultaneous data acquisition enables a more comprehensive examination of when and where appetitive and defensive systems modulate cortical activity.

For greater ecological validity, future work could investigate cross modalities such as auditory stimuli corresponding with natural visual images, as we normally use more than one source of sensory input to evaluate perception of valence in our natural environment. Multimodal perception is achieved simultaneously to external events. Take for instance the image of fireworks used in this experiment. Here we investigated only visual perception, but under normal circumstances, we would be exposed not only to the visual stimulation from light, but also olfactory stimulation from the smell of gunpowder and auditory stimulation from the whistling and repeated explosive sounds. Research is already expanding in crossmodal integration by investigating several modalities and correlating neural mechanisms both in conscious and non-conscious processing (e.g. de Gelder and Bertelson, 2003).

6:5 Abstract Publication and Presentations Arising from this Thesis

6:5:1 Abstract Publication

Shaw, L. J., Wright, M. J. and O'Brien J. (2006) Unconscious processing of high and low valence visual stimuli: an fMRI analysis. Toward a Science of Consciousness VII, Tucson. Journal of Consciousness Studies: Consciousness Research Abstracts 102 (2006).

6:5:2 Oral Presentations

Presented at the First Annual Psychology Conference Brunel University:
Shaw, L. J., Wright, M. J. and O'Brien, J. (2008), Can we research subliminal emotional processing using natural images?

Presented at the Graduate Interdisciplinary Conference on Perceptual Experience, University of Glasgow:
Shaw, L. J., Wright, M. J. and O'Brien, J. (2005), Attention effect of high and low valence visual stimuli: an fMRI analysis.

6:5:3 Poster Presentations

Presented at the Applied Vision Association, Active and Passive Visions Conference, Bradford University:
Shaw, L. J. and Wright, M. J., (2007), Identification of positive and negative emotional valence in four categories of pictures in a forward-backward masking paradigm.

Presented at Royal Holloway University:
Shaw, L. J., Wright, M. J. and O'Brien, J (2006) Unconscious processing of high and low valence visual stimuli: an fMRI analysis.

Presented for the fMRI Experience Conference, Aston University, Birmingham:
Shaw, L. J., Wright, M. J. and O'Brien, J. (2005), Attention effect of high and low valence visual stimuli: an fMRI analysis.

Presented at the BPS Cognitive Psychology Section Annual Conference, Leeds University:
Shaw, L. J. and Wright, M. J. (2005), Identification of positive and negative emotional valence in the absence of conscious perception.

Winner of the Brunel University poster competition 2005:
Shaw, L. J., (2005), Unconscious and conscious processing of emotion: a behavioural and fMRI study.

References

Adolphs, R. (2002), Neural Systems for recognizing emotion. **Current Opinion in Neurobiology**, 12 (2)**,** 169-177.

Adolphs, R., Baron-Cohen, S. and Tranel, D. (2002), Impaired recognition of social emotions following amygdala damage. **Journal of Cognitive Neuroscience**, 14 (8)**,** 1264-1274.

Adolphs, R., Damasio, H., Tranel, D. and Damasio, A. R. (1996), Cortical systems for the recognition of emotion in facial expressions. **The Journal of Neuroscience**, 16 (23)**,** 7678-7687.

Adolphs, R., Jansari, A. and Tranel, D. (2001), Hemispheric perception of emotional valence from facial expressions. **Neuropsychology**, 15 (4)**,** 516-524.

Adolphs, R., Tranel, D., Damasio, H. and Damasio, A. R. (1995), Fear and the human amygdala. **The Journal of Neuroscience**, 15 (9)**,** 5879-5891.

Amaral, D. G., Behniea, H. and Kelly, J. L. (2003), Topographic organization of projections from the amygdala to the visual cortex in the macaque monkey. **Neuroscience**, 118 (4)**,** 1099-1120.

Anderson, A. K. and Phelps, E. A. (2001), Lesions of the human amygdala impair enhanced perception of emotionally salient events. **Nature**, 411 (6835)**,** 305-309.

Anokhin, A. P., Golosheykin, S., Sirevaag, E., Kristjansson, S., Rohrbaugh, J. W. and Heath, A. C. (2006), Rapid discrimination of visual scene content in the human brain. **Brain Research**, 1093 (1)**,** 167-177.

Attneave, F. (1961), In Defense of Homunculi. In Sensory Communication, (Ed, Rosenblith, W. A.) MIT Press, New York, pp. 777-782

Baars, B. J. and Gage, N. M. (2007) Cognition, Brain, and Consciousness Introduction to Cognitive Neuroscience, Academic Press, London.

Bachmann, T., Luiga, I. and Põder, E. (2004), Forward masking of faces by spatially quantized random and structured masks: On the roles of wholistic

configuration, local features, and spatial-frequency spectra in perceptual identification. **Psychological Research**, 69 (1-2)**,** 11-21.

Bacon-Macé, N., Macé, M. J.-M., Fabre-Thorpe, M. and Thorpe, S. J. (2005), The time course of visual processing: Backward masking and natural scene categorisation. **Vision Research**, 45 (11)**,** 1459-1469.

Barbas, H. (2000), Connections underlying the synthesis of cognition, memory, and emotion in primate prefrontal cortices. **Brain Research Bulletin**, 52 (5)**,** 319-330.

Bard, P. (1934), On emotional expression after decortication with some remarks on certain theoretical views: Part I. **Psychological Review**, 41 (4)**,** 309-329.

Barrett, L. F., Niedenthal, P. M. and Winkielman, P. (2005) Emotion and Consciousness, The Guildford Press, New York.

Becerra, L., Breiter, H. C., Wise, R., Gonzalez, R. G. and Borsook, D. (2001), Reward circuitry activation by noxious thermal stimuli. **Neuron**, 32 (5)**,** 927-946.

Bechara, A., Damasio, H., Damasio, A. R. and Lee, G. P. (1999), Different contributions of the human amygdala and ventromedial prefrontal cortex to decision-making. **The Journal of Neuroscience**, 19 (13)**,** 5473-5481.

Beck, D. M. and Lavie, N. (2005), Look here but ignore what you see: effects of distractors at fixation. **Journal of Experimental Psychology: Human Perception and Performance**, 31 (3)**,** 592-607.

Beck, D. M., Rees, G., Frith, C. D. and Lavie, N. (2001), Neural correlates of change detection and change blindness. **Nature Neuroscience**, 4 (6)**,** 645-650.

Beck, E. D. (2002), The perception, experience and regulation of emotion: an fMRI approach. **Dissertation Abstracts International: Section B: The Sciences and Engineering**, 62 (9-B)**,** 4270.

Bermpohl, F., Pascual-Leone, A., Amedi, A., Merabet, L. B., Fregni, F., Gaab, N., Alsop, D., Schlaug, G. and Northoff, G. (2006), Dissociable networks for the expectancy and perception of emotional stimuli in the human brain. **NeuroImage**, 30 (2)**,** 588-600.

Berthoz, S., Blair, R. J. R., Le Clec'h, G. and Martinot, J.-L. (2002), Emotions: From neuropsychology to functional imaging. **International Journal of Psychology**, 37 (4)**,** 193-203.

Bisiach, E. and Luzzatti, C. (1978), Unilateral neglect of representational space. **Cortex**, 14 (1)**,** 129-133.

Blackmore, S. (2003) Consciousness, An Introduction, Hodder & Stoughton, London.

Blair, R. J. R., Morris, J. S., Frith, C. D., Perrett, D. I. and Dolan, R. J. (1999), Dissociable neural responses to facial expressions of sadness and anger. **Brain**, 122 (5)**,** 883-893.

BPS (2000) The British Psychological Society Code of Conduct, Ethical Principles & Guidelines. The British Psychological Society, Leicester.

Bradley, M. M., Codispoti, M., Cuthbert, B. N. and Lang, P. J. (2001a), Emotion and motivation I: defensive and appetitive reactions in picture processing. **Emotion**, 1 (3)**,** 276-298.

Bradley, M. M., Codispoti, M., Sabatinelli, D. and Lang, P. J. (2001b), Emotion and motivation II: sex differences in picture processing. **Emotion**, 1 (3)**,** 300-319.

Bradley, M. M. and Lang, P. J. (1999), Fearfulness and affective evaluations of pictures. **Motivation and Emotion**, 23 (1)**,** 1-13.

Bradley, M. M., Sabatinelli, D., Lang, P. J., Fitzsimmons, J. R., King, W. and Desai, P. (2003), Activation of the visual cortex in motivated attention. **Behavioral Neuroscience**, 117 (2)**,** 369-380.

Braun, J. (1994), Visual search among items of different salience: removal of visual attention mimics a lesion in extrastriate area V4. **The Journal of Neuroscience**, 14 (2)**,** 554-567.

Braun, J. (2003), Natural scenes upset the visual applecart. **Trends In Cognitive Sciences**, 7 (1)**,** 7-9.

Braun, J. and Sagi, D. (1990), Vision outside the focus of attention. **Perception and Psychophysics**, 48 (1)**,** 45-58.

Breiter, H. C., Etcoff, N. L., Whalen, P. J., Kennedy, W. A., Rauch, S. L., Buckner, R. L., Strauss, M. M., Hyman, S. E. and Rosen, B. R. (1996), Response and habituation of the human amygdala during visual processing of facial expression. **Neuron**, 17 (5)**,** 875-887.

Breiter, H. C., Gollub, R. L., Weisskoff, R. M., Kennedy, D. N., Makris, N., Berke, J. D., Goodman, J. M., Kantor, H. L., Gastfriend, D. R., Riorden, J.

P., Mathew, R. T., Rosen, B. R. and Hyman, S. E. (1997), Acute effects of cocaine on human brain activity and emotion. **Neuron**, 19 (3)**,** 591-611.

Breitmeyer, B. G. and Ogmen, H. (2000), Recent models and findings in visual backward masking: A comparison, review and update. **Perception and Psychophysics**, 62 (8)**,** 1572-1595.

Brett, M., Anton, J.-L., Valabregue, R. and Poline, J.-B., MarsBar. (0.2), [Computer program]. SourceForge Inc.

Britton, J. C., Phan, L. K., Taylor, S. F., Welsh, R. C., Berridge, K. C. and Liberzon, I. (2006a), Neural correlates of social and nonsocial emotions: An fMRI study. **NeuroImage**, 31 (1)**,** 397-409.

Britton, J. C., Taylor, S. F., Sudheimer, K. D. and Liberzon, I. (2006b), Facial expressions and complex IAPS pictures: Common and differential networks. **NeuroImage**, 31 (2)**,** 906-919.

Broadbent, D. E. (1958) Perception and communication, Pergamon, New York.

Broca, P. P. (1878), Anatomie comparée des circonvolutions cérébrales: Le grand lobe limbique et le scissure limbique dans le serie des mammiferes. **Révue d'Anthropologique**, 2 (1)**,** 385-498.

Bush, G., Luu, P. and Posner, M. I. (2000), Cognitive and emotional influences in anterior cingulate cortex. **Trends In Cognitive Sciences**, 4 (6)**,** 215-222.

Calder, A. J., Lawrence, A. D. and Young, A. W. (2001), Neuropsychology of fear and loathing. **Nature Reviews Neuroscience**, 2 (5)**,** 352-363.

Calvo, M. G. and Lang, P. J. (2004), Gaze patterns when looking at emotional pictures: Motivationally biased attention. **Motivation and Emotion**, 28 (3)**,** 221-243.

Calvo, M. G. and Lang, P. J. (2005), Parafoveal semantic processing of emotional visual scenes. **Journal of Experimental Psychology: Human Perception and Performance**, 31 (3)**,** 502-519.

Calvo, M. G. and Nummenmaa, L. (2007), Processing of unattended emotional visual scenes. **Journal of Experimental Psychology: General**, 136 (3)**,** 347-369.

Calvo, M. G., Nummenmaa, L. and Hyönä, J. (2007), Emotional and neutral scenes in competition: Orienting, efficiency, and identification. **The Quarterly Journal of Experimental Psychology**, 60 (12)**,** 1585-1593.

Calvo, M. G., Nummenmaa, L. and Hyönä, J. (2008), Emotional scenes in peripheral vision: Selective orienting and gist processing, but not content identification. **Emotion**, 8 (1)**,** 68-80.

Canli, T., Desmond, J. E., Zhao, Z., Glover, G. and Gabrieli, J. D. E. (1998), Hemispheric asymmetry for emotional stimuli detected with fMRI. **NeuroReport**, 9 (14)**,** 3233-3239.

Cannon, W. B. (1927), The James-Lange theory of emotion: A critical examination and an alternative theory. **American Journal of Psychiatry**, 39 106-124.

Cannon, W. B. (1931), Again the James-Lange and the thalamic theories of emotion. **Psychological Review**, 38 (4)**,** 281-295.

Cavada, C., Compañy, T., Tejedor, J., Cruz-Rizzolo, R. J. and Reinoso-Suárez, F. (2000), The anatomical connections of the macaque monkey orbitofrontal cortex. A review. **Cerebral Cortex**, 10 (3)**,** 220-242.

Cave, K. R. and Bichot, N. P. (1999), Visuospatial attention: beyond a spotlight model. **Psychonomic Bulletin and Review**, 6 (2)**,** 204-223.

Center for the Study of Emotion and Attention [CSEA-NIMH] (2001) The Center for Research in Psychophysiology, University of Florida, Gainsville, Florida.

Chao, L. L., Haxby, J. V. and Martin, A. (1999), Attribute based neural substrates in temporal cortex for perceiving and knowing about objects. **Nature Neuroscience**, 2 (10)**,** 913-919.

Cheesman, J. and Merikle, P. M. (1986), Distinguishing conscious from unconscious perceptual processes. **Canadian Journal of Psychology**, 40 (4)**,** 343-367.

Cherry, E. C. (1953), Some experiments on the recognition of speech, with one and with two ears. **Journal of the Acoustical Society of America**, 25 (5)**,** 975-979.

Codispoti, M., Ferrari, V., De Cesarei, A. and Cardinale, R. (2006a), Implicit and explicit categorization of natural scenes. **Progress in Brain Research**, 156 53-65.

Codispoti, M., Ferrari, V., Junghöfer, M. and Schupp, H. T. (2006b), The categorization of natural scenes: Brain attention networks revealed by dense sensor ERPs. **NeuroImage**, 32 (2)**,** 583-591.

Corbetta, M. (1998), Frontoparietal cortical networks for directing attention and the eye to visual locations: Identical, independent, or overlapping neural systems? **PNAS**, 95 (3)**,** 831-838.

Craig, A. D. (2005), Forebrain emotional asymmetry: a neuroanatomical basis? **Trends In Cognitive Sciences**, 9 (12)**,** 566-571.

Crick, F. C. and Koch, C. (2004), A Framework for Consciousness. In The Cognitive Neurosciences III, (Eds, Gazzaniga, M. S., Bizzi, E., Black, I. B., Caramazza, A., Grafton, S. T., Heatherton, T. F., Koch, C., LeDoux, J. E., Logothetis, N. K., Movshon, J. A., Phelps, E. A., Rakic, P., Schacter, D. L., Treisman, A. M. and Wandell, B.) MIT Press, Cambridge Massachusetts, pp. 1133- 1143

Crick, F. H. C. (1994) The Astonishing Hypothesis: The Scientific Search for the Soul, Simon & Schuster, New York, NY, England.

Critchley, H. D., Melmed, R. N., Featherstone, E., Mathias, C. J. and Dolan, R. J. (2002), Volitional control of autonomic arousal: A functional magnetic resonance study. **NeuroImage**, 16 (4)**,** 909-919.

Cunningham, W. A., Raye, C. L. and Johnson, M. K. (2004), Implicit and explicit evaluation: fMRI correlates of valence, emotional intensity, and control in the processing of attitudes. **Journal of Cognitive Neuroscience**, 16 (10)**,** 1717-1729.

Cuthbert, B. N., Schupp, H. T., Bradley, M. M., Birbaumer, N. and Lang, P. J. (2000), Brain potentials in affective picture processing: covariation with autonomic arousal and affective report. **Biological Psychology**, 52 (2)**,** 95-111.

Damasio, A. (1994) Descartes' Error. Emotion, Reason and the Human Brain, Putnam's & Sons, New York.

Damasio, A. (1999) The Feeling of What Happens: Body, Emotion and the Making of Consciousness, Vintage, London.

Damasio, A. (2001), Fundamental feelings. **Nature**, 413 (6858)**,** 781.

Damasio, A. R., Grabowski, T. J., Bechara, A., Damasio, H., Ponto, L. L., Parvizi, J. and Hichwa, R. D. (2000), Subcortical and cortical brain activity during the feeling of self-generated emotions. **Nature Neuroscience**, 3 (10)**,** 1049-1056.

Darwin, C. (1872/1999) The Expression of Emotions in Man and Animals, Fontana, London.

Davidson, R. J. and Irwin, W. (1999), The functional neuroanatomy of emotion and affective style. **Trends in Cognitive Sciences**, 3 (1)**,** 11-21.

Davidson, R. J., Saron, C. D., Senulis, J. A., Ekman, P. and Friesen, W. V. (1990), Approach-withdrawal and cerebral asymmetry: Emotional expression and brain physiology I. **Journal of Personality and Social Psychology**, 58 (2)**,** 330-341.

Davis, W. J., Rahman, M. A., Smith, L. J., Burns, A., Senecal, L., McArthur, D., Halpern, J. A., Perlmutter, A., Sickels, W. and Wagner, W. (1995), Properties of human affect induced by static color slides (IAPS): dimensional, categorical and electromyographic analysis. **Biological Psychiatry**, 41 (3)**,** 229-253.

de Gelder, B. and Bertelson, P. (2003), Multisensory integration, perception and ecological validity. **Trends In Cognitive Sciences**, 7 (10)**,** 460-467.

de Gelder, B., Pourtois, G. and Weiskrantz, L. (2002), Fear recognition in the voice is modulated by unconsciously recognized facial expressions but not by unconsciously recognized affective pictures. **PNAS**, 99 (6)**,** 4121-4126.

Dehaene, S., Changeux, J.-P., Naccache, L., Sackur, J. and Sergent, C. (2006), Conscious, preconscious, and subliminal processing: a testable taxonomy. **Trends In Cognitive Sciences**, 10 (5)**,** 204-11.

Dehaene, S. and Naccache, L. (2001), Towards a cognitive neuroscience of consciousness: basic evidence and a workspace framework. **Cognition**, 79 (1-2)**,** 1-37.

Delorme, A., Richard, G. and Fabre-Thorpe, M. (1999), Rapid processing of complex natural scenes: A role for the magnocellular visual pathways? **Neurocomputing**, 26-27 663-670.

Delorme, A., Richard, G. and Fabre-Thorpe, M. (2000), Ultra-rapid categorisation of natural scenes does not rely on colour cues: a study in monkeys and humans. **Vision Research**, 40 (16)**,** 2187-2200.

Delorme, A., Rousselet, G. A., Macé, M. J.-M. and Fabre-Thorpe, M. (2004), Interaction of top-down and bottom-up processing in the fast visual analysis of natural scenes. **Cognitive Brain Research**, 19 (2)**,** 103-113.

Delorme, A. and Thorpe, S. J. (2001), Face identification using one spike per neuron: Resistance to image degradations. **Neural Networks**, 14 (6-7)**,** 795-803.

Delplanque, S., N'diaye, K., Scherer, K. R. and Grandjean, D. (2007), Spatial frequencies or emotional effects? A systematic measure of spatial frequencies for IAPS pictures by a discrete wavelet analysis. **Journal of Neuroscience Methods**, 165 (1)**,** 144-150.

Dennett, D. C. (1978) Brainstorms: Philosophical Essays on Mind and Psychology, MIT Press, Cambridge MA.

Dennett, D. C. (1991) Consciousness Explained, The Penguin Press, London and New York.

Descartes, R. (1637/1909), Discourse on the method of rightly conducting the reason and seeking the truth in the sciences. (Discours de la Methode pour bien conduire sa raison, et chercher la verite dans les sciences). Vol. 34 Part 1 of 51 (Ed, Eliot, C. W.) P. F. Collier & Son, pp. Part IV.(Original work published 1637.)

Desimone, R. and Duncan, J. (1995), Neural mechanisms of selective visual attention. **Annual Review of Neuroscience**, 18 193-222.

Deutsch, J. A. and Deutsch, D. (1963), Attention: Some theoretical considerations. **Psychological Review**, 70 (1)**,** 51-60.

Dimberg, U., Thunberg, M. and Elmehed, K. (2000), Unconscious facial reactions to emotional facial expressions. **Psychological Science**, 11 (1)**,** 86-89.

Dolan, R. J. (2002), Emotion, cognition and behavior. **Science**, 298 (5596)**,** 1191-1194.

Downar, J., Crawley, A. P., Mikulis, D. J. and Davis, K. D. (2002), A cortical network sensitive to stimulus salience in a neutral behavioral context across multiple sensory modalities. **Journal of Neurophysiol**, 87 (1)**,** 615-620.

Drevets, W. C. and Raichle, M. E. (1998), Reciprocal suppression of regional cerebral blood during emotional versus higher cognitive implications for interactions between emotion and cognition. **Cognition and Emotion**, 12 (3)**,** 353-385.

Driver, J. (1996), What can visual neglect and extinction reveal about the extent of "preattentive" processing. In Converging Operations in the Study of Visual Selective Attention, Vol. xxv (Eds, Kramer, A. F., Coles, M. G. H. and Logan, G. D.) American Psychological Association Press, Washington, pp. 193-224

Durrant-Peatfield, M. R., Tyler, L. K., Moss, H. E. and Levy, J. P. 1997 The distinctiveness of form and function in category structure: A connectionist model, Proceedings of the 19th Annual Conference of the Cognitive Science Society, Mahwah New Jersey

Durston, S., Thomas, K. M., Worden, M. S., Yang, Y. and Casey, B. J. (2002), The effect of preceding context on inhibition: An event-related fMRI study. **NeuroImage**, 16 (2)**,** 449-453.

Efron, R. (1973), Conservation of temporal information by perceptual systems. **Perception & Psychophysics**, 14 518-530.

Ekman, P. (1993), Facial expression and emotion. **American Psychologist**, 48 (4)**,** 384-392.

Enns, J. T. (2004) The Thinking Eye, the Seeing Brain: Explorations in Visual Cognition, W.W. Norton & Company, New York London.

Epstein, R., Harris, A., Stanley, D. and Kanwisher, N. (1999), The parahippocampal place area recognition, navigation, or encoding? **Neuron**, 23 (1)**,** 115-125.

Epstein, R. and Kanwisher, N. (1998), A cortical representation of the local visual environment. **Nature**, 392 (6676)**,** 598-601.

Erdelyi, M. H. (1974), A new look at the new look: Perceptual defense and vigilance. **Psychological Review**, 81 (1)**,** 1-25.

Etkin, A., Klemenhagen, K. C., Dudman, J. T., Rogan, M. T., Hen, R., Kandel, E. R. and Hirsch, J. (2004), Individual differences in trait anxiety predict the response of the basolateral amygdala to unconsciously processed fearful faces. **Neuron**, 44 (6)**,** 1043-1055.

Eysenck, M. W. and Keane, M. T. (2005) Cognitive Psychology: A Student's Handbook, Psychology Press

Fabre-Thorpe, M., Delorme, A., Marlot, C. and Thorpe, S. (2001), A limit to the speed of processing in ultra-rapid visual categorization of novel natural scenes. **Journal of Cognitive Neuroscience**, 13 (2)**,** 171-80.

Fahim, C., Stip, E., Mancini-Marïe, A., Boualem, M., Malaspina, D. and Beauregard, M. (2004), Negative socio-emotional resonance in schizophrenia: a functional magnetic resonance imaging hypothesis. **Medical Hypotheses**, 63 (3)**,** 467-475.

Farah, M. J. and McClelland, J. L. (1991), A computational model of semantic memory impairment: modality specificity and emergent category specificity. **Journal of Experimental Psychology: General**, 120 (4)**,** 339-357.

Fecteau, S., Belina, P., Joanette, Y. and Armony, J. L. (2007), Amygdala responses to nonlinguistic emotional vocalizations. **NeuroImage**, 36 (2)**,** 480-487.

Findlay, J. M. and Gilchrist, I. D. (2003) Active Vision: The Psychology of Looking and Seeing, Oxford University Press, USA, Oxford.

Fischer, H., Wright, C. I., Whalen, P. J., Mclnerney, S. C., Shin, L. M. and Rauch, S. L. (2003), Brain habituation during repeated exposure to fearful and neutral faces: A functional MRI study. **Brain Research Bulletin**, 59 (5)**,** 387-392.

Fize, D., Boulanouar, K., Chatel, Y., Ranjeva, J.-P., Fabre-Thorpe, M. and Thorpe, S. (2000), Brain areas involved in rapid categorization of natural images: an event-related fMRI study. **Neurolmage**, 11 (6)**,** 634-643.

Fize, D., Fabre-Thorpe, M., Richard, G., Doyon, B. and Thorpe, S. J. (2005), Rapid categorization of foveal and extrafoveal natural images: Associated ERPs and effects of lateralization. **Brain and Cognition**, 59 (2)**,** 145-158.

Flavell, J. H. and Draguns, J. (1957), A microgenetic approach to perception and thought. **Psychological Bulletin**, 54 (3)**,** 197-217.

Fodor, J. A. (2000) The Mind Doesn't Work that Way: The Scope and Limits of Computational Psychology, MIT Press, Cambridge, Mass.

Freud, S. (1895/2001), Project for a Scientific Psychology. In The Standard Edition of the Complete Psychological Works of Sigmund Freud; translated from the German under the general editorship of James Strachey, in collaboration with Anna Freud; assisted by Alex Strachey and Alan Tyson. Vol. 1, (1886-1899), Pre-Psyco-Analytic Publications and Unpublished Drafts., Vol. 1 (Ed, Strachey, J.) Vintage, London, pp. 295-398.(Original work published in 1895.)

Friston, K. and Wellcome Department of Imaging Neuroscience, Statistical Parametric Mapping. (SPM2), London, UK: Wellcome Department of Imaging Neuroscience, Institute of Neurology, UCL.

Friston, K. J., Holmes, A. P., Worsley, K. J., Poline, J.-P., Frith, C. D. and Frackowiak, R. S. J. (1995), Statistical parametric maps in functional imaging: A general linear approach. **Hum Brain Mapping**, 2 (4)**,** 189-210.

Gainotti, G., Azzoni, A., Gasparini, F., Marra, C. and Razzano, C. (1997), Relation of lesion location to verbal and nonverbal mood measures in stroke patients. **Stroke**, 28 (11)**,** 2145-2149.

Gainotti, G., Caltagirone, C. and Zoccolotti, P. (1993), Left/right and cortical/subcortical dichotomies in the neuropsychological study of human emotions. **Cognition and Emotion**, 7 (1)**,** 71-93.

Ganel, T., Valyear, K. F., Goshen-Gottstein, Y. and Goodale, M. A. (2005), The involvement of the "fusiform face area" in processing facial expression. **Neuropsychologia**, 43 (11)**,** 1645-1654.

Gauthier, I., Skudlarski, P., Gore, J. C. and Anderson, A. W. (2000), Expertise for cars and birds recruits brain areas involved in face recognition. **Nature Neuroscience**, 3 (2)**,** 191-197.

Gelman, S. A. (1988), The development of induction within natural kind and artifact categories. **Cognitive Psychology**, 20 (1)**,** 65-95.

Gorno-Tempini, M. L. and Price, C. J. (2001), Identification of famous faces and buildings: A functional neuroimaging study of semantically unique items. **Brain**, 124 (10)**,** 2087-2097.

Gray, C. M. and Singer, W. (1989), Stimulus specific neuronal oscillations in orientation columns of cat visual cortex. **PNAS**, 86 (5)**,** 1698-1702.

Grimes, J. (1996), On the Failure to Detect Changes in Scenes across Saccades. In Perception, Vol. 2 (Ed, Akins, K.) Oxford University Press, New York, pp. 89-110

Grimm, S., Schmidt, C. F., Bermpohl, F., Heinzel, A., Dahlem, Y., Wyss, M., Hell, D., Boesiger, P., Boeker, H. and Northoff, G. (2006), Segregated neural representation of distinct emotion dimensions in the prefrontal cortex - an fMRI study. **NeuroImage**, 30 (1)**,** 325-340.

Gupta, K. (1999) Human Brain Coloring Workbook: An interactive approach to learning, Random House Inc., New York.

Guyonneau, R., VanRullen, R. and Thorpe, S. J. (2004), Temporal codes and sparse representations: A key to understanding rapid processing in the visual system. **Journal of Physiology**, 98 (4-6)**,** 487-497.

Hajcak, G., Dunning, J. P. and Foti, D. (2007), Neural response to emotional pictures is unaffected by concurrent task difficulty: an event-related potential study. **Behavioral Neuroscience**, 121 (6)**,** 1156-1162.

Hariri, A. R., Mattay, V. S., Tessitore, A., Fera, F. and Weinberger, D. R. (2003), Neocortical modulation of the amygdala response to fearful stimuli. **Biological Psychiatry**, 53 (6)**,** 494-501.

Hariri, A. R., Tessitore, A., Mattay, V. S., Fera, F. and Weinberger, D. R. (2002), The amygdala response to emotional stimuli: A comparison of faces and scenes. **Neuroimaging**, 17 (1)**,** 317-323.

Harlow, J. M. (1848), Passage of an iron rod through the head. **Boston Medical and Surgical Journal**, 39 389-393.

Harlow, J. M. (1868), Recovery from the passage of an iron rod through the head. **Bulletin of the Massachusetts Medical Society**, 2 327-347.

Hartikainen, K. M., Ogawa, K. H. and Knight, R. T. (2000), Transient interference of right hemispheric function due to automatic emotional processing. **Neuropsychologia**, 38 (12)**,** 1576-1580.

Haxby, J. V., Hoffman, E. A. and Gobbini, M. I. (2000), The distributed human neural system for face perception. **Trends In Cognitive Sciences**, 4 (6)**,** 223-233.

Heinzel, A., Bermpohl, F., Niese, R., Pfennig, A., Pascual-Leone, A., Schlaug, G. and Northoff, G. (2005), How do we modulate our emotions? Parametric fMRI reveals cortical midline structures as regions specifically involved in the processing of emotional valences. **Cognitive Brain Research**, 25 (1)**,** 348-358.

Heller, W. (1993), Neuropsychological mechanisms of individual differences in emotion, personality, and arousal. **Neuropsychology**, 7 (4)**,** 476-489.

Hochstein, S. and Ahissar, M. (2002), View from the top: hierarchies and reverse hierarchies in the visual system. **Neuron**, 36 (5)**,** 791-804.

Holm, L., Eriksson, J. and Andersson, L. (2008), Looking as if you know: Systematic object inspection precedes object recognition. **Journal of Vision**, 8 (4, Article 14)**,** 1-7.

Hornak, J., Bramham, J., Rolls, E. T., Morris, R. G., O'Doherty, J., Bullock, P. R. and Polkey, C. E. (2003), Changes in emotion after circumscribed surgical lesions of the orbitofrontal and cingulate cortices. **Brain**, 126 (7)**,** 1691-1712.

Hornak, J., Rolls, E. T. and Wade, D. (1996), Face and voice expression identification in patients with emotional and behavioural changes following ventral frontal lobe damage. **Neuropsychologia**, 34 (4)**,** 247-261.

House, A., Dennis, M., Warlow, C., Hawton, K. and Molyneux, A. (1990), Mood disorders after stroke and their relation to lesion location study. **Brain**, 113 (4)**,** 1113-1129.

Huang, Y.-X. and Luo, Y. J. (2006), Temporal course of emotional negativity bias: An ERP study. **Neuroscience Letters**, 398 (1-2)**,** 91-96.

Huettal, S. A., Song, A. W. and McCarthy, G. (2004) Functional Magnetic Resonance Imaging, Sinauer Associates Inc., Sunderland Massachusetts.

Irwin, D. E. and Brockmole, J. R. (2000), Mental rotation is suppressed during saccadic eye movements. **Psychonomic Bulletin & Review**, 7 (4)**,** 654-661.

Itti, L. and Koch, C. (2001), Computational modelling of visual attention. **Nature Reviews Neuroscience**, 2 (3)**,** 194-203.

James, W. (1884), What is an Emotion. **Mind**, 9 188-205.

James, W. (1890/1950) The Principles of Psychology, Courier Dover Publications (Original work published in 1890.)

Jezzard, P., Matthews, P. M. and Smith, S. M. (2001) Functional MRI and Introduction to Methods, Oxford University Press., Oxford.

Junghofer, M., Bradley, M. M., Elbert, T. R. and Lang, P. J. (2001), Fleeting images: A new look at early emotion discrimination. **Psychophysiology**, 38 (2)**,** 175-8.

Kanwisher, N., Chun, M. M., McDermott, J. and Ledden, P. J. (1996), Functional Imaging of human visual recognition. **Cognitive Brain Research**, 5 ((1-2))**,** 55-67.

Keightley, M. L., Winocur, G., Graham, S. J., Mayberg, H. S., Hevenor, S. J. and Grady, C. L. (2003), An fMRI study investigating cognitive modulation of brain regions associated with emotional processing of visual stimuli. **Neuropsychologia**, 41 (5)**,** 585-596.

Kentridge, R. W., Heywood, C. A. and Weiskrantz, L. (1999), Attending, Seeing and Knowing in Blindsight. In Towards a Science of Consciousness III The Third Tucson Discussions and Debates, (Eds, Hameroff, S. R., Kaszniak, A. W. and Chalmers, D. J.) MIT Press, Cambridge MA, pp. 149-160

Kern, R. P., Libkuman, T. M., Otani, H. and Holmes, K. (2005), Emotional stimuli, divided attention, and memory. **Emotion**, 5 (4)**,** 408-417.

Killgore, W. D. S. and Yurgelun-Todd, D. A. (2004), Activation of the amygdala and anterior cingulate during nonconscious processing of sad versus happy faces. **Neuroimage**, 21 (4)**,** 1215-1223.

Kilpatrick, L. and Cahill, L. (2003), Amygdala modulation of parahippocampal and frontal regions during emotionally influenced memory storage. **Neurolmage**, 20 (4)**,** 2091-2099.

Kim, H., Somerville, L. H., Johnstone, T., Alexander, A. L. and Whalen, P. J. (2003), Inverse amygdala and medial prefrontal cortex responses to surprised faces. **NeuroReport**, 14 (18)**,** 2317-2322.

Kimura, Y., Yoshino, A., Takahashi, Y. and Nomura, S. (2004), Interhemispheric difference in emotional response without awareness. **Physiology and Behavior.**, 82 (4)**,** 727-731.

Kirchner, H. and Thorpe, S. J. (2006), Ultra-rapid object detection with saccadic eye movements: Visual processing speed revisited. **Vision Research**, 46 (11)**,** 1762-1776.

Kline, J. P., Schwartz, G. E., Allen, J. J. B. and Dikman, Z. V. (1998), Perceptual and electroencephalographic registration of masked emotional words in defensiveness: An exploratory study. **Personality and Individual Differences**, 24 (4)**,** 499-512.

Koch, C. (2004) The Quest for Consciousness A Neurobiological Approach, Roberts and Company Publishers, Englewood.

Koch, C. and Ullman, S. (1985), Shifts in selective visual attention: towards the underlying neural circuitry. **Human Neurobiology**, 4 (4)**,** 219-227.

Kolb, F. C. and Braun, J. (1995), Blindsight in normal observers. **Nature**, 377 (6547)**,** 336-338.

Kowler, E., Anderson, E., Dosher, B. A. and Blaser, E. (1995), The role of attention in the programming of saccades. **Vision Research**, 35 (13)**,** 1897-1916.

Kreiman, G., Koch, C. and Fried, I. (2000), Category-specific visual responses of single neurons in the human medial temporal lobe. **Nature Neuroscience**, 3 (9)**,** 946-953.

Kuniecki, M., Urbanik, A., Sobiecka, B., Kozub, J. and Binder, M. (2003), Central control of heart rate changes during visual affective processing as revealed by fMRI. **Acta Neurobiol. Exp.**, 63 (1)**,** 39-48.

Kunimoto, C., Miller, J. and Pashler, H. (2001), Confidence and accuracy of near-threshold discrimination responses. **Consciousness and Cognition**, 10 (3)**,** 294-340.

LaBar, K. S., Gatenby, J. C., Gore, J. C. and Phelps, E. A. (1998), Role of the amygdala in emotional picture evaluation as revealed by fMRI. **Journal of Cognitive Neuroscience (Supplement S)**, 108.

LaBerge, D., Auclair, L. and Sieroff, E. (2000), Preparatory attention: Experiment and theory. **Consciousness and Cognition**, 9 (3)**,** 396-434.

Lane, R. D., Fink, G. R., Chau, P. M.-L. and Dolan, R. J. (1997a), Neural activation during selective attention to subjective emotional responses. **NeuroReport**, 8 (18)**,** 3969-72.

Lane, R. D. and Nadel, L. (2000) Cognitive Neuroscience of Emotion, Oxford University Press, Oxford.

Lane, R. D., Reiman, E. M., Ahern, G. L., Schwartz, G. E. and Davidson, R. J. (1997b), Neuroanatomical correlates of happiness, sadness and disgust. **American Journal of Psychiatry**, 154 (7)**,** 926-933.

Lane, R. D., Reiman, E. M., Bradley, M. M., Lang, P. J., Ahern, G. L., Davidson, R. J. and Schwartz, G. E. (1997c), Neuroanatomical correlates of pleasant and unpleasant emotion. **Neuropsychologia**, 35 (11)**,** 1437-1444.

Lang, P. J. (2000), Emotion and motivation: attention, perception, and action. **Journal of Sport & Exercise Psychology**, 22 (2)**,** 122-140.

Lang, P. J., Bradley, M. M. and Cuthbert, B. N. (1997), Motivated Attention: Affect, Activation, and Action. In Attention and Orienting: Sensory and Motivational Processes, Lawrence Erlbaum Associates, Mahwah, New Jersey London, pp. 97-136

Lang, P. J., Bradley, M. M. and Cuthbert, B. N. (2001) International affective picture system (IAPS): Instruction Manual and Affective Ratings. Technical Report A-5, The Center for Research in Psychophysiology, University of Florida, Gainsville, Florida.

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

Lange, C. (1885), The Emotions. In The Emotions, (Ed, Dunlap, E.) Williams and Wilkins, Baltimore,

Lange, K., Williams, L. M., Young, A. W., Bullmore, E. T., Brammer, M. J., Williams, S. C. R., Gray, J. A. and Phillips, M. L. (2003), Task instructions modulate neural responses to fearful facial expressions. **Biological Psychiatry**, 53 (3)**,** 226-232.

Lau, H. C. and Passingham, R. E. (2006), Relative blindsight in normal observers and the neural correlate of visual consciousness. **PNAS**, 103 (49)**,** 18763-18768.

Lavie, N. (1995), Perceptual load as a necessary condition for selective attention. **Journal of Experimental Psychology: Human Perception and Performance**, 21 (3)**,** 451-468.

Lavie, N. (2005), Distracted and confused?: Selective attention under load. **Trends In Cognitive Sciences**, 9 (2)**,** 75-82.

Lavie, N. and Tsal, Y. (1994), Perceptual load as a major determinant of the locus of selection in visual attention. **Perception & Psychophysics**, 56 (2)**,** 183-197.

LeDoux, J. (1998) The Emotional Brain, The Mysterious Underpinnings of Emotional Life, Simon & Schuster, New York.

LeDoux, J. (2000), Emotion circuits in the brain. **Annual Review of Neuroscience**, 23 155-184.

LeDoux, J. (2002) Synaptic Self: How Our Brains Become Who We Are, Penguin, London; NY.

LeDoux, J. (2003), The emotional brain, fear and the amygdala. **Cellular and Molecular Neurobiology**, 23 (4-5)**,** 727-738.

Lee, T. S., Mumford, D., Romero, R. and Lamme, V. A. F. (1998), The role of the primary visual cortex in higher level vision. **Vision Research**, 38 (15-16)**,** 2429–2454.

Levesque, J., Eugene, F., Joanette, Y., Paquette, V., Mensour, B., Beaudoin, G., Leroux, J.-M., Bourgouin, P. and Beauregard, M. (2003), Neural circuitry underlying voluntary suppression of sadness. **Biol. Psychiatry**, 53 (6)**,** 502-510.

Levesque, J., Joanette, Y., Mensour, B., Beaudoin, G., Leroux, J.-M., Bourgouin, P. and Beauregard, M. (2004), Neural basis of emotional self-regulation in childhood. **Neuroscience**, 129 (2)**,** 361-369.

Li, F. F., VanRullen, R., Koch, C. and Perona, P. (2002), Rapid natural scene categorization in the near absence of attention. **PNAS**, 99 (14)**,** 9596-9601.

Li, F.-F., VanRullen, R., Koch, C. and Perona, P. (2005), Why does natural scene categorization require little attention? Exploring attentional requirements for natural and synthetic stimuli. **Visual Cognition**, 12 (6)**,** 893-924.

Liberzon, I., Phan, K. L., Decker, L. R. and Taylor, S. F. (2003), Extended amygdala and emotional salience: A PET study of positive and negative affect. **Neuropsychopharmacology**, 28 (4)**,** 726-733.

Libet, B., Gleason, C. A., Wright, E. W. and Pearl, D. K. (1983), Time of conscious intention to act in relation to onset of cerebral activity (readiness potential). The unconscious initiation of a freely voluntary act. **Brain**, 106 (3)**,** 623-642.

Libet, B., Pearl, D. K., Morledge, D. E., Gleason, C. A., HosoBuchi, Y. and Barbaro, N. M. (1991), Control of the transition from sensory detection to sensory awareness in man by the duration of a thalamic stimulus. The cerebral 'time-on' factor. **Brain**, 114 (4)**,** 1731-1757.

Liversedge, S. P. and Findlay, J. M. (2000), Saccadic eye movements and cognition. **Trends In Cognitive Sciences**, 4 (1)**,** 6-14.

Livingstone, M. S. and Hubel, D. H. (1987), Psychophysical evidence for separate channels for the perception of form, color, movement, and depth. **The Journal of Neuroscience**, 7 (11)**,** 3416-3468.

Loftus, G. R. and Harley, E. M. (2005), Why is it easier to identify someone close than far away? **Psychonomic Bulletin and Review**, 12 (1)**,** 43-65.

LON Cogent 2000 team and Romaya, J., Cogent 2000. [Computer program]. London, England: Laboratory of Neurobiology.

Lycan, W. G. (1981), Form, function, feel. **Journal of Philosophy**, 78 (1)**,** 24-50.

Mace, M. J.-M., Thorpe, S. J. and Fabre-Thorpe, M. (2005), Rapid categorization of achromatic natural scenes: how robust at very low contrasts? **European Journal of Neuroscience**, 21 (7)**,** 2007-2018.

Mack, A. and Rock, I. (1998), Inattentional Blindness An Overview. In Inattentional Blindness, (Eds, Mack, A. and Rock, I.) MIT Press, Cambridge MA, pp. 296

MacLean, P. (1970), The triune brain, emotion, and scientific bias. In The Neurosciences: Second Study Program, (Ed, Schmitt, F.) Rockefeller University Press, New York, pp. 336-349

Maldjian, J. A., Laurienti, P. J., Kraft, R. A. and Burdette, J. H. (2003), An automated method for neuroanatomic and cytoarchitectonic atlas-based interrogation of fMRI data sets. **NeuroImage**, 19 (3)**,** 1233-1239.

Masquelier, T. and Thorpe, S. J. (2007), Unsupervised learning of visual features through spike timing dependent plasticity. **PLoS Computational Biology**, 3 (2)**,** 0247-0257.

MATLAB Inc, MATLAB The Language of Technical Computing. (6.5.0.180913a Release 13), [Computer program]. Natick, MA USA: The MathWorks Inc.

Matthews, S. C., Paulus, M. P., Simmons, A. N., Nelesen, R. A. and Dimsdale, J. E. (2004), Functional subdivisions within anterior cingulate cortex and their relationship to autonomic nervous system function. **NeuroImage**, 22 (3)**,** 1151-1156.

Mayberg, H. S., Liotti, M., Brannan, S. K., McGinnis, S., Mahurin, R. K., Jerabek, P. A., Silva, J. A., Tekell, J. L., Martin, C. C., Lancaster, J. L. and Fox, P. T. (1999), Reciprocal limbic-cortical function and negative mood: converging PET findings in depression and normal sadness. **American Journal of Psychiatry**, 156 (5)**,** 675-682.

McLean, P. (1949), Psychosomatic disease and the visceral brain and their bearing on the Papez theory of emotion. **Psychosomatic Medicine**, 11 (6)**,** 338-353.

Merikle, P. M. and Joordens, S. (1997), Parallels between perception without attention and perception without awareness. **Consciousness and Cognition**, 6 (2-3)**,** 219-236.

Merikle, P. M., Smilek, D. and Eastwood, J. D. (2001), Perception without awareness: perspectives from cognitive psychology. **Cognition**, 79 (1-2)**,** 115-134.

Millikan, R. G. (1993) White Queen Psychology and other Essays for Alice, MIT Press, Cambridge, Mass.

Milner, D. and Goodale, M. (2006) The Visual Brain, Oxford University Press., Oxford.

Mineka, S., Watson, D. and Clark, L. A. (1998), Comorbidity of anxiety and unipolar mood disorders. **Annual Review of Psychology**, 49 377-412.

Mobbs, D., Hagan, C. C., Azim, E., Menon, V. and Reiss, A. L. (2005), Personality predicts activity in reward and emotional regions associated with humor. **PNAS**, 102 (45)**,** 16502-16506.

Moore, C. J. and Price, C. J. (1999), A functional neuroimaging study of the variables that generate category-specific object processing differences. **Brain**, 122 (5)**,** 943-962.

Morgan, M. J., Mason, A. J. and Solomon, J. A. (1997), Blindsight in normal subjects? **Nature**, 385 (6615)**,** 401-2.

Morris, J. S., de Gelder, B., Weiskrantz, L. and Dolan, R. (2001), Differential extrageniculostriate and amygdala responses to presentation of emotional faces in a cortically blind field. **Brain**, 124 (6)**,** 1241-1252.

Morris, J. S., Friston, K. J., Büchel, C., Frith, C. D., Young, A. W., Calder, A. J. and Dolan, R. J. (1998a), A neuromodulatory role for the human amygdala in processing emotional facial expressions. **Brain**, 121 (1)**,** 47-57.

Morris, J. S., Ohman, A. and Dolan, R. J. (1998b), Conscious and unconscious emotional learning in the human amygdala. **Nature**, 393 (6684)**,** 467-470.

Morris, M., Bradley, M. M., Bowers, D., Lang, P. J. and Heilman, K. M. (1991), Valence-specific hypoarousal following right temporal lobectomy. **Journal of Clinical and Experimental Neuropsychology**, 13 (42).

Mourao-Miranda, J., Volchan, E., Moll, J., de Oliveira-Souza, R., Oliveira, L., Bramati, I., Gattass, R. and Pessoa, L. (2003), Contributions of stimulus valence and arousal to visual activation during emotional perception. **Neuroimage**, 20 (4)**,** 1955-1963.

Mugler, J. P. and Brookeman, J. R. (1990), Three-dimensional magnetization-prepared rapid gradient-echo imaging (3D MP RAGE). **Magnetic Resonance in Medicine**, 15 (1)**,** 152-7.

Mundale, J. and Bechtel, W. (1996), Integrating neuroscience, psychology, and evolutionary biology through a teleological conception of function. **Minds and Machines**, 6 (4)**,** 481-505.

Murphy, F. C., Nimmo-Smith, I. and Lawrence, A. D. (2003), Functional neuroanatomy of emotions: A meta-analysis. **Cognitive, Affective, & Behavioral Neuroscience**, 3 (3)**,** 207-233.

Nakamura, K., Kawashima, R., Sato, N., Nakamura, A., Sugiura, M., Kato, T., Hatano, K., Ito, K., Fukuda, H., Schormann, T. and Zilles, K. (2000), Functional delineation of the human occipito-temporal areas related to face and scene processing: A PET study. **Brain**, 123 (9)**,** 1903-1912.

Narumoto, J., Okada, T., Sadato, N., Fukui, K. and Yonekura, Y. (2001), Attention to emotion modulates fMRI activity in human right superior temporal sulcus. **Cognitive Brain Research**, 12 (2)**,** 225-231.

Nitschke, J. B., Sarinopoulos, I., Mackiewicz, K. L., Schaefer, H. S. and Davidson, R. J. (2006), Functional neuroanatomy of aversion and its anticipation. **NeuroImage**, 29 (1)**,** 106-116.

Noe, A. and O'Regan, K. J. (2000), Perception, attention and the grand illusion. **Psyche**, 6 (15)**,** 1-8.

Nolte, J. (2002) The Human Brain: An Introduction to Its Functional Anatomy, Elsevier Health Sciences, London.

Norman, D. A. (1969), Memory while shadowing. **The Quarterly Journal of Experimental Psychology**, 21 (1)**,** 85-93.

Northoff, G., Richter, A., Gessner, M., Schlagenhauf, F., Fell, J., Baumgart, F., Kaulisch, T., Kötter, R., Stephan, K. E., Leschinger, A., Hagner, T., Bargel, B., Witzel, T., Hinrichs, H., Bogerts, B., Scheich, H. and Heinze, H.-J. (2000), Functional dissociation between medial and lateral prefrontal cortical spatiotemporal activation in negative and positive emotions: A combined fMRI/MEG study. **Cerebral Cortex**, 10 (1)**,** 93-107.

Nowak, L. G., Munk, M. H., Girard, P. and Bullier, J. (1995), Visual latencies in areas V1 and V2 of the macaque monkey. **Visual Neuroscience**, 12 (2)**,** 371-384.

Nummenmaa, L., Hyönä, J. and Calvo, M. G. (2006), Eye movement assessment of selective attentional capture by emotional pictures. **Emotion**, 6 (2)**,** 257-268.

O'Doherty, J., Kringelbach, M. L., Rolls, E. T., Hornak, J. and Andrews, C. (2001), Abstract reward and punishment representations in the human orbitofrontal cortex. **Nature Neuroscience**, 4 (1)**,** 95-102.

Ochsner, K. N., Bunge, S. A., Gross, J. J. and Gabrieli, J. D. E. (2002), Rethinking feelings: An fMRI study of the cognitive regulation of emotion. **Journal of Cognitive Neuroscience**, 14 (8)**,** 1215-1229.

Ochsner, K. N., Knierim, K., Ludlow, D. H., Hanelin, J., Ramachandran, T., Glover, G. and Mackey, S. C. (2004a), Reflecting upon feelings: An fMRI study of neural systems supporting the attribution of emotion to self and other. **Journal of Cognitive Neuroscience**, 16 (10)**,** 1746-1772.

Ochsner, K. N., Ray, R. D., Cooper, J. C., Robertson, E. R., Chopra, S., Gabrieli, J. D. E. and Gross, J. J. (2004b), For better or for worse: neural systems supporting the cognitive down- and up-regulation of negative emotion. **NeuroImage**, 23 (2)**,** 483-499.

O'Craven, K. M. and Kanwisher, N. (2000), Mental imagery of faces and places activates corresponding stimulus-specific brain regions. **Journal of Cognitive Neuroscience**, 12 (6)**,** 1013-1023.

Öhman, A. (2002), Automaticity and the amygdala: nonconscious responses to emotional faces. **Current Directions in Psychological Science**, 11 (2)**,** 62-66.

Öhman, A. (2005), The role of the amygdala in human fear: Automatic detection of threat. **Psychoneuroendocrinology**, 30 (10)**,** 953-958.

Öhman, A., Flykt, A. and Esteves, F. (2001a), Emotion drives attention: detecting the snake in the grass. **Journal of Experimental Psychology: General**, 130 (3)**,** 466-478.

Öhman, A., Lundqvist, D. and Esteves, F. (2001b), The face in the crowd revisited; a threat advantage with schematic stimuli. **Journal of Personality and Social Psychology**, 80 (3)**,** 381-396.

Öngür, D., An, X. and Price, J. L. (1998), Prefrontal cortical projections to the hypothalamus in Macaque monkeys. **The Journal of Comparative Neurology**, 401 (4)**,** 480-505.

Oppenheimer, S. M., Gelb, A., Girvin, J. P. and Hachinski, V. C. (1992), Cardiovascular effects of human insular cortex stimulation. **Neurology**, 42 (9)**,** 1727-1732.

Panksepp, J. (1998) Affective Neuroscience: The Foundations of Human and Animal Emotions, Oxford University press, Oxford.

Papez, J. W. (1937), A proposed mechanism of emotion. **Archives of Neurology and Psychiatry**, 38 725-744.

Paradiso, S., Johnson, D. L., Andreasen, N. C., O'Leary, D. S., Watkins, G. L., Boles Ponto, L. L. and Hichwa, R. D. (1999), Cerebral blood flow changes associated with attribution of emotional valence to pleasant, unpleasant, and neutral visual stimuli in a PET study of normal subjects. **American Journal of Psychiatry**, 156 (10)**,** 1618-1629.

Pashler, H. (1998) The Psychology of Attention, MIT Press, Cambridge, Mass.

Pegna, A. J., Khateb, A., Lazeyras, F. and Seghier, M. L. (2005), Discriminating emotional faces without primary visual cortices involves the right amygdala. **Nature Neuroscience**, 8 (1)**,** 24-25.

Pessoa, L. (2005), To what extent are emotional visual stimuli processed without attention and awareness? **Current Opinion in Neurobiology**, 15 (2)**,** 188-196.

Pessoa, L. (2008), On the relationship between emotion and cognition. **Nature Reviews Neuroscience**, 9 (2)**,** 148-158.

Pessoa, L., Japee, S. and Ungerleider, L. G. (2005a), Visual awareness and the detection of fearful faces. **Emotion**, 5 (2)**,** 243-247.

Pessoa, L., Kastner, S. and Ungerleider, L. G. (2002a), Attentional control of the processing of neutral and emotional stimuli. **Cognitive Brain Research**, 15 (1)**,** 31-45.

Pessoa, L., McKenna, M., Gutierrez, E. and Ungerleider, L. G. (2002b), Neural processing of emotional faces requires attention. **PNAS**, 99 (17)**,** 11458-11463.

Pessoa, L., Padmala, S. and Morland, T. (2005b), Fate of unattended fearful faces in the amygdala is determined by both attentional resources and cognitive modulation. **NeuroImage**, 28 (1)**,** 249-255.

Phan, K. L., Wager, T., Taylor, S. F. and Liberzon, I. (2002), Functional neuroanatomy of emotion: A meta-analysis of emotion activation studies in PET and fMRI. **NeuroImage**, 16 (2)**,** 331-348.

Phan, L., Taylor, S. F., Welsh, R. C., Ho, S. H., Britton, J. C. and Liberzon, I. (2004), Neural correlates of individual ratings of emotional salience: a trial-related fMRI study. **NeuroImage**, 21 (2)**,** 768-780.

Phelps, E. A. (2006), Emotion and cognition: Insights from studies of the human amygdala. **Annual Review of Psychology**, 24 (57)**,** 27-53.

Phelps, E. A. and LeDoux, J. E. (2005), Contributions of the amygdala to emotion processing: from animal models to human behavior. **Neuron**, 48 (2)**,** 175-187.

Phelps, E. A., Ling, S. and Carrasco, M. (2006), Emotion facilitates perception and potentiates the perceptual benefits of attention. **Psychological Science**, 17 (4)**,** 292-299.

Phillips, M. L., Drevets, W. C., Rauch, S. L. and Lane, R. (2003), Neurobiology of emotion perception I: the neural basis of normal emotion perception. **Biological Psychiatry**, 54 (5)**,** 504-514.

Phillips, M. L., Williams, L. M., Heining, M., Herba, C. M., Russell, T., Andrew, C., Bullmore, E. T., Brammer, M. J., Williams, S. C. R., Morgan, M., Young, A. W. and Gray, J. A. (2004), Differential neural responses to overt and covert presentations of facial expressions of fear and disgust. **NeuroImage**, 21 (4)**,** 1484-1496.

Phillips, M. L., Young, A. W., Scott, S. K., Calder, A. J., Andrew, C., Giampietro, V., Williams, S. C. R., Bullmore, E. T., Brammer, M. J. and Gray, J. A. (1998), Neural responses to facial and vocal expressions of fear and disgust. **Proc. R. Soc. Lond.B. Biol. Sci**, 265 (1408)**,** 1809-1817.

Phillips, M. L., Young, A. W., Senior, C., Brammer, M., Andrew, C., Calder, A. J., Bullmore, E. T., Perrett, D. I., Rowland, D., Williams, S. C., Gray, J. A. and David, A. S. (1997), A specific neural substrate for perceiving facial expressions of disgust. **Nature**, 389 (6650)**,** 495-498.

Posner, J., Russell, J. A. and Peterson, B. S. (2005), The circumplex model of affect: An integrative approach to affective neuroscience, cognitive development, and psychopathology. **Dev Psychobiol**, 17 (3)**,** 715-734.

Posner, M. I. (1980), Orienting of attention. **The Quarterly Journal of Experimental Psychology**, 32 (1)**,** 3-25.

Posner, M. I. (1994), Attention: The mechanisms of consciousness. **PNAS**, 91 (16)**,** 7398-7404.

Posner, M. I., Snyder, C. R. R. and Davidson, B. J. (1980), Attention and the detection of signals. **Journal of Experimental Psychology: General**, 109 (2)**,** 160-174.

Potter, M. C. (1976), Short-term conceptual memory for pictures. **Journal of Experimental Psychology: Human Learning and Memory**, 2 (5)**,** 509-522.

Potter, M. C. and Levy, E. I. (1969), Recognition memory for a rapid sequence of pictures. **Journal of Experimental Psychology**, 81 (1)**,** 10-15.

Prado, J., Clavagnier, S., Otzenberger, H., Scheiber, C., Kennedy, H. and Perenin, M.-T. (2005), Two cortical systems for reaching in central and peripheral vision. **Neuron**, 48 (5)**,** 849-858.

Pribram, K. H. (1998), A Century of Progress. In Neuroscience of the Mind on the Centennial of Freud's Project for a Scientific Psychology, Vol. 843 (Eds, Bilder, R. M. and LeFever, F. F.) New York Academy of Sciences, New York, pp. 11-19; 185pp

Reddy, L., Wilken, P. and Koch, C. (2004), Face-gender discrimination is possible in the near-absence of attention. **Journal of Vision**, 4 (2)**,** 106-117.

Rees, G., Frith, C. D. and Lavie, N. (1997), Modulating irrelevant motion perception by varying attentional load in an unrelated task. **Science**, 278 (5343)**,** 1616-1619.

Rees, G., Wojciulik, E., Clarke, K., Husain, M., Frith, C. and Driver, J. (2000), Unconscious activation of visual cortex in the damaged right hemisphere of a parietal patient with extinction. **Brain**, 123 (8)**,** 1624-1633.

Reiman, E. M., Lane, R. D., Ahern, G. L., Schwartz, G. E., Schwartz, G. E., Davidson, R. J., Friston, K. J., Yun, L. S. and Chen, K. (1997), Neuroanatomical correlates of externally and internally generated human emotion. **American Journal of Psychiatry**, 154 (7)**,** 918-925.

Reinders, A. A. T. S., Gläscher, J., de Jong, J. R., Willemsen, A. T. M., den Boer, J. A. and Büchel, C. (2006), Detecting fearful and neutral faces: BOLD latency differences in amygdala - hippocampal junction. **Neurolmage**, 33 (2)**,** 805-814.

Reingold, E. M. (1992), Conscious versus unconscious processes: Are they qualitatively different? **Behavioral and Brain Sciences.**, 15 (2)**,** 218-219.

Reingold, E. M. and Merikle, P. M. (1990), On the inter-relatedness of theory and measurement in the study of unconscious processes. **Mind and Language**, 5 (1)**,** 9-28.

Ribeiro, R. L., Teixeira-Silva, F., Pompéia, S. and Bueno, O. F. A. (2007), IAPS includes photographs that elicit low-arousal physiological responses in healthy volunteers. **Physiology and Behavior**, 91 (15)**,** 671-675.

Robertson, E. M., Tormos, J. M., Maeda, F. and Pascual-Leone, A. (2001), The role of the dorsolateral prefrontal cortex during sequence learning is specific for spatial information. **Cerebral Cortex**, 11 (7)**,** 628-635.

Robichaud, L. and Stelmach, L. B. (2003), Inducing blindsight in normal observers. **Psychonomic bulletin & review**, 10 (1)**,** 206-209.

Rolls, E. T. (2005) Emotion Explained, Oxford University Press, Oxford.

Rosch, E. (1975), Cognitive representations of semantic categories. **Journal of Experimental Psychology: General**, 104 (3)**,** 192-233.

Rosch, E. and Mervis, C. B. (1975), Family resemblances: studies in the internal structure of categories. **Cognitive Psychology**, 7 (4)**,** 573-605.

Rose, D. (2006) Consciousness: Philosophical, Psychological and Neural Theories, Oxford University Press, Oxford.

Ross, E. D. (1984), Right hemisphere's role in language, affective behaviour and emotion. **Trends in Neuroscience**, 7 (342-346).

Rousselet, G. A., Fabre-Thorpe, M. and Thorpe, S. J. (2002), Parallel processing in high-level categorization of natural images. **Nature Neuroscience**, 5 (7)**,** 629-630.

Rousselet, G. A., Joubert, O. R. and Fabre-Thorpe, M. (2005), How long to get to the ``gist'' of real-world natural scenes? **Visual Cognition**, 12 (6)**,** 852-877.

Rousselet, G. A., Macé, M. J. M. and Fabre-Thorpe, M. (2003), Is it an animal? Is it a human face? Fast processing in upright and inverted natural scenes. **Journal of Vision**, 3 (6)**,** 440-455.

Rousselet, G. A., Macé, M. J. M. and Fabre-Thorpe, M. (2004a), Animal and human faces in natural scenes: How specific to human faces is the N170 ERP component? **Journal of Vision**, 4 (1)**,** 13-21.

Rousselet, G. A., Macé, M. J. M. and Fabre-Thorpe, M. (2004b), Comparing animal and face processing in the context of natural scenes using a fast categorization task. **Neurocomputing**, 58-60 783-791.

Rousselet, G. A., Thorpe, S. J. and Fabre-Thorpe, M. (2004c), Processing of one, two or four natural scenes in humans: the limits of parallelism. **Vision Research**, 44 (9)**,** 877-894.

Rozin, P., Lowery, L. and Ebert, R. (1994), Varieties of disgust faces and the structure of disgust. **Journal of Personality and Social Psycholology,**, 66 (5)**,** 870-881.

Russell, J. A. (1980), A circumplex model of affect. **Journal of Personality and Social Psychology**, 39 (6)**,** 1161-1178.

Ryle, G. (1949) The Concept of Mind, University of Chicago Press, Chicago.

Sabatinelli, D., Bradley, M. M., Fitzsimmons, J. R. and Lang, P. J. (2005), Parallel amygdala and inferotemporal activation reflect emotional intensity and fear relevance. **NeuroImage**, 24 (4)**,** 1265-1270.

Sackheim, H. A., Greenberg, M. S., Weiman, A. L., Gur, R. C., Hungerbuhler, J. P. and Geschwind, N. (1982), Hemispheric asymmetry in the expression of positive and negative emotions. Neurologic evidence. **Archives of Neurology**, 39 (4)**,** 210-218.

Sah, P., Faber, E. S. L., Lopez, D. A. M. and Power, J. (2003), The amygdaloid complex: Anatomy and physiology. **Physiol Rev**, 83 (3)**,** 803-834.

Sander, D., Grandjean, D., Pourtois, G., Schwartz, S., Seghier, M. L., Scherer, K. R. and Vuilleumier, P. (2005), Emotion and attention interactions in social cognition: Brain regions involved in processing anger prosody. **Neuroimage**, 28 (4)**,** 848-858.

Scharli, H., Brugger, P., Regard, M., Mohr, C. and Landis, T. (2003), Localisation of "unseen" visual stimuli: Blindsight in normal observers? **Swiss Journal of Psychology**, 62 (3)**,** 159-165.

Schroeder, U., Hennenlotter, A., Erhard, P., Haslinger, B., Stahl, R., Lange, K. W. and Ceballos-Baumann, A. O. (2004), Functional neuroanatomy of perceiving surprised faces. **Hum Brain Mapping**, 23 (4)**,** 181-187.

Schultz, R. T., Grelotti, D. J., Klin, A., Kleinman, J., Van der Gaag, C., Marois, R. and Skudlarski, P. (2003), The role of the fusiform face area in social cognition: implications for the pathobiology of autism. **Philosophical Transactions R Soc Lond: Biological Sciences**, 358 (1430)**,** 415-427.

Schupp, H. T., Cuthbert, B. N., Bradley, M. M., Cacioppo, J. T., Ito, T. and Lang, P. J. (2000), Affective picture processing: The late positive potential is modulated by motivational relevance. **Psychophysiology**, 37 (2)**,** 257-261.

Schupp, H. T., Junghofer, M., Weike, A. I. and Hamm, A. O. (2003), Emotional facilitation of sensory processing in the visual cortex. **Psychological Science**, 14 (1)**,** 7-13.

Schupp, H. T., Junghöfer, M., Weike, A. I. and Hamm, A. O. (2004), The selective processing of briefly presented affective pictures: an ERP analysis. **Psychophysiology**, 41 (3)**,** 441-449.

Sergerie, K., Lepage, M. and Armony, J. L. (2005), A face to remember: emotional expression modulates prefrontal activity during memory formation. **NeuroImage**, 24 (2)**,** 580-585.

Sherrington, C. S. (1897), The Central Nervous System. In A Textbook of Physiology, (Ed, Foster, M.) Macmillan and Company, New York, pp. 582-594

Simons, D. J. and Levin, D. T. (1997), Change Blindness. **Trends In Cognitive Sciences**, 1 (7)**,** 261-267.

Simpson, J. R., Drevets, W. C., Snyder, A. Z., Gusnard, D. A. and Raichle, M. E. (2001a), Emotion-induced changes in human medial prefrontal cortex: II. During anticipatory anxiety. **PNAS**, 98 (2)**,** 688-693.

Simpson, J. R., Snyder, A. Z., Gusnard, D. A. and Raichle, M. E. (2001b), Emotion-induced changes in human medial prefrontal cortex: I. During cognitive task performance. **PNAS**, 98 (2)**,** 683-687.

Singer, T., Seymour, B., O'Doherty, J., Kaube, H., Dolan, R. J. and Frith, C. D. (2004), Empathy for pain involves the affective but not sensory components of pain. **Science**, 303 (5661)**,** 1157-1162.

Skottun, B. C. and Skoyles, J. R. (2006), The use of phantom contours to isolate magnocellular and parvocellular responses. **International Journal of Neuroscience**, 116 (3)**,** 315-320.

Small, D. M., Gitelman, D. R., Gregory, M. D., Nobre, A. C., Parrish, T. B. and Mesulam, M. M. (2003), The posterior cingulate and medial prefrontal cortex mediate the anticipatory allocation of spatial attention. **NeuroImage**, 18 (3)**,** 633-641.

Smith, J. C., Low, A., Bradley, M. M. and Lang, P. J. (2006), Rapid picture presentation and affective engagement. **Emotion**, 6 (2)**,** 208-214.

Smith, S. D. and Bulman-Fleming, M. B. (2004), A hemispheric asymmetry for the unconscious perception of emotion. **Brain and Cognition**, 55 (3)**,** 452-457.

Solms, M. (1998), Before and after Freud's Project. In Neuroscience of the Mind on the Centennial of Freud's Project for a Scientific Psychology, Vol. 843

(Eds, Bilder, R. M. and Lefever, F. F.) New York Academy of Sciences, New York, pp. 1-10; 185pp

Solms, M. and Turnbull, O. (2002) The Brain and the Inner World: An introduction to the neuroscience of subjective experience, H. Karnac (Books) Ltd., London.

Sperling, G. and Weichselgartner, E. (1995), Episodic theory of the dynamics of spatial attention. **Psychological Review**, 102 (3)**,** 503-532.

Sprengelmeyer, R., Rausch, M., Eysel, U. T. and Przuntek, H. (1998), Neural structures associated with recognition of facial expressions of basic emotions. **Proc. R. Soc. Lond.B. Biol. Sci**, 265 (1409)**,** 1927-1931.

SPSS Inc, SPSS. (10.1-13.0.1), [Computer program]. Chicago, IL. USA: SPSS Inc.

Tabachnick, B. G. and Fidell, L. S. (2001) Using Multivariate Statistics, Allyn and Bacon, Boston.

Takeuchi, S., Mochizuki, Y., Masaki, H., Takasawa, N. and Yamazaki, K. (2005), Stimulus preceding negativity represents arousal induced by affective picture. **International Congress Series**, 1278 385-388.

Taylor, S. F., Phan, K. L., Decker, L. R. and Liberzon, I. (2003), Subjective rating of emotionally salient stimuli modulates neural activity. **NeuroImage**, 18 (3)**,** 650-659.

Thorpe, S. J. (2002), Ultra-rapid scene categorization with a wave of spikes. In Biologically Motivated Computer Vision: Second International Workshop, Vol. 2525 (Eds, Bülthoff, H. H., Lee, S.-W., Poggio, T. A. and Wallraven, C.) Springer-Verlag Berlin, Heidelberg, pp. 335-351 (662)

Thorpe, S. J., Crouzet, S., Kirchner, H. and Fabre-Thorpe, M. (2006), Ultra rapid face detection in natural images: implications for computation in the visual system. **Neurocomputing**, 6.

Thorpe, S. J., Delorme, A. and VanRullen, R. (2001a), Spike based strategies for rapid processing. **Neural Networks**, 14 (6-7)**,** 715-725.

Thorpe, S. J., Fize, D. and Marlot, C. (1996), Speed of processing in the human visual system. **Nature**, 381 (6582)**,** 520-522.

Thorpe, S. J., Gegenfurtner, K. R., Fabre-Thorpe, M. and Bülthoff, H. H. (1999), Categorisation of complex natural images in extreme peripheral vision. **Perception**, 28 (ECVP Supplement)**,** 61.

Thorpe, S. J., Gegenfurtner, K. R., Fabre-Thorpe, M. and Bülthoff, H. H. (2001b), Detection of animals in natural images using far peripheral vision. **European Journal of Neuroscience**, 14 (5)**,** 869-876.

Thorpe, S. J., Guyonneau, R., Guilbaud, N., Allegraud, J.-M. and VanRullen, R. (2004), SpikeNet: real-time visual processing with one spike per neuron. **Neurocomputing**, 58-60 857-864.

Thorpe, S. J. and Imbert, M. (1989), Biological Constraints on Connectionist Modelling. In Connectionism in perspective, (Eds, Pfeifer, R., Fogelman-Soulie, F., Steels, L. and Schreter, Z.) Elsevier, Amsterdam, pp. 63-93

Tranel, D., Damasio, H. and Damasio, A. R. (1997), A neural basis for the retrieval of conceptual knowledge. **Neuropsychologia**, 35 (10)**,** 1319-1327.

Treisman, A. M. and Gelade, G. (1980), A feature-integration theory of attention. **Cognitive Psychology**, 12 (1)**,** 97-136.

Treue, S. (2003), Visual attention: the where, what, how and why of saliency. **Current Opinion in Neurobiology**, 13 (4)**,** 428-432.

Tucker, D. M. (1981), Lateral brain function, emotion, and conceptualization. **Psychological Bulletin**, 89 (1)**,** 19-46.

VanRullen, R. (2007), The power of the feed forward sweep. **Advances in Cognitive Psychology Special Issue**, 3 (1-2)**,** 167-176.

VanRullen, R., Gautrais, J., Delorme, A. and Thorpe, S. J. (1998), Face processing using one spike per neurone. **BioSystems**, 48 (1)**,** 229-239.

VanRullen, R. and Koch, C. (2003a), Competition and selection during visual processing of natural scenes and objects. **Journal of Vision**, 3 (1)**,** 75-85.

VanRullen, R. and Koch, C. (2003b), Visual selective behavior can be triggered by a feed-forward process. **Journal of Cognitive Neuroscience**, 15 (2)**,** 209-217.

VanRullen, R., Reddy, L. and Li, F.-F. (2005), Binding is a local problem for natural objects and scenes. **Vision Research**, 45 (25-26)**,** 3133-3144.

VanRullen, R. and Thorpe, S. J. (2001a), Is it a bird? Is it a plane? Ultra-rapid visual categorisation of natural and artifactual objects. **Perception**, 30 (6)**,** 655-668.

VanRullen, R. and Thorpe, S. J. (2001b), Rate coding versus temporal order coding: what the retinal ganglion cells tell the visual cortex. **Neural Computation**, 13 (6)**,** 1255-1283.

VanRullen, R. and Thorpe, S. J. (2001c), The time course of visual processing: from early perception to decision-making. **Journal of Cognitive Neuroscience**, 13 (4)**,** 454-461.

Vuilleumier, P. (2002), Facial expression and selective attention. **Current Opinion in Psychiatry**, 15 (3)**,** 291-300.

Vuilleumier, P., Armony, J. L., Clarke, K., Husain, M., Driver, J. and Dolan, R. J. (2002), Neural response to emotional faces with and without awareness: event-related fMRI in a parietal patient with visual extinction and spatial neglect. **Neuropsychologia**, 40 (12)**,** 2156-2166.

Vuilleumier, P., Armony, J. L. and Dolan, R. (2003a), Reciprocal Links Between Emotion and Attention. In Human Brain Function, (Eds, Frackowiak, R. S. J., Friston, K. J., Firth, C. D., Dolan, R. J., Price, C. J., Zeki, S., Ashburner, J. and Penny, W.) Academic Press, San Diego, pp. 419-444

Vuilleumier, P., Armony, J. L., Driver, J. and Dolan, R. J. (2001), Effects of attention and emotion on face processing in the human brain: an event-related fMRI study. **Neuron**, 30 (3)**,** 829-841.

Vuilleumier, P., Armony, J. L., Driver, J. and Dolan, R. J. (2003b), Distinct spatial frequency sensitivities for processing faces and emotional expressions. **Nature Neuroscience**, 6 (6)**,** 624-631.

Vuilleumier, P. and Driver, J. (2007), Modulation of visual processing by attention and emotion: windows on causal interactions between human brain regions. **Phil. Trans. R Soc. Lond. B**, 362 (1481)**,** 837-855.

Wada, Y. and Yamamoto, T. (2001), Selective impairment of facial recognition due to a haematoma restricted to the right fusiform and lateral occipital region. **Journal of Neurology, Neurosurgery and Psychiatry**, 71 (2)**,** 254-257.

Wager, T. D., Phan, K. L., Liberzon, I. and Taylor, S. F. (2003), Valence, gender, and lateralisation of functional brain anatomy in emotion: a meta analysis of indings from neuroimaging. **Neuroimage**, 19 (3)**,** 513-531.

Walker, S., Stafford, P. and Davis, G. (2008), Ultra-rapid categorization requires visual attention: Scenes with multiple foreground objects. **Journal of Vision**, 8 (4, Article 21)**,** 1-12.

Walther, D. and Koch, C. (2006), Modelling attention to salient proto-objects. **Neural Networks**, 19 (9)**,** 1395–1407.

Warrington, E. K. and Shallice, T. (1984), Category specific semantic impairments. **Brain**, 107 (3)**,** 829-854.

Watson, D., Clark, L. A. and Tellegen, A. (1988), Development and validation of brief measures of positive and negative affect: The PANAS Scales. **Journal of Personality and Social Psychology**, 47 1063-1070.

Watson, D. and Tellegen, A. (1985), Toward a Consensual Structure of Mood. **Psychological Bulletin**, 98 (2)**,** 219-235.

Weiskrantz, L., Warrington, E. K., Sanders, M. D. and Marshall, J. (1974), Visual capacity in the hemianopic field following a restricted occipital ablation. **Brain**, 97 (4)**,** 709-728.

Whalen, P. J., Bush, G., McNally, R. J., Wilhelm, S., McInerney, S. C., Jenike, M. A. and Rauch, S. L. (1998a), The emotional counting Stroop paradigm: a functional magnetic resonance imaging probe of the anterior cingulate affective division. **Biological Psychiatry**, 44 (12)**,** 1219-1228.

Whalen, P. J., Rauch, S. L., Etcoff, N. L., McInerney, S. C., Lee, M. B. and Jenike, M. A. (1998b), Masked presentations of emotional facial expressions modulate amygdala activity without explicit knowledge. **The Journal of Neuroscience**, 18 (1)**,** 411-418.

Whalen, P. J., Shin, L. M., McInerney, S. C., Fischer, H., Wright, C. I. and Rauch, S. L. (2001), A functional MRI study of human amygdala responses to facial expressions of fear versus anger. **Emotion**, 1 (1)**,** 70-83.

Williams, L. M., Liddell, B. J., Kemp, A. H., Bryant, R. A., Meares, R. A., Peduto, A. S. and Gordon, E. (2006), Amygdala prefrontal dissociation of subliminal and supraliminal fear. **Hum Brain Mapping**, 27 (8)**,** 652– 661.

Williams, M. A., McGlone, F., Abbott, D. F. and Mattingley, J. B. (2005), Differential amygdala responses to happy and fearful facial expressions depend on selective attention. **NeuroImage**, 24 (2)**,** 417-425.

Winston, J. S., O'Doherty, J. and Dolan, R. J. (2003), Common and distinct neural responses during direct and incidental processing of multiple facial emotions. **NeuroImage**, 20 (1)**,** 84-97.

Wojciulik, E., Kanwisher, N. and Driver, J. (1998), Covert visual attention modulates face-specific activity in the human fusiform gyrus: fMRI study. **Journal of Neurophysiol**, 79 (3)**,** 1574-1578.

Wrase, J., Klein, S., Gruesser, S. M., Hermann, D., Flor, H., Mann, K., Braus, D. F. and Heinz, A. (2003), Gender differences in the processing of standardized emotional visual stimuli in humans: a functional magnetic resonance imaging study. **Neuroscience Letters**, 348 (1)**,** 41-45.

Wright, M. J. (2005), Saliency predicts change detection in pictures of natural scenes. **Spatial Vision**, 18 (4)**,** 413-430.

Xiao, D. and Barbas, H. (2004), Circuits through prefrontal cortex, basal ganglia, and ventral anterior nucleus map pathways beyond motor control. **Thalamus & related systems**, 2 (4)**,** 325-343.

Yang, J.-C. (2004), Functional neuroanatomy in depressed patients with sexual dysfunction: blood oxygenation level dependent functional MR imaging. **Korean Journal of Radiology**, 5 (2)**,** 87-95.

Zajonc, R. B. (1962), Response suppression in perceptual defense. **Journal of Experimental Psychology**, 64 (3)**,** 206-214.

Zald, D. H. (2003), The human amygdala and the emotional evaluation of sensory stimuli. **Brain Research Reviews**, 41 (1)**,** 88-123.

Zeki, S., Watson, J. D. G., Lueck, C. J., Friston, K. J., Kennard, C. and Frackowiak, R. S. J. (1991), A direct demonstration of functional specialization in human visual cortex. **Journal of Neuroscience**, 11 (3)**,** 641-649.

Zeman, A. (2001), Consciousness. **Brain**, 124 (7)**,** 1263-1289.

Zipern, K. (2004), Fleeting Images of Fearful Faces Reveal Neurocircuitry of Unconscious Anxiety. In Science Daily, 15 December 2004, Columbia, Press release Columbia University Medical Center.

Appendices

Appendix I

Rules of Operation

of the

Combined University's Brain Imaging Centre

(CUBIC)

Royal Holloway

University of London

Magnetic Resonance Imaging Unit

RULES OF OPERATION

February 2004

This version was approved by the Policy Committee on 9 February 2004.
It supersedes all previous versions, copies of which should be destroyed.

Contents

APPENDICES

1. INTRODUCTION

This document governs the use of the magnetic resonance (MR) scanner installed on the campus of Royal Holloway, University of London and jointly owned by Royal Holloway, the University of Reading, the University of Surrey and Brunel University.

Although there are no known adverse effects to humans from the static or time-varying electromagnetic fields used in MR scanning, there is a need for caution for a number of reasons:

- The static field can cause pacemakers or other implanted devices to malfunction and cause other metal implants or shards to move.
- The static magnetic field can cause loose ferro-magnetic articles to become projectile causing injury or death to persons near or in the magnet bore.
- The static field can cause damage to personal possessions such as analogue watches and credit cards.
- The gradient field can cause peripheral nerve stimulation.
- Radiofrequency (RF) exposure can heat tissue, particularly if any metallic implants or objects are present.

The MRI scanner therefore can pose a dangerous environment unless operated according to strict safety protocols.

This document outlines the rules that MR scanner users MUST adhere to, in order to ensure the safety of themselves, colleagues and participants. It has been drawn up by the Management Committee and approved by the Policy Committee as constituted by the Memorandum of Agreement among the four universities dated October 2002. ALL users of the scanner, whatever their affiliations, MUST adhere strictly to its provisions.

This document is compiled from all the currently available safety literature, the main reference source being the *GUIDELINES FOR MAGNETIC RESONANCE DIAGNOSTIC EQUIPMENT IN CLINICAL USE, WITH PARTICULAR REFERENCE TO SAFETY (MEDICAL DEVICES AGENCY).*

PERSONNEL AND RESPONSIBILITIES

As with all Health and Safety directives, all personnel have a responsibility to behave sensibly and ensure the well-being of themselves, their colleagues, participants in MRI examinations and any other visitors. Some personnel (*THE AUTHORISED PERSONNEL)* have additional responsibilities; these people are identified in Appendix 2.

2. DESIGNATION OF THE CONTROLLED AREA

2.1 A plan of the MRI unit is shown in Appendix 1. Within the unit there exists a **Controlled Area** which totally encloses the 0.5 mT (5 Gauss) magnetic field contour. The extent of the controlled area is shown in Appendix 1.
2.2 Access to the controlled area is through the Preparation Room, which is entered via a door with a security-coded lock to prevent unauthorised access.
2.3 All unauthorised personnel including unauthorised staff and visitors must be screened and must be supervised by an authorised person at all times whilst within the controlled area (see Sections 3 and 4). All objects and equipment must similarly be screened.

3. WORKING PROCEDURES: GENERAL RULES

3.1 No person or object must enter the controlled area without screening by an authorised person to ensure that entry is safe.

3.2 These rules are in addition to and can be seen as an extension of the Health and Safety at Work Act. This clearly lays down the mandatory responsibilities and statutory requirements of the employer, employees and visitors who have access to the place of work. All the terms of the Act must be adhered to, including that persons must behave in a responsible and considerate manner in order not to endanger themselves or others and to maintain a good working atmosphere.
3.3 Equipment must only be used by trained and competent personnel.
3.4 Equipment must be properly used, serviced and maintained in a good state of repair. If faults occur that prevent normal safe operation of the equipment, the equipment must be taken out of service until repaired and passed fit for use. ALL faults must be reported and a record kept. The procedure for the reporting and documentation of faults must be followed (see Section 6)**.**
3.5 Working areas and exits should be kept clean, tidy and free from obstruction.
3.6 Should the use of equipment produce an accident, near miss or hazardous situation, operation must cease immediately until the cause is investigated and the hazard is removed.
3.7 An Accident/Incident Report Form must be completed without delay following any accident or hazardous situation. Copies of this form are kept in the Control Room. The incident should also be reported immediately to the MRI Safety Officer (see Appendix 2).
3.8 In the event of an emergency such as fire, local procedures must be followed (see Section 5 and Appendix 6). All personnel should know the location of fire alarms and escape routes.

4. WORKING PROCEDURES: MRI-SPECIFIC RULES

4.1 Control of access

4.1.1 Authorised Personnel (defined in Appendix 2), and other persons with the authority of the MRI Safety Officer (see Appendix 2), have free access to parts of the MRI Unit that are NOT WITHIN THE CONTROLLED AREA. Screening is not necessary in order to enter the outer rooms of the Unit.
4.1.2 No person may enter the controlled area unless at least TWO able-bodied adults, both of whom have been screened in the previous 12 months and have removed all metal items from their clothing, and at least one of whom is an Authorised Person, are present in the MRI Unit. No person may be placed inside the scanner unless at least TWO AUTHORISED PERSONS, at least one of whom is an employee of one of the four universities and at least one of whom has full (as opposed to probationary; see Appendix 2) status, are present in the MRI Unit. The boundaries of the MRI Unit are defined on the plan in Appendix 1. NO person, whatever their status, may enter the controlled area when alone in the MRI Unit.
4.1.3 Authorised Personnel must be trained in MR safety to a level prescribed by the MRI Safety Officer. They must be screened at least on a yearly basis, with records of screening kept securely in the MRI unit. Any person who is not an Authorised Person but who assists an Authorised Person in order to permit entry to the Controlled Area (see 4.1.2) must first receive basic training in safety as prescribed by the MRI Safety Officer.
4.1.4 Unauthorised Personnel and objects DO NOT have free access to the controlled area. **This includes domestic services; responsibility for cleaning the controlled area resides with the authorised personnel.**
4.1.5 All people and objects must be “screened” (see Section 4.2) by authorised personnel before access to the controlled area is permitted. Screening people requires the written questionnaires shown in Appendix 3 to be completed and to show no contra-indications for access.
4.1.6 The outer door to the MRI unit must be kept closed at all times – even when the area is being supervised by an authorised person. Admission is by security code only. Only authorised persons will have access to this code. The code must not be divulged to others and any inadvertent disclosure must be reported to the MRI Safety Officer, who will then change the code.

4.1.7 When the MRI unit is not in use, the following doors must be kept locked:

Unit outer door
Examination room door
Preparation Room door
Equipment room door

These doors are identified in Appendix 1.

4.2 Screening

4.2.1 Only Authorised Personnel are permitted to "screen" participants and other visitors. The person must understand, complete and sign two written questionnaires (see Appendix 3). The authorised person must then decide if access is safe for the participant, using the rules and guidelines in Appendix 3.

4.2.2 ALL persons must undergo primary screening before access to the controlled area is permitted. Primary screening must exclude the presence of the following from the controlled area:

Any person fitted with a cardiac pacemaker.

4.2.3 All persons and objects must undergo secondary screening before access to the controlled area is permitted. Secondary screening must exclude the following from the controlled area:

Aneurysm clips of any type
Occlusive clips or pins
Heart valve replacements and cochlear implants
Mechanical/Electrical/Magnetically operated devices
People with metallic splinters in the eye or other remaining metal from injury
Catheters and intra-venous devices
Persons under 18 years of age
Pregnant women
Mechanical watches, credit cards, magnetic tapes, other magnetic recording media.
All loose ferro-magnetic objects about a person such as dentures, hair grips, hearing aids, jewellery (except wedding ring), keys, money, pens, scissors, spectacles and tools
All other ferro-magnetic objects including gas cylinders, trolleys and computer equipment, but with the exception of certain small items of equipment (e.g. photometers and other optical equipment) which may be taken into the controlled area for specific purposes provided that express permission is granted by the MRI Safety Officer, that the MRI Safety Officer is present in the controlled area and that no persons other than authorised personnel are present in the controlled area at the time

4.2.4 Persons to be given an MRI examination must undergo additional screening, to identify the following:

People suffering from epilepsy, thermoregulatory problems or diabetes
People with intra-uterine contraceptive devices in place
People with implants or prostheses that are known to be made of non-ferro-magnetic materials and are not specifically excluded in 4.2.3 above

Such people are not excluded from entering the controlled area without being scanned. They may only be scanned after appropriate medical consultation and approval. Any medical recommendations for supervision during scanning must be implemented if the scan proceeds.

4.3 MRI Examination

4.3.1 Only participants who have been approved by an authorised person are permitted to be scanned.

4.3.2 Only Authorised Personnel who are trained are permitted to operate the equipment.

4.3.3 The person operating the equipment on any given occasion is personally responsible for ensuring that the participant has been properly screened, even if the examination has been arranged and approved by another authorised person.

4.3.4 All participants must be fully consenting adults and must have given written informed consent, using the approved form (Appendix 4). The person operating the scanner is personally responsible for ensuring that this has been done. The participant must be free to withdraw such consent and to withdraw from the experiment at any time.

4.3.5 The purpose and nature of the examination should be explained to the participant, who must be given the opportunity to ask questions.

4.3.6 Contrast agents must not be administered and no other invasive procedure may be performed.

4.3.7 A record must be maintained of all persons who are scanned (see Section 7).

4.3.8 A record must be maintained of the screening forms for all persons entering the controlled area. These must be treated as confidential and held in a locked cabinet in the MRI Unit.

4.3.9 An alarm buzzer must be available to participants during their examination. The operation of the alarm must be explained to participants before scanning commences and the alarm should be tested regularly.

4.3.10 The Operator must check every few minutes (normally via the intercom) that the participant is comfortable.

4.3.11 If a participant experiences undue discomfort or distress during scanning, the examination must stop.

4.3.12 Suitable earplugs or sound-attenuating earphones must be provided to all participants. Where participants refuse to wear the hearing protection provided, they must not be scanned. Earplugs must be of disposable type and discarded after a single use. Where earphones are used these should be adequately maintained and inspected on a regular basis, and cleaned after each use. If fitted with disposable ear inserts, these must be discarded after a single use. Any damage to the earphones should be reported immediately to the MRI Safety Officer.

4.3.13 Persons must not be examined during servicing or be in position in the scanner during switch on/off of the magnet (except in emergency).

4.3.14 Only equipment that is safe and designed for the purpose may be connected to the MR scanner or used within the controlled area (see also Appendix 3).

4.3.15 If a participant who is unable to position him/herself on the bed unaided is to be scanned, assistance should be given but only by prior arrangement with the MRI Safety Officer and only by staff who are trained in such procedures.

4.4 Result of examination

4.4.1 Scanning of human participants should be performed for research purposes only, using volunteers who are either healthy or have a known, previously documented neurological abnormality which does not present a contraindication for MRI.

4.4.2 In the event that a scan reveals a suspected abnormality that was unknown to the authorised person in charge of the scan and which they suspect might require treatment, the following procedure must be adopted.

(i) So as to avoid distress to participants arising from false alarms, staff *must not disclose their concerns to the participant*.

(ii) The authorised person involved must, without delay, report his/her concerns to the MRI Safety Officer and supply a high-quality print displaying the suspected abnormality.

(iii) The MRI Safety Officer should, as a matter of urgency, write to the participant's General Practitioner (whose name must be supplied by the

participant prior to scanning; see Section 7 and Appendix 3), enclosing the print and describing the cause for concern. The letter should state whether or not the person expressing concern is medically qualified. It should also state that the participant concerned has not been informed and that the decision as to whether the participant should be informed, and the task of informing, are referred to the GP.
(iv) In the interests of participant confidentiality, the authorised person concerned should not discuss the situation with colleagues or other participants.

4.4.3 Assuming that there is no suspicion of abnormality, staff are encouraged, but not required, to offer to provide the participant with a sample image obtained during the examination, either electronically or in printed form as the participant prefers.

4.5 Exposure limits
4.5.1 The time spent in the magnet by any one person must not exceed 90 minutes in any 24-hour period. Other than this, there is no restriction on the frequency with which a screened person may be scanned.
4.5.2 The exposure of any one person to the static magnetic field must not exceed an average of 0.2 Tesla, averaged over any 24-hour period. In practice, this means that operators and others may work within the MR Unit but outside the controlled area for unlimited periods, provided that they enter the controlled area only occasionally and for short periods, to supervise volunteers. An operator standing by the bore opening will experience a field of the order of 0.5T.

5. EMERGENCY PROCEDURES

Current emergency procedures are described in Appendix 5 and Appendix 6.

5.1 Should any part of the system fail that may endanger participants, staff or equipment, the examination must stop and the participant must be removed from the scanner. If there is a risk of damage to the equipment, an authorised person must then electrically isolate the equipment by pressing one of the red ‘stop’ buttons in the Control Room and Examination Room. No further scanning is permitted to take place until the fault has been corrected.
5.2 Emergency shutdown of the magnet (quenching) must only be undertaken by authorised personnel, only after due consideration of the relative risks and only in one of the following circumstances (see also Appendix 5):

(i) if a participant or other person is in a life-threatening situation resulting directly from the magnetic field. If the endangered person is in the scanner, the magnet should be quenched before the person is removed from the scanner.
(ii) if the emergency services, e.g. fire service, require access to the controlled area with ferromagnetic equipment. In this event, the participant must be removed from the scanner before the magnet is quenched.

NOTE: The magnet MUST be quenched before the emergency services may have access to the controlled area.

5.3 In the event of a medical emergency occurring in the controlled area, medical help must be summoned immediately (see Appendix 5). If possible, the affected person should be removed from the controlled area before treatment commences. If this is difficult or unsafe, first aid may be administered within the controlled area, but only by a person who is qualified in first aid, has been screened within the past 12 months and has removed any loose metal objects from their person. If treatment by medical or paramedical staff who have not been screened is necessary, the affected person must be removed from the

controlled area before such treatment commences. An MR-safe patient trolley is kept in the examination room at all times. If the affected person is unable to walk, even with assistance, he/she should be moved onto the trolley and wheeled out of the controlled area. This must be done by authorised persons, all of whom have been trained in this procedure.
5.4 In the event of a fire, the fire procedure (see Appendix 6) must be followed. If evacuation is required, all participants and visitors must be removed from the scanner area, taking due care of the magnetic field. All doors must be secured on leaving especially those that govern access to the controlled area. Note that the fire alarm does not automatically unlock doors to the controlled area.

6 REPORTING OF FAULTS

6.1 ALL faults must be (i) reported to the MRI Safety Officer (see Appendix 2) at the earliest opportunity and (ii) documented in the Faults Book, which is kept in the Control Room.
6.2 If faults occur that prevent normal safe operation of the equipment, it must be taken out of service until repaired and passed fit for use.
6.3 Should the use of equipment produce an accident, near miss or hazardous situation, operation must cease immediately until the cause is investigated and the hazard is removed.
6.4 To minimize inconvenience, faults should also be reported to all other authorised users who may be intending to use the equipment in the following 48 hours.
6.5 In the event of a fault that prevents normal safe operation:

- The MRI Safety Officer must be informed
- The fault must be recorded in the Incident Book
- The room must be signed out of use
- A “Do not use” sign must be fixed to the equipment
- The equipment must be signed over to the engineer and then signed back by the engineer once repaired and tested. Only then may it be signed back into use for scanning.

7. RECORD KEEPING

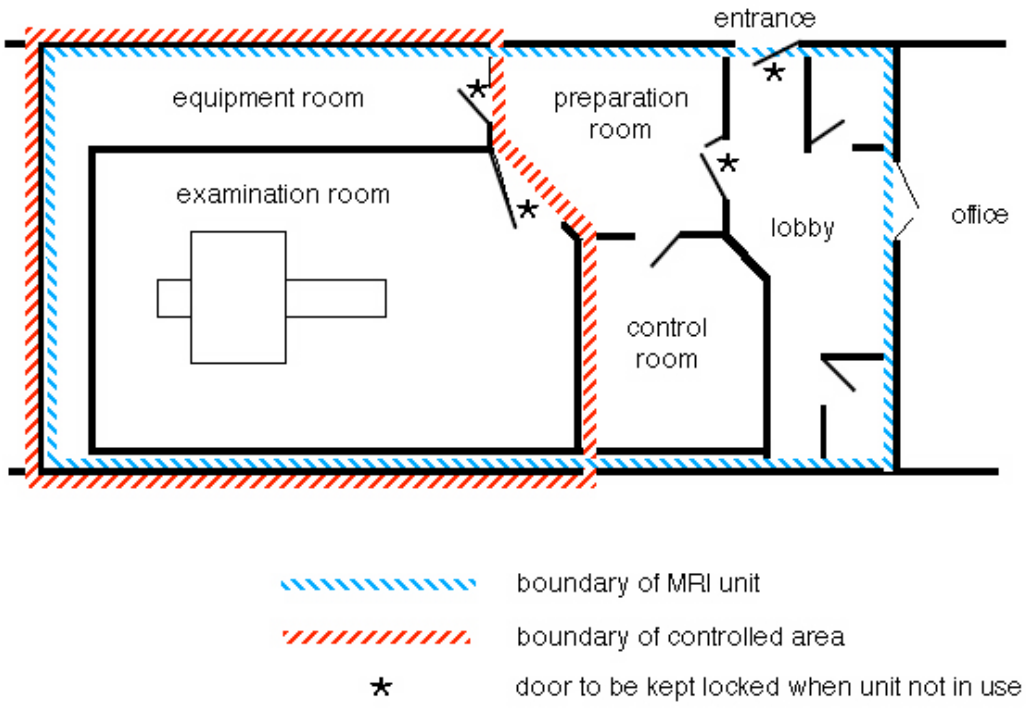
For each person scanned the following information must be recorded and retained for 10 years:

- Name, sex and age
- Date of scan
- The name and address of the person’s general practitioner (GP)
- Region of body scanned and type of coil used
- Approximate time spent in the magnet
- Scan data including sequence type, TR, TE, number and size of slices scanned.
- SAR

The two screening forms and the consent form must also be retained for 10 years.

All information should initially be held in a locked filing cabinet in the control room. It may be removed after not less that one year for safe keeping elsewhere at the discretion of the MRI Safety Officer.

APPENDIX 1 – PLAN OF MRI UNIT INDICATING CONTROLLED AREA



APPENDIX 2 – PERSONNEL AND RESPONSIBILITIES

MRI SAFETY OFFICER

This person is responsible for ensuring that the rules and procedures set out in this document are adhered to at all times. He/she also carries responsibility for keeping abreast of any new legislation or external guidelines that may be relevant to internal procedures.

The MRI Safety Officer is the Departmental Superintendent, Department of Psychology, Royal Holloway. In times of absence, he/she may appoint a deputy who must previously have been approved by the Management Committee.

AUTHORISED PERSONNEL

These are essential staff who are conversant with, and are able to put into practice all the rules and emergency practices outlined in this document. These personnel have access to the Controlled Area (subject to the rules in section 4.1). They are responsible for screening participants and other visitors to ensure that it is safe for them to enter the controlled area, and they must supervise all non-authorised people at all times when in the controlled area. Records of screening are kept by the MRI Safety Officer and held in the Control Room.

Authorised person status is granted by the Management Committee. This Committee will maintain a list of current authorised users at all times and will immediately inform the MRI Safety Officer of any alterations to it. Before Authorised Person status can be conferred, a person must undergo the following training and testing:

(i) Training in the operation of the scanner
(ii) Training in First Aid (to the level of 'appointed persons')
(iii) Basic fire training (internal programme; content to be determined by the Royal Holloway Safety Officer)
(iv) Training in removing an unconscious participant from the controlled area
(v) Viewing the current Siemens safety video
(vi) Attendance at a safety lecture given by a suitably qualified person approved by the Management Committee (or viewing a video recording of such a lecture)
(vii) Reading the *Guidelines for Magnetic Resonance Equipment in Clinical Use* (2nd edn. 2002) published by the Medical Devices Agency
(viii) Studying all relevant risk assessment forms (provided by the MRI Safety Officer)
(ix) Thoroughly reading the local *Rules of Operation* and successfully completing a written test, to be administered by the MRI Safety Officer, covering the rules and procedures covered in this document,

These requirements apply to all persons, including members of the Management Committee.

Persons who satisfy all the above requirements but have little or no practical experience will initially be given Probationary Authorised Person Status. Such persons will automatically become full Authorised Persons when they have been present at 10 scans and have operated the scanner on at least 5 of those occasions.

Authorised persons must be screened at least yearly. They must also be trained in the use of any new equipment, software or procedures that may be introduced from time to time.

The current list of authorised personnel, together with their qualifications, training and experience, will be made available on request to all relevant university ethics committees.

EQUIPMENT MANUFACTURERS

Trained service personnel or representatives of the equipment manufacturers can operate the equipment for quality control testing, servicing and demonstration purposes. Such people may be admitted to the controlled area by authorised personnel on production of identification (and normally by arrangement with the MRI Safety Officer).

APPENDIX 3 – SCREENING FORMS AND THEIR INTERPRETATION

There are two screening forms and an information form. The purpose of the initial screening form is to identify and eliminate at-risk individuals without the need for them to go to the MR unit. The purpose of the second screening form is to ensure that scanning is safe at the time of the scan. The purpose of the information form is to provide volunteers with information about the procedure.

The information form must be given to the participant at the time of, or prior to, initial screening. The participant should be encouraged to read it before deciding to participate or completing the initial screening form. Authorised persons carrying out screening may add project-specific information to the information form but must not remove any information. They may also add additional project-specific questions to the initial screening form, but may not remove any items.

The initial screening form can be completed at any time prior to the scan, at any convenient location. Wherever possible it should be completed in the presence of an authorised person as defined in Appendix 2, who should ensure that the questions are fully understood and that considered answers are given, and should witness the participant's signature. Where it is not convenient to complete the form in the presence of an authorised person, the participant 's signature should be witnessed by another adult who should countersign and add his/her name and address. In this case an authorised person should subsequently establish by conversation with the participant that adequate attention to the questions has been paid. He/she should verbally go over the questions in the initial screening form taking particular care to check that the participant has no pacemaker, artificial heart valve, cochlear implant or any other ferromagnetic metal implant.

The second screening form must be completed in the MR Unit immediately prior to scanning. The participant's completed initial screening form must be available for inspection by the participant when completing the second screening form. The authorised person who will operate the scanner must then certify, by signing the second screening form, that all necessary checks have been made.

In addition, a consent form must be signed by all participants before scanning (see Appendix 4). This can be signed at any time after the initial screening has been completed. The signature must be witnessed by another adult, who should be either Authorised Person, or a scientific colleague informed about the details of the particular study, and should add his/her address if not an authorised person. As well as witnessing the signature, this person is responsible for ensuring that the participant fully understands the consent form and has had adequate opportunity to ask questions.

All three forms must be lodged in the MR unit before scanning takes place.
Exceptions:
(i) If the person to be scanned is an authorised person who has been scanned on a previous occasion, the second screening form need not be completed.
(ii) For persons who will enter the controlled area but will not be placed inside the magnet, the initial screening form must be completed in accordance with the rules; however the second screening form and consent form need not be completed.

For participants who are scanned more than once, the answers to the questions on the two screening forms must be confirmed on each occasion, either be countersigning the original screening forms or by completing fresh forms. The consent form must be completed in relation to each scan.

Copies of the information form and the two screening forms follow.

ROYAL HOLLOWAY, UNIVERSITY OF LONDON - MAGNETIC RESONANCE IMAGING UNIT

INFORMATION FORM

These notes give some information about an fMRI study in which you are invited to take part. FMRI is a method for producing images of the activity in the brain as people carry out various mental tasks. It involves placing the participant inside a large, powerful magnet which forms part of the brain scanner. When particular regions of the brain are active, they require more oxygen, which comes from red corpuscles in the blood. As a result, the flow of blood increases. This can be detected as changes in the echoes from brief pulses of radio waves. These changes can then be converted by a computer into 3D images. This enables us to determine which parts of the brain are active during different tasks.

As far as we know, this procedure poses no direct health risks. However, the Department of Health advises that certain people should NOT be scanned. Because the scanner magnet is very powerful, it can interfere with heart pacemakers and clips or other metal items which have been implanted into the body by a surgeon, or with body-piercing items. If you have had surgery which may have involved the use of metal items you should NOT take part. Note that only ferromagnetic materials (e.g. steel) are likely to cause significant problems. Thus normal dental amalgam fillings do not prohibit you from being scanned, though a dental plate which contained metal would do so, and you would be asked to remove it. You will be asked to remove metal from your pockets (coins, keys), remove articles of clothing which have metal fasteners (belts, bras, etc), as well as most jewellery. Alternative clothing will be provided as necessary. Watches and credit cards should not be taken into the scanner since it can interfere with their operation. You will be asked to complete a questionnaire (the Initial Screening Form) which asks about these and other matters to determine whether it is safe for you to be scanned. In addition, you are asked to give the name and address of your Family Doctor. This is because there is a very small chance that the scan could reveal something which required investigation by a doctor. If that happened, we would contact your doctor directly. By signing the consent form, you authorise us to do this. You will also be asked to complete a second, shorter, screening form immediately before the scan.

To be scanned, you would lie on your back on a narrow bed on runners, on which you would be moved until your head was inside the magnet. This is rather like having your head put inside the drum of a very large front-loading washing machine. The scanning process itself creates intermittent loud noises, and you would wear ear-plugs or sound-attenuating headphones. We would be able to talk to you while you are in the scanner through an intercom. If you are likely to become very uneasy in this relatively confined space (suffer from claustrophobia), you should NOT take part in the study. If you do take part and this happens, you will be able to alert the experimenters by activating an alarm and will then be removed from the scanner quickly. It is important that you keep your head as still as possible during the scan, and to help you with this, your head will be partially restrained with padded headrests. We shall ask you to relax your head and keep it still for a period that depends on the experiment but may be more than one hour, which may require some effort on your part. If this becomes unacceptably difficult or uncomfortable, you may demand to be removed from the scanner.

You may be asked to look at a screen through a small mirror (or other optical device) placed just above your eyes and/or be asked to listen to sounds through headphones. You may be asked to make judgements about what you see or asked to perform some other kind of mental task. Details of the specific experiment in which you are invited to participate will either be appended to this sheet or else given to you verbally by the experimenter. Detailed instructions will be given just before the scan, and from time to time during it.

The whole procedure will typically take about 1 hour, plus another 15 minutes to discuss with you the purposes of the study and answer any questions about it which you may raise. You will be able to say that you wish to stop the testing and leave at any time, without giving a reason. This would not affect your relationship with the experimenters in any way. The study will not benefit you directly, and does not form part of any medical diagnosis or treatment. If you agree to participate you will be asked to sign the initial screening form that accompanies this information sheet, in the presence of the experimenter (or other witness, who should countersign the form giving their name and address, if this is not practical). It is perfectly in order for you to take time to consider whether to participate, or discuss the study with other people, before signing. After signing, you will still have the right to withdraw at any time before or during the experiment, without giving a reason.

The images of your brain will be held securely and you will not be identified by name in any publications that might arise from the study. The information in the two screening forms will also be treated as strictly confidential and the forms will be held securely until eventually destroyed.

Further information about the specific study in which you are invited to participate may have been appended overleaf, if the experimenter has felt that this would be helpful. Otherwise, he/she will already have told you about the study and will give full instructions prior to the scan. Please feel free to ask any questions about any aspect of the study or the scanning procedure before completing the initial screening form.

ROYAL HOLLOWAY, UNIVERSITY OF LONDON - MAGNETIC RESONANCE IMAGING UNIT

INITIAL SCREENING FORM

NAME OF PARTICIPANT …….. Sex: M / F
Date of birth…… Approximate weight in kg……. (one stone is about 6.3 kg)

Please read the following questions CAREFULLY and provide answers. For a very small number of individuals, being scanned can endanger comfort, health or even life. The purpose of these questions is to make sure that you are not such a person.

You have the right to withdraw from the screening and subsequent scanning if you find the questions unacceptably intrusive. The information you provide will be treated as strictly confidential and will be held in secure conditions.

Delete as appropriate

1. Have you been fitted with a pacemaker or artificial heart valve? YES/NO
2. Have you any aneurysm clips, shunts or stents in your body or a cochlear implant? YES/NO
3. Have you ever had any metal fragments in your eyes? YES/NO
4. Have you ever had any metal fragments, e.g. shrapnel in any other part of your body? YES/NO
5. Have you any surgically implanted metal in any part of your body, other than dental fillings and crowns (e.g. joint replacement or bone reconstruction) YES/NO
6. Have you ever had any surgery that might have involved metal implants of which you are not aware? YES/NO
7. Do you wear a denture plate or brace with metal in it? YES/NO
8. Do you wear a hearing aid? YES/NO
9. Have you ever suffered from any of: epilepsy, diabetes or thermoregulatory problems? YES/NO
10. Have you ever suffered from any heart disease? YES/NO
11. Is there any possibility that you might be pregnant? YES/NO
12. Have you been sterilised using clips? YES/NO
13. Do you have a contraceptive coil (IUD) installed? YES/NO
14. Are you currently breast-feeding an infant? YES/NO

I have read and understood the questions above and have answered them correctly.

SIGNED…… DATE……

In the presence of …… (name) ……..(signature)

Address of witness, if not the experimenter:

Please enter below the name and address of your doctor (general practitioner).
(Not required for persons entering the controlled area but not being scanned.)

ROYAL HOLLOWAY, UNIVERSITY OF LONDON - MAGNETIC RESONANCE IMAGING UNIT

SECOND SCREENING FORM

This form should be completed and signed immediately before your scan, after removal of any jewellery or other metal objects and (if required by the operator) changing your clothes.

NAME OF PARTICIPANT ……

Date of birth…….. Sex: M / F

Please read the following questions CAREFULLY and provide answers. For a very small number of individuals, being scanned can endanger comfort, health or even life. The purpose of these questions is to make sure that you are not such a person.

You have the right to withdraw from the screening and subsequent scanning if you find the questions unacceptably intrusive. The information you provide will be treated as strictly confidential and will he held in secure conditions.

BEFORE YOU ARE TAKEN THROUGH FOR YOUR SCAN IT IS ESSENTIAL THAT YOU REMOVE **ALL METAL OBJECTS** INCLUDING:-WATCHES, PENS, LOOSE CHANGE, KEYS, HAIR CLIPS, ALL JEWELLERY, BRASSIERES WITH METAL FASTNERS, METALLIC COSMETICS, CHEQUE/CASH POINT CARDS.

Delete as appropriate

1. Are you wearing or carrying any metal items such as those listed above? YES/NO
2. Have your answers to any of the questions in the initial screening form changed? (The initial screening form must be shown to you before you answer this question.) YES/NO

Specifically, please confirm:

3. Have you been fitted with a pacemaker, artificial heart valve or cochlear implant? YES/NO
4. Is there any possibility that you might be pregnant? YES/NO

I have read and understood the questions above and have answered them correctly.

SIGNATURE…… DATE……

FOR STAFF USE:

I certify that the initial screening form and the consent form have been completed by the person named above and I have attached them to this form. The volunteer has been given the standard information sheet about MRI experiments, together with any necessary study-specific information, and has been given an opportunity to ask questions. I am satisfied that the volunteer is adequately informed and understands the content of the consent form. I have taken adequate steps to ensure that the volunteer has no ferro-magnetic metal in or on his/her person and I am satisfied that the scan can proceed.

SIGNATURE…… NAME (print) ……..

APPENDIX 3 continued

RULES FOR ADMINISTRATION OF SCREENING FORMS

GENERAL

1. All participants must complete both the initial and second screening forms before entering the controlled area.
2. Completion of the screening forms must be supervised by an authorised person (see Appendix 2) who must be satisfied that the participant has read the questions carefully and understands their importance.
3. The second screening form must be countersigned by an authorised person before the participant enters the controlled area. The form should only be signed if all questions have been answered satisfactorily (see below), the participant's GP details have been added and the participant has signed both screening forms and the consent form.
4. If the participant answers "no" to all questions on both screening forms and the authorised person is satisfied that the participant has given the questions due consideration, the participant may be permitted to enter the controlled area.

INITIAL SCREENING FORM

5. If the participant answers 'yes' to any of questions 1, 2, 3, 4, 8, 10, 11, 12 and 14 then the participant MUST NOT be allowed into the controlled area. The person supervising the screening should explain the situation clearly, making clear that there is no cause for alarm, and cancel any MRI examination that has been arranged. They should also point out that rejection as a research participant does not necessarily mean that a future MR scan for medical purposes would be unsafe and that they should be guided by the medical personnel concerned if such a need should arise.
6. If the participant answers 'yes' to any of questions 5, 6, 7, 9 and 13, the person must not be scanned unless medical advice is first taken and any medical supervision that may be recommended is implemented. In such cases, explicit permission to proceed must be obtained from the MR Safety Officer before scanning. The following specific rules apply in such cases:
(Q.6) A person who has had surgery that clearly did not involve implantation of metal (e.g. tonsillectomy) may be scanned. Persons who have had any surgery where the use of metal implants cannot be ruled out must not enter the controlled area unless it is first established that the implant contains no ferromagnetic material. They must not be scanned unless medical advice has been taken and any medical supervision that has been recommended is provided. Scanning may proceed only if the answer to question 6 has become "no" and the initial screening form has been re-administered and the answers reflect this.

(Q.7) A person wearing a dental plate or brace may enter the controlled area but must remove the device before being scanned. If it is not readily removable, the person should not be asked to remove it and scanning must not proceed.
(Q.9) A person suffering from thermo-regulatory problems, diabetes or epilepsy may enter the controlled area but must not be scanned without medical supervision.
(Q.13) A woman with an intra-uterine contraceptive device may enter the controlled area but must not be scanned.

If there is ANY DOUBT as to whether it is safe to proceed, the participant MUST NOT be allowed to enter the controlled area.

7. If a participant has answered 'yes' to a question but is subsequently permitted to enter the controlled area, the facts and the basis of the decision must be documented and

attached to the filed screening forms. Any material statements made by the participant should be made in writing on the screening form.

SECOND SCREENING FORM

8. If the participant answers ‘yes’ to question 1 then he/should should be asked to remove the item(s) in question, if that is practical, and then amend the answer and initial the change, or complete a fresh second screening form.
9. If the participant answers ‘yes’ to question 2, the initial screening form must be completed afresh and any affirmative answers acted upon in accordance with the rules above.
10. If the participant answers 'yes' to question 3, they must not be allowed into the controlled area.
11. A person answering ‘yes’ to question 4 must not be scanned, but may be allowed into the controlled area for other purposes (e.g. a pregnant authorised person may enter to supervise volunteers, but has the right to refuse to do so).

APPENDIX 4 – CONSENT FORM

ROYAL HOLLOWAY, UNIVERSITY OF LONDON - MAGNETIC RESONANCE IMAGING UNIT

CONSENT FORM

NAME OF PARTICIPANT…….

Please read the following statement carefully and then add your signature. If you have any questions, please ask the person who gave you this form. You are under no pressure to give your consent and you are free to withdraw from the MRI examination at any time.

I agree to participate in an MRI examination conducted for research purposes by ……..(name of operator) on …….(name of project).

I understand that the examination is not part of any medical treatment. I have completed two screening forms and I have been given an opportunity to discuss any issues arising from them. The nature of the examination has been explained to me and I have had an opportunity to ask questions about it. I consent to my general practitioner being contacted in the unlikely event that the scan reveals any suspected abnormality.

Signature …… Date…….

WITNESS:

Statement by a witness, who must be either an authorised person or a scientific collaborator who is familiar with the experimental procedure and is able to answer questions about it.

I certify that the above participant signed this form in my presence. I am satisfied that the participant fully understands the statement made and I certify that he/she had adequate opportunity to ask questions about the procedure before signing.

Signature…… Date…….

Name ……..

Address of witness (if not an Authorised Person):

APPENDIX 5 – EMERGENCY PROCEDURES AND QUENCH

QUENCHING refers to the loss of absolute zero in the magnet coils. If the temperature rises, the coils cease to be superconducting and become resistive. Heat is then generated, resulting in boil-off of helium, and the field strength falls sharply. Quenching can be manually instigated in an emergency. Re-establishing the static field after quenching is an expensive, specialist procedure. In addition, the magnet may be permanently damaged.

Procedure in the event of a person being in a life-threatening situation due to the magnetic field

1. Manually quench the magnet by pressing one of the emergency buttons located in the control room and the examination room. The DOOR to the examination room should be OPEN during quenching. Manually quenching may be performed only by an Authorised Person who must first have given due consideration to the relative risks (see Note below).

2. Dial 444 and call for an ambulance.

3. Do not attempt to remove the participant from the scanner.

Procedure in the event of a person being in a life-threatening situation that does not involve the magnetic field

1. Dial 444 and call for an ambulance

2. Unless there is an injury that requires the person to be kept still, remove the person from the Controlled Area

NOTE: Quenching the magnet carries its own risks. Quenching involves the release of large amounts of energy, which can cause a significant rise in temperature in the magnet. Cryogens are vented to the outside air but there is a risk of release into the scanner room, which can cause changes in air pressure or even asphyxiation. A careful balancing of risks must be made as to whether quenching is appropriate. Quenching should only be performed if the situation is judged to be life-threatening AND it is judged that the presence of the magnetic field poses a bigger risk than the quenching procedure itself. Such situations are extremely rare and quenching should be regarded as a last resort.

APPENDIX 6 – FIRE PROCEDURES

Procedures in the event of a fire involving the MRI unit

If you discover a fire:

1 Immediately operate the nearest fire alarm. This is located just inside the main entrance door to the MRI unit

2 Implement the evacuation procedure (see below).

DO NOT tackle the fire, unless you have received fire training to a level commensurate with the severity of the incident.

DO NOT take fire-fighting equipment into the Controlled Area unless it is known to be MR-safe.

Evacuation procedure:

1. Stop all scanning.

2 Remove participant from the scanner.

3 Electrically isolate the scanner by pressing either of the two unprotected red buttons located on the walls of the control room and the examination room. DO NOT QUENCH the magnet.

4 Do not stop to collect personal belongings.

5 Leave the Unit and building by the nearest convenient exit.

6 Secure all doors after leaving.

7 Do not re-enter the building until instructed by the Fire Brigade or a responsible officer of the College.

8 Proceed to the designated Assembly point (Car Park 5).

9 The MRI Safety Officer or an Authorised Person must be available to liase with the Fire Brigade and College Safety Officer. They should jointly assess whether it is necessary to enter the Controlled Area with fire-fighting equipment. If this is deemed necessary, the magnet must first be quenched by the MRI Safety Officer or an Authorised Person.

Appendix II

Self-report Questionnaire

Behavioural Experiment HA only - Questionnaire

Name……

Today's date……..……

DOB……Age……...

Gender. Male ☐ Female ☐

Are you left or right handed. Left ☐ Right ☐

PLEASE MAKE SURE YOU CAN SEE THE SCREEN CLEARLY

PRACTICE TRIAL

TRIAL IMAGE 1

Was your overall impression pleasant or unpleasant? Please tick one of the following:

Pleasant ☐ Unpleasant ☐

On a scale of 1-9 how confident do you feel about your answer? Please tick one of the following:

Not at all Confident ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ Very Confident

1 2 3 4 5 6 7 8 9

How many images did you see?

One ☐ Two ☐ Three ☐

On a scale of 1-9 how confident do you feel about your answer? Please tick one of the following:

Not at all Confident ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ Very Confident

1 2 3 4 5 6 7 8 9

TRIAL IMAGE 2

Was your overall impression pleasant or unpleasant? Please tick one of the following:

Pleasant ☐ Unpleasant ☐

On a scale of 1-9 how confident do you feel about your answer? Please tick one of the following:

Not at all Confident ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ Very Confident

1 2 3 4 5 6 7 8 9

How many images did you see?

One ☐ Two ☐ Three ☐

On a scale of 1-9 how confident do you feel about your answer? Please tick one of the following:

Not at all Confident ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ Very Confident

1 2 3 4 5 6 7 8 9

Now the experiment will begin. Please make sure that you answer all four questions for EACH image – even if you need to 'guess'.

IMAGE 1

Was your overall impression pleasant or unpleasant? Please tick one of the following:

Pleasant ☐ Unpleasant ☐

On a scale of 1-9 how confident do you feel about your answer? Please tick one of the following:

Not at all Confident ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ Very Confident

1 2 3 4 5 6 7 8 9

How many images did you see?

One ☐ Two ☐ Three ☐

On a scale of 1-9 how confident do you feel about your answer? Please tick one of the following:

Not at all Confident ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ Very Confident

1 2 3 4 5 6 7 8 9

IMAGE 2

Impression? Pleasant ☐ Unpleasant ☐

Not at all Confident ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 Very Confident

How Many? One ☐ Two ☐ Three ☐

Not at all Confident ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 Very Confident

IMAGE 3

Impression? Pleasant ☐ Unpleasant ☐

Not at all Confident ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 Very Confident

How Many? One ☐ Two ☐ Three ☐

Not at all Confident ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 Very Confident

IMAGE 4

Impression? Pleasant ☐ Unpleasant ☐

Not at all Confident ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 Very Confident

How Many? One ☐ Two ☐ Three ☐

Not at all Confident ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 Very Confident

IMAGE 5

Impression? Pleasant ☐ Unpleasant ☐

Not at all Confident ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 Very Confident

How Many? One ☐ Two ☐ Three ☐

Not at all Confident ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 Very Confident

IMAGE 6

Impression? Pleasant ☐ Unpleasant ☐

Not at all Confident ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 Very Confident

How Many? One ☐ Two ☐ Three ☐

Not at all Confident ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 Very Confident

IMAGE 7

Impression? Pleasant ☐ Unpleasant ☐

Not at all Confident ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 Very Confident

How Many? One ☐ Two ☐ Three ☐

Not at all Confident ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 Very Confident

IMAGE 8

Impression? Pleasant ☐ Unpleasant ☐

Not at all Confident ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 Very Confident

How Many? One ☐ Two ☐ Three ☐

Not at all Confident ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 Very Confident

IMAGE 9

Impression? Pleasant ☐ Unpleasant ☐

Not at all Confident ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 Very Confident

How Many? One ☐ Two ☐ Three ☐

Not at all Confident ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 Very Confident

IMAGE 10

Impression? Pleasant ☐ Unpleasant ☐

Not at all Confident ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 Very Confident

How Many? One ☐ Two ☐ Three ☐

Not at all Confident ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 Very Confident

IMAGE 11

Impression? Pleasant ☐ Unpleasant ☐

Not at all Confident ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 Very Confident

How Many? One ☐ Two ☐ Three ☐

Not at all Confident ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 Very Confident

IMAGE 12

Impression? Pleasant ☐ Unpleasant ☐

Not at all Confident ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 Very Confident

How Many? One ☐ Two ☐ Three ☐

Not at all Confident ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 Very Confident

IMAGE 13

Impression? Pleasant ☐ Unpleasant ☐

Not at all Confident ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 Very Confident

How Many? One ☐ Two ☐ Three ☐

Not at all Confident ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 Very Confident

IMAGE 14

Impression? Pleasant ☐ Unpleasant ☐

Not at all Confident ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 Very Confident

How Many? One ☐ Two ☐ Three ☐

Not at all Confident ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 Very Confident

IMAGE 15

Impression? Pleasant ☐ Unpleasant ☐

Not at all Confident ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 Very Confident

How Many? One ☐ Two ☐ Three ☐

Not at all Confident ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 Very Confident

IMAGE 16

Impression? Pleasant ☐ Unpleasant ☐

Not at all Confident ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 Very Confident

How Many? One ☐ Two ☐ Three ☐

Not at all Confident ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 Very Confident

IMAGE 17

Impression? Pleasant ☐ Unpleasant ☐

Not at all Confident ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 Very Confident

How Many? One ☐ Two ☐ Three ☐

Not at all Confident ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 Very Confident

IMAGE 18

Impression? Pleasant ☐ Unpleasant ☐

Not at all Confident ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 Very Confident

How Many? One ☐ Two ☐ Three ☐

Not at all Confident ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 Very Confident

IMAGE 19

Impression? Pleasant ☐ Unpleasant ☐

Not at all Confident ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 Very Confident

How Many? One ☐ Two ☐ Three ☐

Not at all Confident ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 Very Confident

IMAGE 20

Impression? Pleasant ☐ Unpleasant ☐

Not at all Confident ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 Very Confident

How Many? One ☐ Two ☐ Three ☐

Not at all Confident ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 Very Confident

IMAGE 21

Impression? Pleasant ☐ Unpleasant ☐

Not at all Confident ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 Very Confident

How Many? One ☐ Two ☐ Three ☐

Not at all Confident ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 Very Confident

IMAGE 22

Impression? Pleasant ☐ Unpleasant ☐

Not at all Confident ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 Very Confident

How Many? One ☐ Two ☐ Three ☐

Not at all Confident ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 Very Confident

IMAGE 23

Impression? Pleasant ☐ Unpleasant ☐

Not at all Confident ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 Very Confident

How Many? One ☐ Two ☐ Three ☐

Not at all Confident ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 Very Confident

IMAGE 24

Impression? Pleasant ☐ Unpleasant ☐

Not at all Confident ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 Very Confident

How Many? One ☐ Two ☐ Three ☐

Not at all Confident ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 Very Confident

IMAGE 25

Impression? Pleasant ☐ Unpleasant ☐

Not at all Confident ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 Very Confident

How Many? One ☐ Two ☐ Three ☐

Not at all Confident ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 Very Confident

IMAGE 26

Impression? Pleasant ☐ Unpleasant ☐

Not at all Confident ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 Very Confident

How Many? One ☐ Two ☐ Three ☐

Not at all Confident ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 Very Confident

IMAGE 27

Impression? Pleasant ☐ Unpleasant ☐

Not at all Confident ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 Very Confident

How Many? One ☐ Two ☐ Three ☐

Not at all Confident ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 Very Confident

IMAGE 28

Impression? Pleasant ☐ Unpleasant ☐

Not at all Confident ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 Very Confident

How Many? One ☐ Two ☐ Three ☐

Not at all Confident ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 Very Confident

IMAGE 29

Impression? Pleasant ☐ Unpleasant ☐

Not at all Confident ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 Very Confident

How Many? One ☐ Two ☐ Three ☐

Not at all Confident ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 Very Confident

IMAGE 30

Impression? Pleasant ☐ Unpleasant ☐

Not at all Confident ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 Very Confident

How Many? One ☐ Two ☐ Three ☐

Not at all Confident ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 Very Confident

IMAGE 31

Impression? Pleasant ☐ Unpleasant ☐

Not at all Confident ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 Very Confident

How Many? One ☐ Two ☐ Three ☐

Not at all Confident ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 Very Confident

IMAGE 32

Impression? Pleasant ☐ Unpleasant ☐

Not at all Confident ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 Very Confident

How Many? One ☐ Two ☐ Three ☐

Not at all Confident ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 Very Confident

IMAGE 33

Impression? Pleasant ☐ Unpleasant ☐

Not at all Confident ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 Very Confident

How Many? One ☐ Two ☐ Three ☐

Not at all Confident ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 Very Confident

IMAGE 34

Impression? Pleasant ☐ Unpleasant ☐

Not at all Confident ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 Very Confident

How Many? One ☐ Two ☐ Three ☐

Not at all Confident ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 Very Confident

IMAGE 35

Impression? Pleasant ☐ Unpleasant ☐

Not at all Confident ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 Very Confident

How Many? One ☐ Two ☐ Three ☐

Not at all Confident ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 Very Confident

IMAGE 36

Impression? Pleasant ☐ Unpleasant ☐

Not at all Confident ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 Very Confident

How Many? One ☐ Two ☐ Three ☐

Not at all Confident ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 Very Confident

THANK YOU

Appendix III

Informed Consent Form

INFORMED CONSENT SHEET:
CONSCIOUS AND UNCONSCIOUS PROCESSING OF EMOTIONAL VISUAL STIMULI

The Department of Human Sciences at Brunel University requires that all persons who participate in psychology studies give their written consent to do so. Please read the following and sign it if you agree with what it says.

I freely and voluntarily consent to be a participant in the research project entitled "Conscious and Unconscious Processing of Emotional Visual Stimuli" to be conducted at Brunel University, with Lynda Shaw as principal investigator. The broad goal of this research program is to explore the neuropsychology of emotion and the relationship between conscious and unconscious processing of emotion. Specifically, I have been told that I will be asked to look at a series of images on a screen, which will involve both subliminal (below threshold) and normal (above threshold) presentations of pictures with strong emotional content (both pleasant and unpleasant). The session should take no longer than thirty minutes to complete.

I have been told that my responses will be kept strictly confidential. I also understand that if at any time during the session I feel unable or unwilling to continue, I am free to leave without negative consequences. That is, my participation in this study is completely voluntary, and I may withdraw from this study at any time. My withdrawal would not result in any penalty, academic or otherwise. My name and my student identification number will not be linked with the research materials, as the researchers are interested in contributing to the investigations and implications on how emotions affect conscious processing in general -- not any particular individual's subjective experience of processing emotional visual stimuli.

I have been given the opportunity to ask questions regarding the procedure, and my questions have been answered to my satisfaction. I have been informed that if I have any questions about this project, I should feel free to contact Lynda Shaw at lyndashaw22@hotmail.com. If I have any comments or concerns about the study or the informed consent procedures, I can contact Prof. Michael Wright at Michael.Wright@brunel.ac.uk.

I have read and understand the above and consent to participate in this study. My signature is not a waiver of any legal rights. Furthermore, I understand that I will be able to keep a copy of the informed consent form for my records.

_____

Participant's Signature Date

I have explained and defined in detail the research procedure in which the student has consented to participate. Furthermore, I will retain one copy of the informed consent form for my records.

_____

Principal Investigator Signature Date

Appendix IV

Ratings Questionnaire

Ratings HA only - questionnaire

"Street" Name……

Today's date…….……

DOB……Age……...

Gender. Male ☐ Female ☐

Are you left or right handed. Left ☐ Right ☐

PLEASE MAKE SURE YOU CAN SEE THE SCREEN CLEARLY

Please make sure that you answer all three questions for EACH image.

TRIAL IMAGE 1 **Umbrella** **7150**

On a scale of 1-9 how pleasant or unpleasant did you find this image? Please tick one of the following:

Very Unpleasant Very Pleasant

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

1 2 3 4 5 6 7 8 9

On a scale of 1-9 how arousing did you find this image? Please tick one of the following:

Not Arousing Very Arousing

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

1 2 3 4 5 6 7 8 9

Do you remember seeing this picture in the experiment?

Yes ☐ No ☐ Not sure ☐

TRIAL IMAGE 2 **Native Boy** **2730**

Very Unpleasant Very Pleasant

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

1 2 3 4 5 6 7 8 9

Not Arousing Very Arousing

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

1 2 3 4 5 6 7 8 9

Do you remember seeing this picture in the experiment?

Yes ☐ No ☐ Not sure ☐

IMAGE 1 **Skydivers** **5621**

Very Unpleasant Very Pleasant

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

1 2 3 4 5 6 7 8 9

Not Arousing Very Arousing

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

1 2 3 4 5 6 7 8 9

Do you remember seeing this picture in the experiment?

Yes No Not sure

☐ ☐ ☐

IMAGE 2 **AirCrash** **9611**

Very Unpleasant Very Pleasant

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

1 2 3 4 5 6 7 8 9

Not Arousing Very Arousing

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

1 2 3 4 5 6 7 8 9

Do you remember seeing this picture in the experiment?

Yes No Not sure

☐ ☐ ☐

IMAGE 3 **Chair** **7235**

Very Unpleasant Very Pleasant

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

1 2 3 4 5 6 7 8 9

Not Arousing Very Arousing

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

1 2 3 4 5 6 7 8 9

Do you remember seeing this picture in the experiment?

Yes No Not sure

☐ ☐ ☐

IMAGE 4 **Fireworks** **5480**

Very Unpleasant Very Pleasant

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

1 2 3 4 5 6 7 8 9

Not Arousing Very Arousing

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

1 2 3 4 5 6 7 8 9

Do you remember seeing this picture in the experiment?

Yes No Not sure

☐ ☐ ☐

IMAGE 5 **Basket** **7010**

Very Unpleasant Very Pleasant

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

1 2 3 4 5 6 7 8 9

Not Arousing Very Arousing

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

1 2 3 4 5 6 7 8 9

Do you remember seeing this picture in the experiment?

Yes No Not sure

☐ ☐ ☐

IMAGE 6 **Jaguar** **1650**

Very Unpleasant Very Pleasant

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

1 2 3 4 5 6 7 8 9

Not Arousing Very Arousing

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

1 2 3 4 5 6 7 8 9

Do you remember seeing this picture in the experiment?

Yes No Not sure

☐ ☐ ☐

IMAGE 7 **BatteredFem** **3180**

Very Unpleasant Very Pleasant

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

1 2 3 4 5 6 7 8 9

Not Arousing Very Arousing

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

1 2 3 4 5 6 7 8 9

Do you remember seeing this picture in the experiment?

Yes No Not sure

☐ ☐ ☐

IMAGE 8 **Bomb** **9630**

Very Unpleasant Very Pleasant

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

1 2 3 4 5 6 7 8 9

Not Arousing Very Arousing

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

1 2 3 4 5 6 7 8 9

Do you remember seeing this picture in the experiment?

Yes No Not sure

☐ ☐ ☐

IMAGE 9 **AttackDog** **1525**

Very Unpleasant Very Pleasant

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

1 2 3 4 5 6 7 8 9

Not Arousing Very Arousing

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

1 2 3 4 5 6 7 8 9

Do you remember seeing this picture in the experiment?

Yes No Not sure

☐ ☐ ☐

IMAGE 10 **FliesOnPie** **7360**

Very Unpleasant Very Pleasant

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

1 2 3 4 5 6 7 8 9

Not Arousing Very Arousing

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

1 2 3 4 5 6 7 8 9

Do you remember seeing this picture in the experiment?

Yes No Not sure

☐ ☐ ☐

IMAGE 11 **Money** **8501**

Very Unpleasant Very Pleasant

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

1 2 3 4 5 6 7 8 9

Not Arousing Very Arousing

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

1 2 3 4 5 6 7 8 9

Do you remember seeing this picture in the experiment?

Yes No Not sure

☐ ☐ ☐

IMAGE 12 **Stool** **7025**

Very Unpleasant Very Pleasant

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

1 2 3 4 5 6 7 8 9

Not Arousing Very Arousing

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

1 2 3 4 5 6 7 8 9

Do you remember seeing this picture in the experiment?

Yes No Not sure

☐ ☐ ☐

IMAGE 13 **Shark** **1932**

Very Unpleasant Very Pleasant

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

1 2 3 4 5 6 7 8 9

Not Arousing Very Arousing

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

1 2 3 4 5 6 7 8 9

Do you remember seeing this picture in the experiment?

Yes No Not sure

☐ ☐ ☐

IMAGE 14 **Baby** **2071**

Very Unpleasant Very Pleasant

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

1 2 3 4 5 6 7 8 9

Not Arousing Very Arousing

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

1 2 3 4 5 6 7 8 9

Do you remember seeing this picture in the experiment?

Yes No Not sure

☐ ☐ ☐

IMAGE 15 **Iron** **7030**

Very Unpleasant Very Pleasant

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

1 2 3 4 5 6 7 8 9

Not Arousing Very Arousing

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

1 2 3 4 5 6 7 8 9

Do you remember seeing this picture in the experiment?

Yes No Not sure

☐ ☐ ☐

IMAGE 16 **Skier** **8190**

Very Unpleasant Very Pleasant

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

1 2 3 4 5 6 7 8 9

Not Arousing Very Arousing

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

1 2 3 4 5 6 7 8 9

Do you remember seeing this picture in the experiment?

Yes No Not sure

☐ ☐ ☐

IMAGE 17 **Fork** **7080**

Very Unpleasant Very Pleasant

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

1 2 3 4 5 6 7 8 9

Not Arousing Very Arousing

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

1 2 3 4 5 6 7 8 9

Do you remember seeing this picture in the experiment?

Yes No Not sure

☐ ☐ ☐

IMAGE 18 **Athletes** **8380**

Very Unpleasant Very Pleasant

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

1 2 3 4 5 6 7 8 9

Not Arousing Very Arousing

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

1 2 3 4 5 6 7 8 9

Do you remember seeing this picture in the experiment?

Yes No Not sure

☐ ☐ ☐

IMAGE 19 **AngryFace** **2120**

Very Unpleasant Very Pleasant

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

1 2 3 4 5 6 7 8 9

Not Arousing Very Arousing

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

1 2 3 4 5 6 7 8 9

Do you remember seeing this picture in the experiment?

Yes No Not sure

☐ ☐ ☐

IMAGE 20 **Book** **7090**

Very Unpleasant Very Pleasant

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

1 2 3 4 5 6 7 8 9

Not Arousing Very Arousing

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

1 2 3 4 5 6 7 8 9

Do you remember seeing this picture in the experiment?

Yes No Not sure

☐ ☐ ☐

IMAGE 21 **IceCream** **7270**

Very Unpleasant Very Pleasant

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

1 2 3 4 5 6 7 8 9

Not Arousing Very Arousing

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

1 2 3 4 5 6 7 8 9

Do you remember seeing this picture in the experiment?

Yes No Not sure

☐ ☐ ☐

IMAGE 22 **Waterfall** **5260**

Very Unpleasant Very Pleasant

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

1 2 3 4 5 6 7 8 9

Not Arousing Very Arousing

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

1 2 3 4 5 6 7 8 9

Do you remember seeing this picture in the experiment?

Yes No Not sure

☐ ☐ ☐

IMAGE 23 **Puppies** **1710**

Very Unpleasant Very Pleasant

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

1 2 3 4 5 6 7 8 9

Not Arousing Very Arousing

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

1 2 3 4 5 6 7 8 9

Do you remember seeing this picture in the experiment?

Yes No Not sure

☐ ☐ ☐

IMAGE 24 **CarCrash** **9911**

Very Unpleasant Very Pleasant

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

1 2 3 4 5 6 7 8 9

Not Arousing Very Arousing

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

1 2 3 4 5 6 7 8 9

Do you remember seeing this picture in the experiment?

Yes No Not sure

☐ ☐ ☐

IMAGE 25 **ElectricChair** **6020**

Very Unpleasant Very Pleasant

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

1 2 3 4 5 6 7 8 9

Not Arousing Very Arousing

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

1 2 3 4 5 6 7 8 9

Do you remember seeing this picture in the experiment?

Yes No Not sure

☐ ☐ ☐

IMAGE 26 **AttractiveFem 4250**

Very Unpleasant Very Pleasant

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

1 2 3 4 5 6 7 8 9

Not Arousing Very Arousing

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

1 2 3 4 5 6 7 8 9

Do you remember seeing this picture in the experiment?

Yes No Not sure

☐ ☐ ☐

IMAGE 27 **Monkies** **1811**

Very Unpleasant Very Pleasant

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

1 2 3 4 5 6 7 8 9

Not Arousing Very Arousing

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

1 2 3 4 5 6 7 8 9

Do you remember seeing this picture in the experiment?

Yes No Not sure

☐ ☐ ☐

IMAGE 28 **HairDyer** **7050**

Very Unpleasant Very Pleasant

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

1 2 3 4 5 6 7 8 9

Not Arousing Very Arousing

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

1 2 3 4 5 6 7 8 9

Do you remember seeing this picture in the experiment?

Yes No Not sure

☐ ☐ ☐

IMAGE 29 **Snake** **1050**

Very Unpleasant Very Pleasant

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

1 2 3 4 5 6 7 8 9

Not Arousing Very Arousing

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

1 2 3 4 5 6 7 8 9

Do you remember seeing this picture in the experiment?

Yes No Not sure

☐ ☐ ☐

IMAGE 30 **BabyTumour** **3170**

Very Unpleasant Very Pleasant

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

1 2 3 4 5 6 7 8 9

Not Arousing Very Arousing

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

1 2 3 4 5 6 7 8 9

Do you remember seeing this picture in the experiment?

Yes No Not sure

☐ ☐ ☐

IMAGE 31 **Toilet** **9301**

Very Unpleasant Very Pleasant

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

1 2 3 4 5 6 7 8 9

Not Arousing Very Arousing

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

1 2 3 4 5 6 7 8 9

Do you remember seeing this picture in the experiment?

Yes No Not sure

☐ ☐ ☐

THANK YOU

Appendix V

Debrief Form

DEBRIEFING FORM:
CONSCIOUS AND UNCONSCIOUS PROCESSING OF EMOTIONAL VISUAL STIMULI

The question of whether there can be unconscious processing of emotional stimuli has been an important theme in psychology for more than a century. Some of the strongest claims for this position come from lesion studies. We intend to expand on the knowledge gained so far by using behavioural studies, such as the one you have just completed, and fMRI (Functional Magnetic Resonance Imaging) experiments.

The type of questions we will be investigating include: there is a difference between valence visual stimuli for conscious and unconscious processing; there is a difference in processing faces, scenes, animals and inaanimate objects.

The following studies might be of interest to you:

Dalgleish, T., Power, M. (1999), **Handbook of Cognition and Emotion.** New York: John Wiley & Sons Ltd.

Damasio, A. (1999), **The Feeling of What Happens: Body, Emotion and the Making of Consciousness.** London: Vintage.

Heilman, K.M., Satz, P (ed). (1983), **Neuropsychology of Human Emotion**. New York and London: The Guildford Press

Once again, we thank you for taking part in the present study. Please feel free to contact Lynda Shaw if you have any questions or comments regarding this study.

Appendix VI

Conclusions from ANOVA

of Individual Slides.

Summary of Results

Appendix VI Summary of results.

Legend:
Col 1: image/ trial number.
Col 2: Overall impression: actual frequency of unpleasant (left cluster) and pleasant (right cluster) responses given to this trial. Blue = 2 images seen (subliminal) green = 3 images seen (supraliminal).
Col 3: Classifier: whether this trial is more frequently judged as high or low valence relative to control trials.
Col 4: Significant between-subjects effects in UNIANOVA, e.g. a significant effect of concordance (concordant vs discordant response) on valence impression confidence; a significant effect of number of pictures seen (2=subliminal, 3=supraliminal) on valence impression confidence.
Col 5: Marginal means for valence impression confidence (y axis) vs discordant (left) and concordant (right). Blue=2seen, green =3seen.

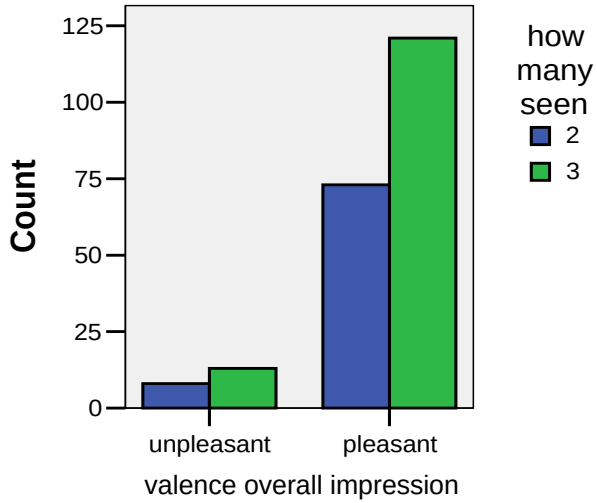
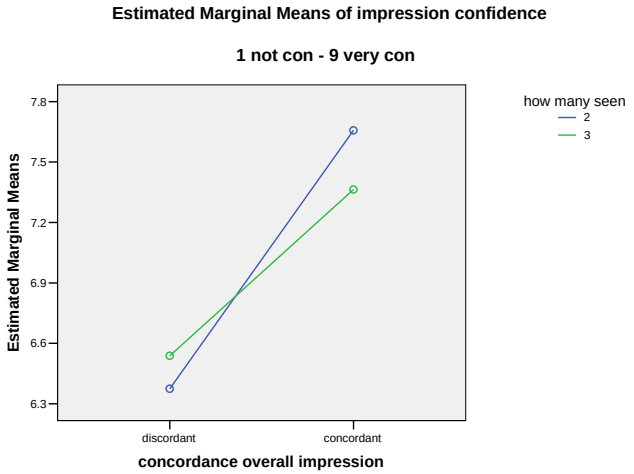
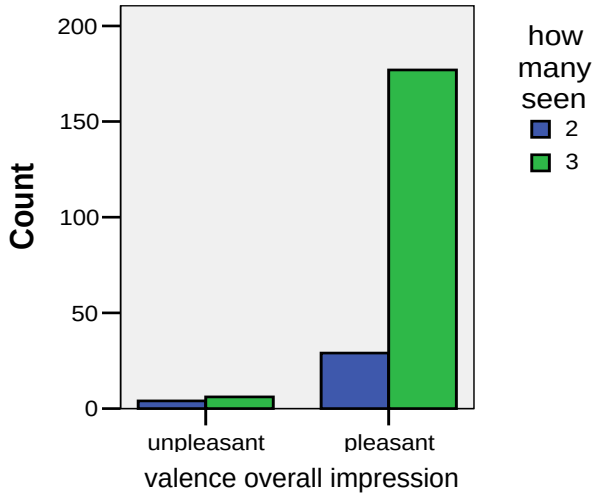
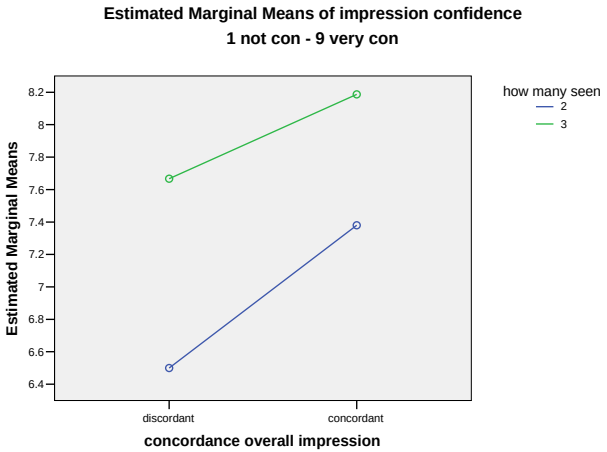
Image	Overall Valence Impression	Classifier	Unianova	Confidence
6 High Valence Animal Jaguar		Higher valence than control trials	Concordant discordant response / impression confidence F = 8.6 df = 1, 211 p < 0.005	
24 High Valence Animal Puppies		Higher valence than control trials	Number of pictures seen / impression confidence F = 2.5 df = 1, 212 p < 0.05	

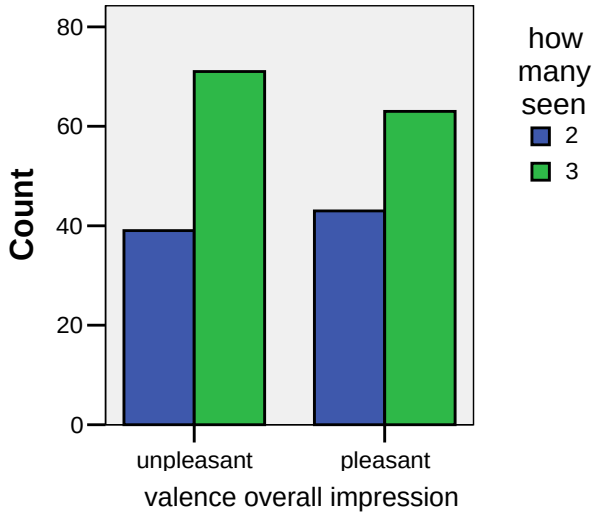
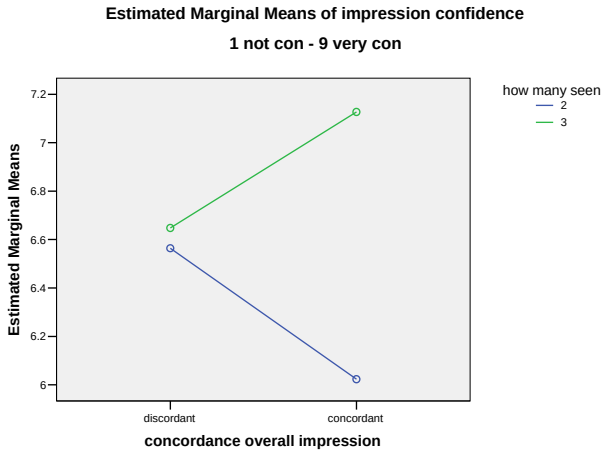
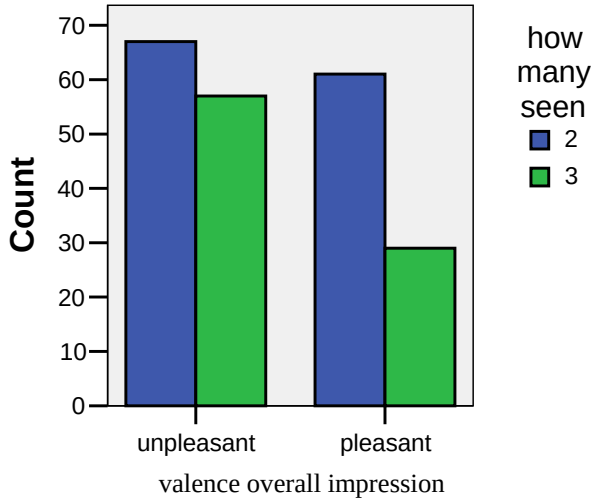
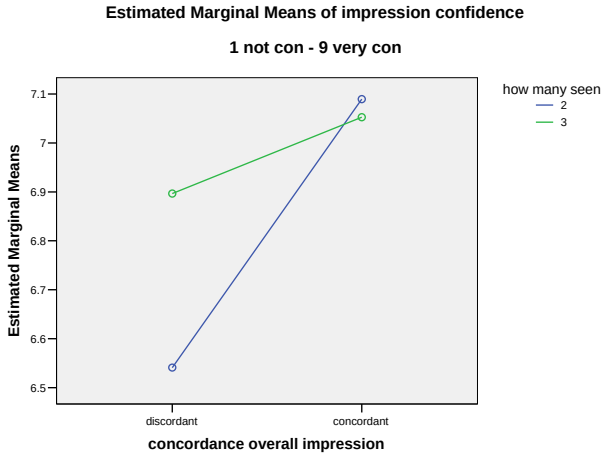
Image	Overall Valence Impression	Classifier	Unianova	Confidence
31 High Valence Animal Monkey		Lower valence than control trials	Number of pictures seen / impression confidence F = 5.8 df = 1, 212 p < 0.05 Concordant discordant response * number seen / impression confidence F = 4.3 df = 1, 212 p < 0.05	
10 Low Valence Animal Attack Dog		Lower	n.s.	

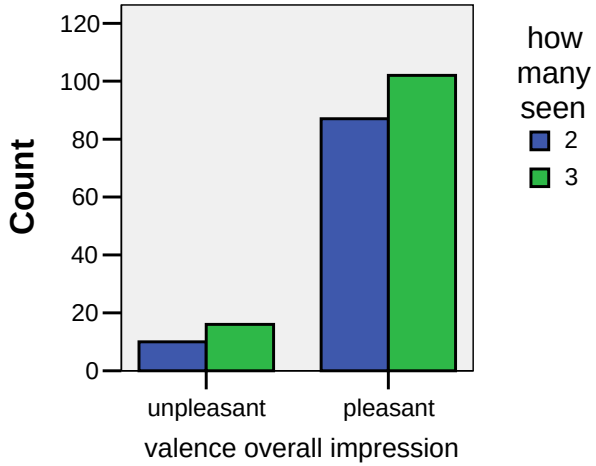
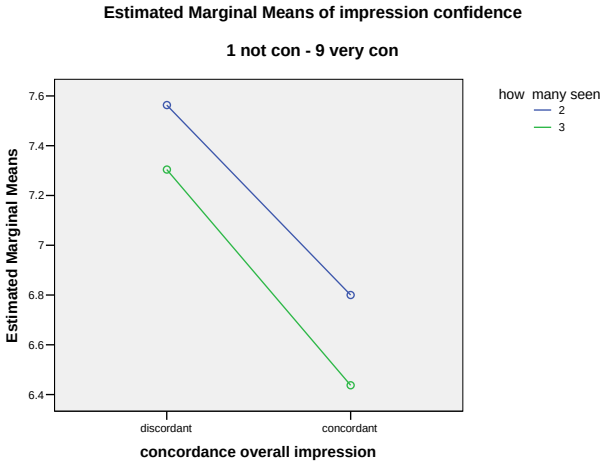
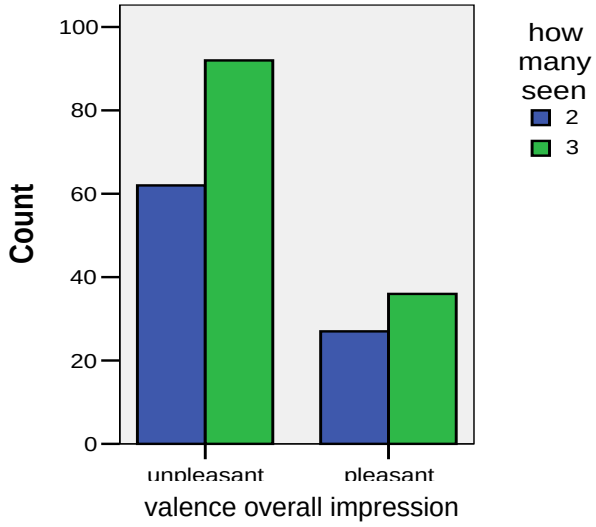
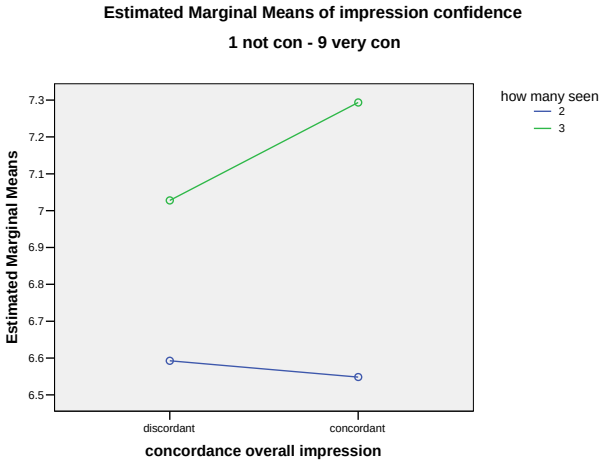
Image	Overall Valence Impression	Classifier	Unianova	Confidence
15 Low Valence Animal Shark		Higher	Concordant discordant response / impression confidence F = 6.1 df = 1, 210 p < 0.05	
33 Low Valence Animal Snake		Lower	Number of pictures seen / impression confidence F = 5.3 df = 1, 213 p < 0.05	

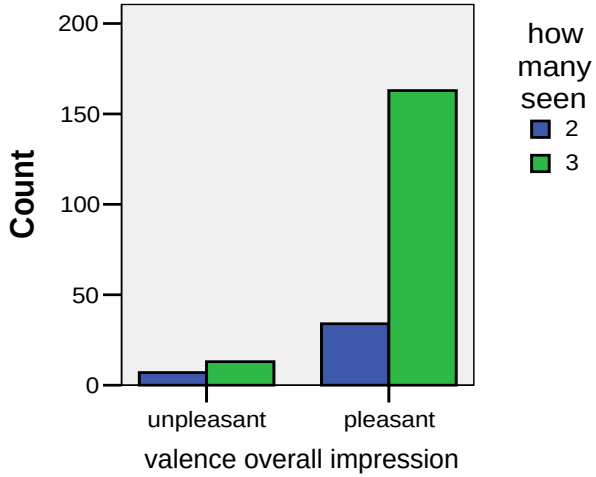
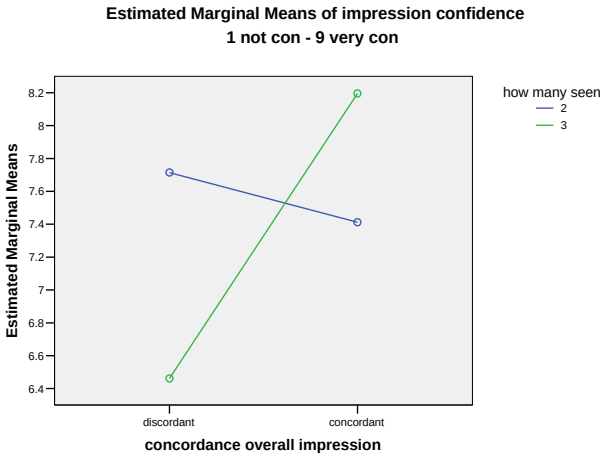
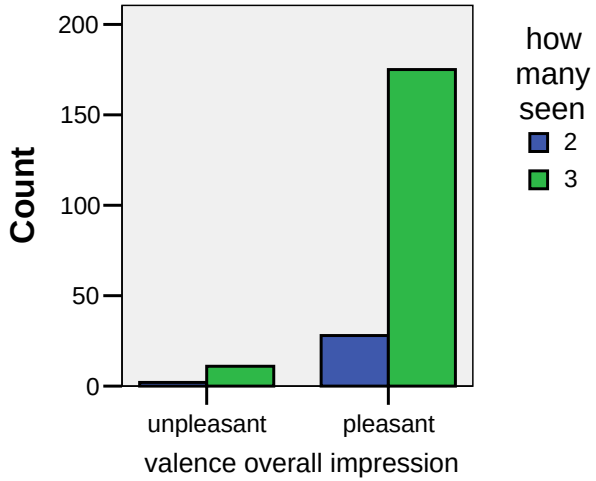
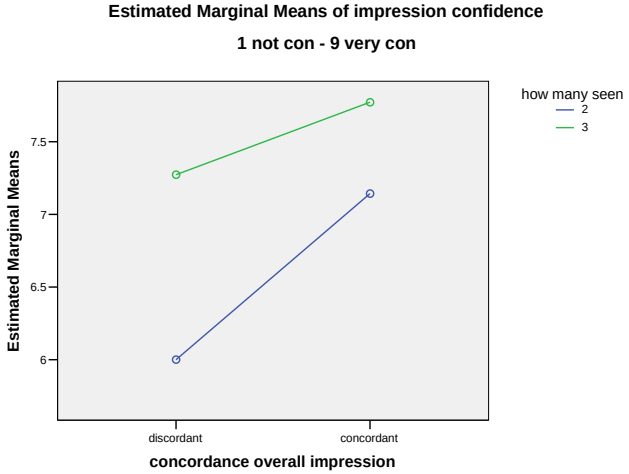
Image	Overall Valence Impression	Classifier	Unianova	Confidence
18 High Valence Face Baby		Higher	Concordant discordant response * number seen / impression confidence F = 7.7 df = 1, 213 p < 0.01	
20 High Valence Face Athletes		Higher	n.s.	

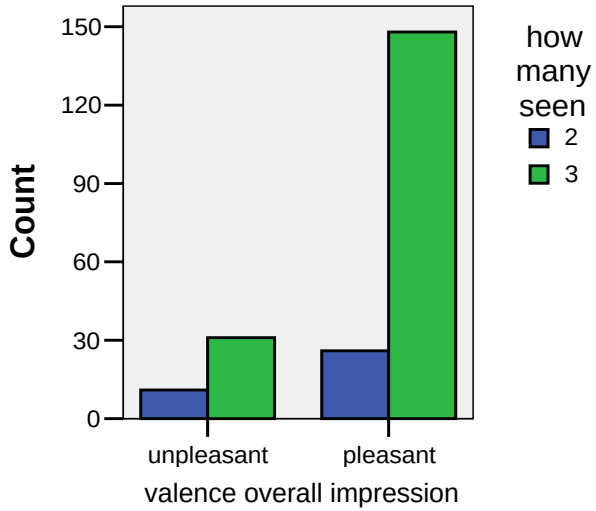
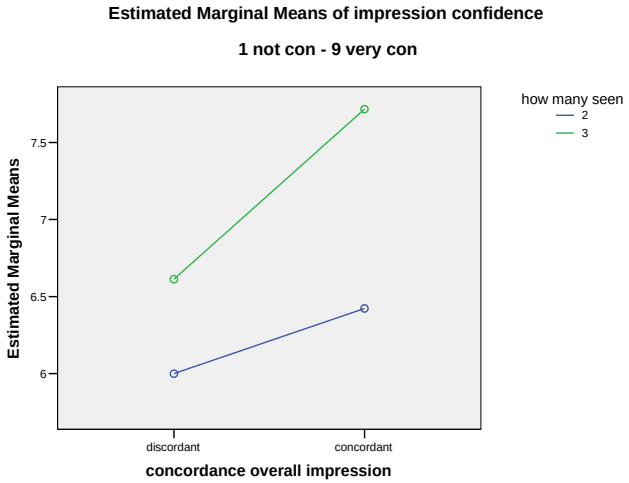
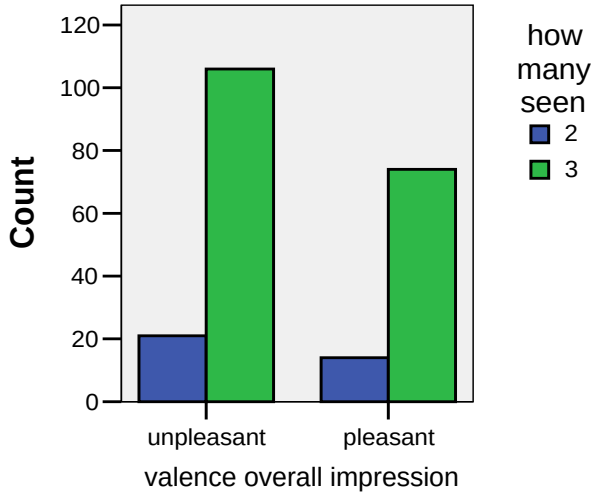
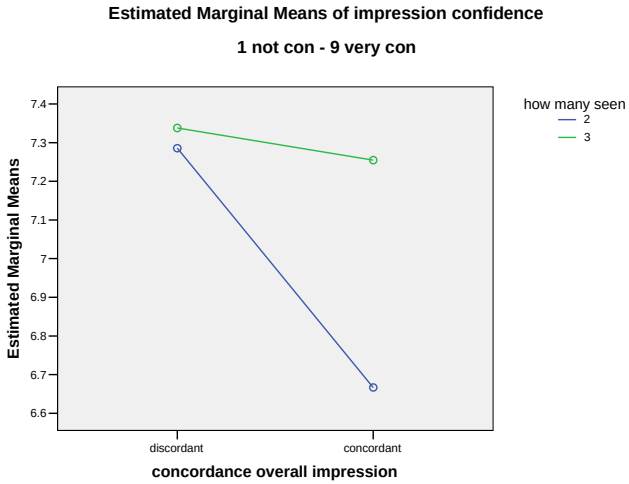
Image	Overall Valence Impression	Classifier	Unianova	Confidence
30 High Valence Face Attr. Female		Higher	Concordant discordant response / impression confidence F = 5.4 df = 1, 212 p < 0.05 Number of pictures seen / impression confidence F = 8.5 df = 1, 212 p < 0.005	
7 Low Valence Face Batt. Female		Lower	n.s.	

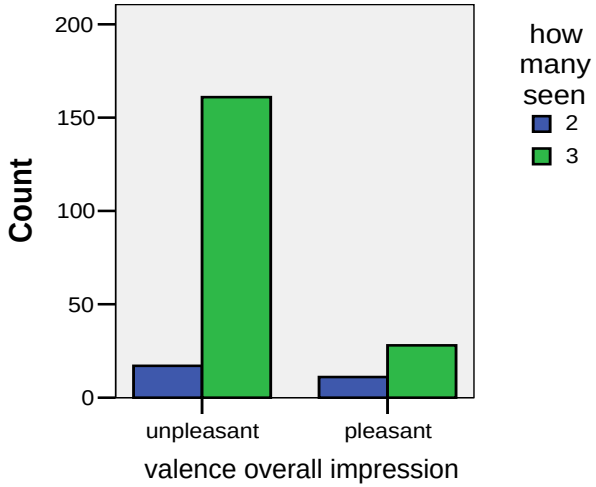
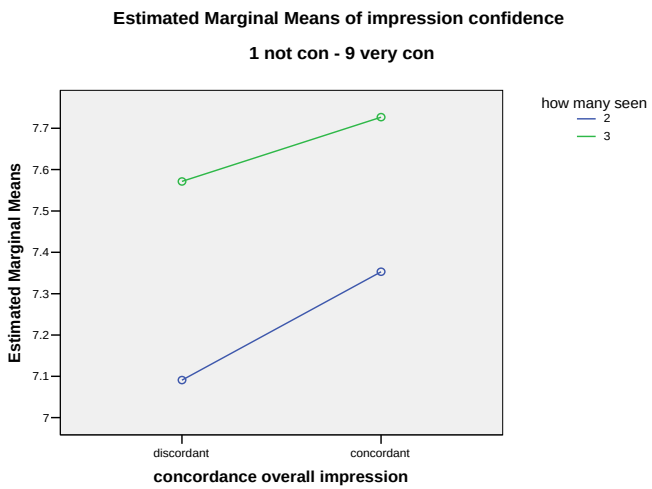
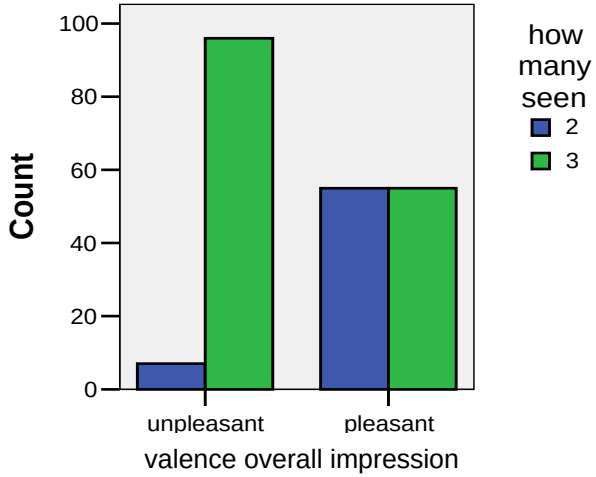
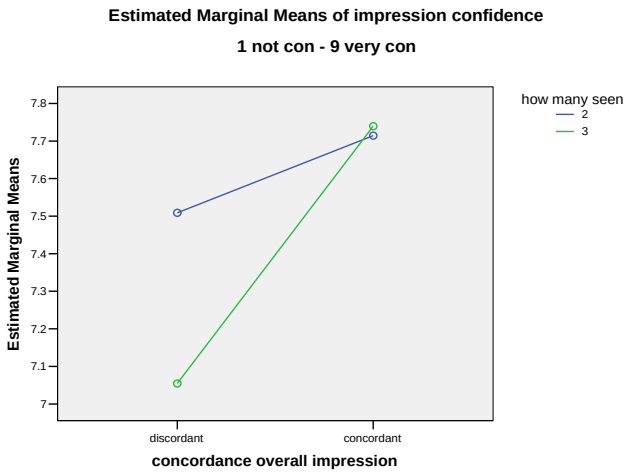
Image	Overall Valence Impression	Classifier	Unianova	Confidence
21 Low Valence Face Angry Man		Lower	n.s.	
35 Low Valence Face Baby Tumour		Lower	n.s.	

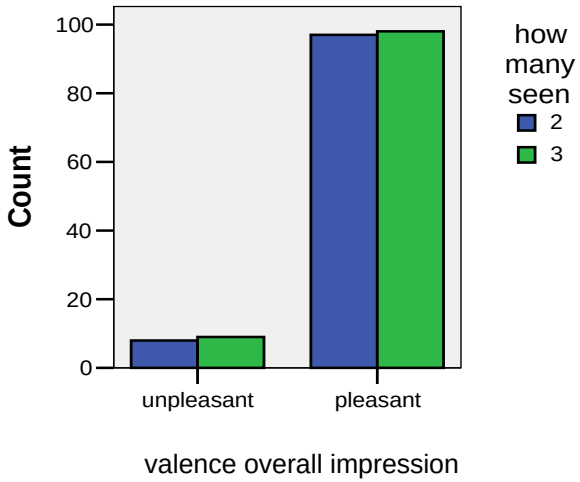
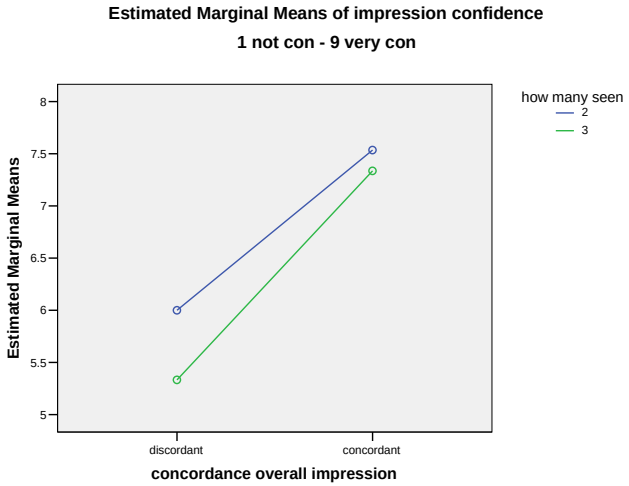
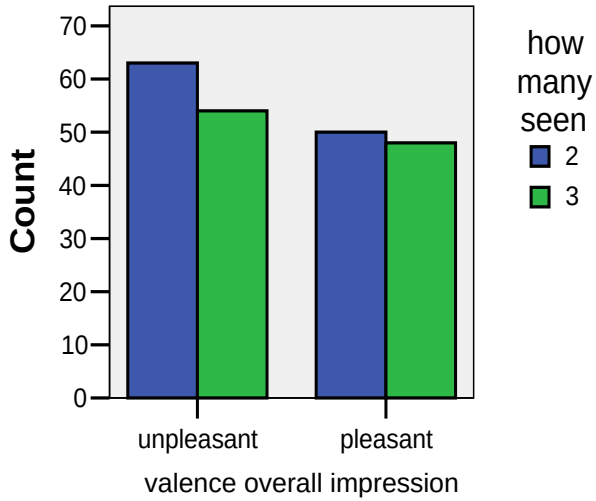
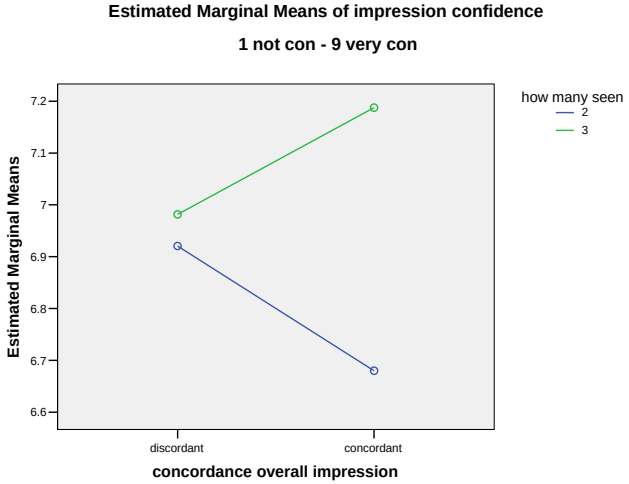
Image	Overall Valence Impression	Classifier	Unianova	Confidence
1 High Valence Scene Sky-divers		Higher	Concordant discordant response / impression confidence F = 18.1 df = 1, 208 p < 0.0005	
19 High Valence Scene Skier		Lower	n.s.	

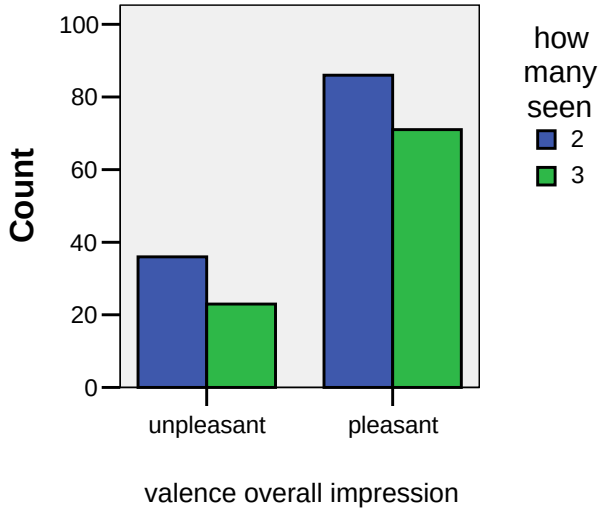
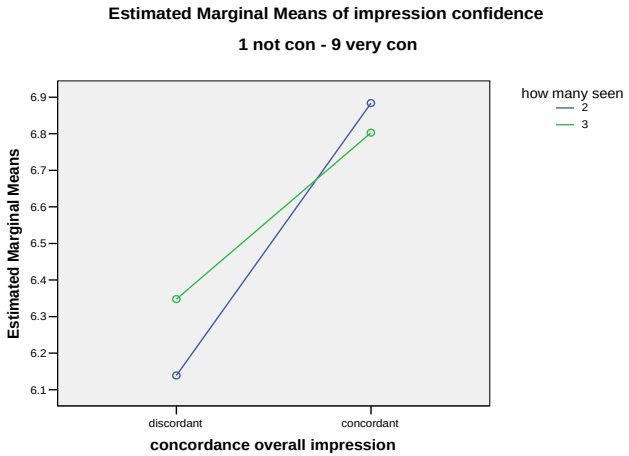
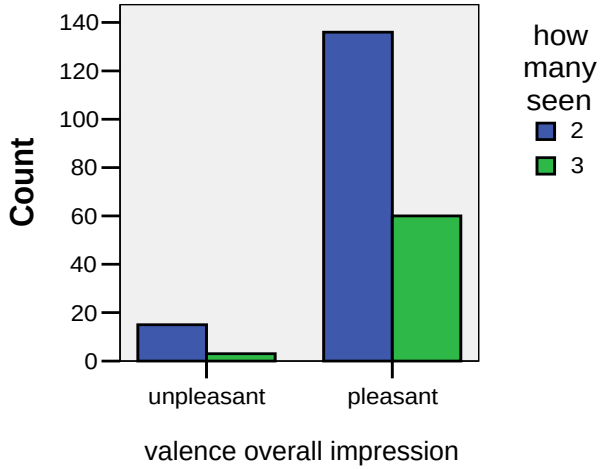
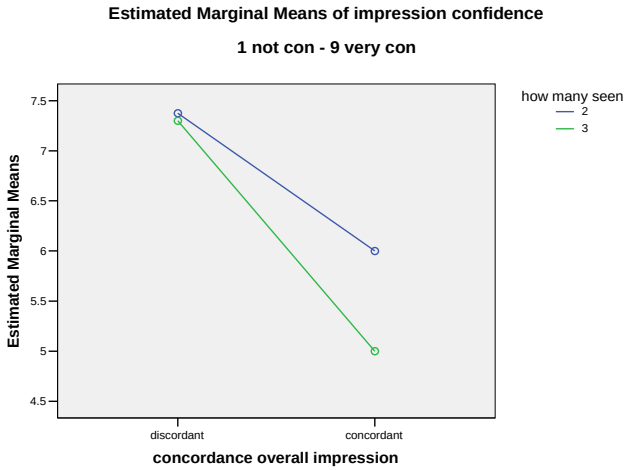
Image	Overall Valence Impression	Classifier	Unianova	Confidence
23 High Valence Scene Water-fall		Higher	Concordant discordant response / impression confidence F = 4.2 df = 1, 212 p < 0.05	
2 Low Valence Scene Air-crash		Higher	Concordant discordant response / impression confidence F = 11.1 df = 1, 210 p < 0.001	

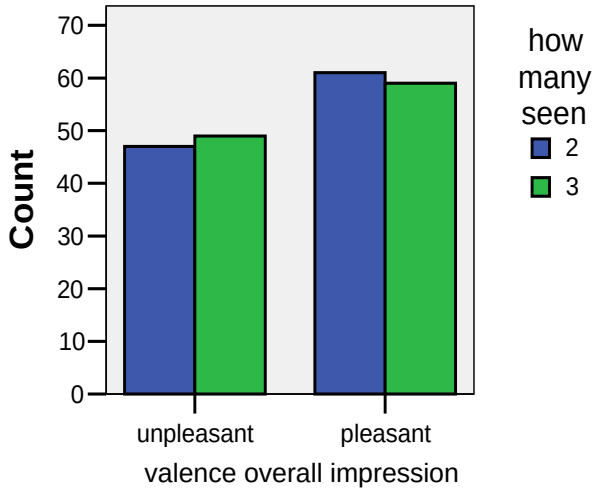
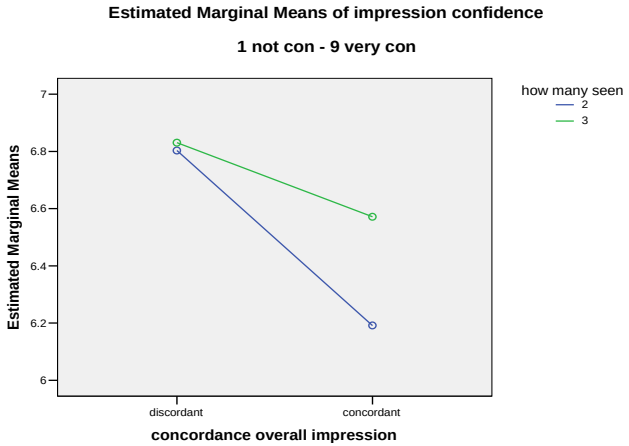
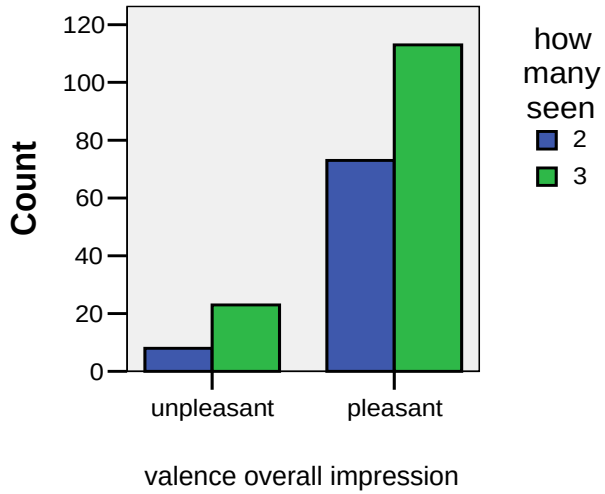
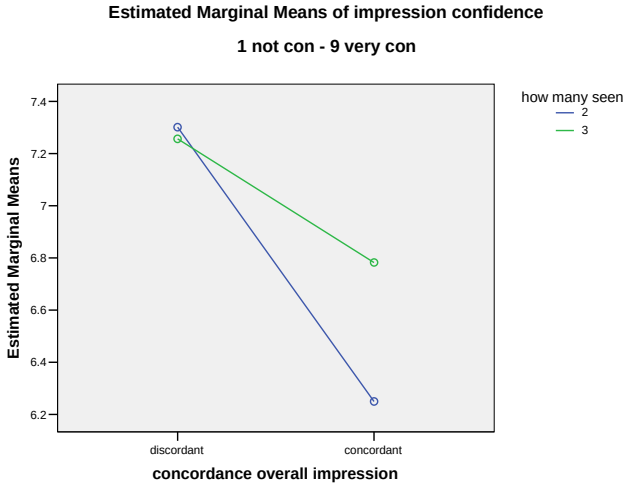
Image	Overall Valence Impression	Classifier	Unianova	Confidence
8 Low Valence Scene Bomb		Lower	n.s.	
25 Low Valence Scene Car Crash		Higher	Concordant discordant response / impression confidence F = 4.3 df = 1, 213 p < 0.05	

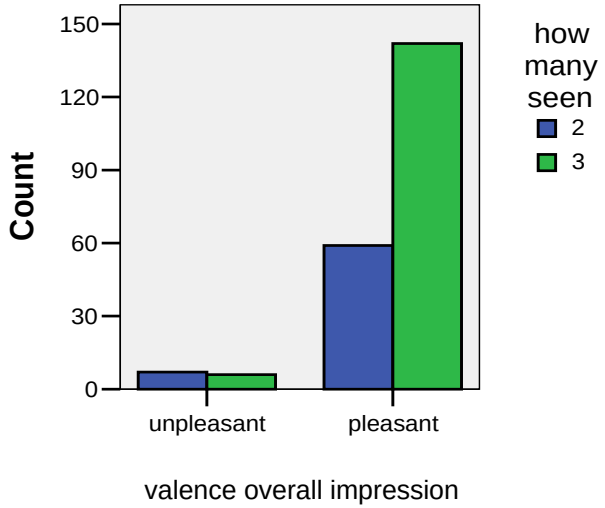
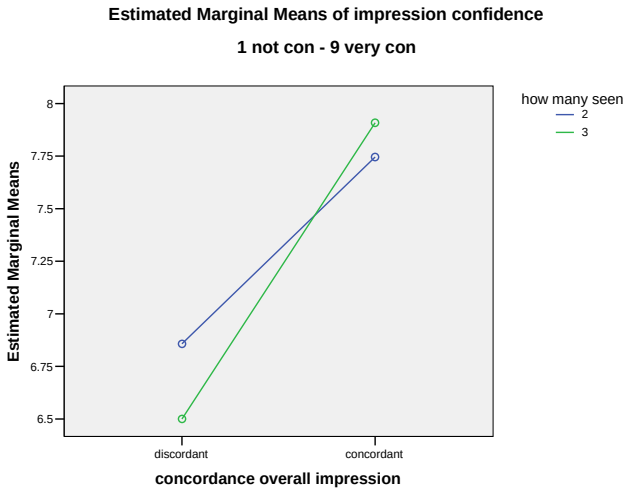
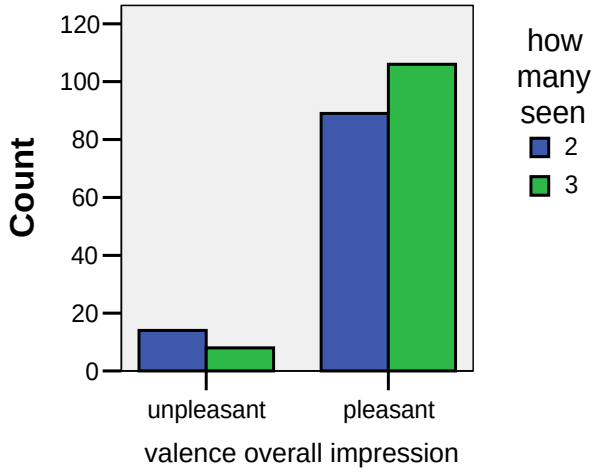
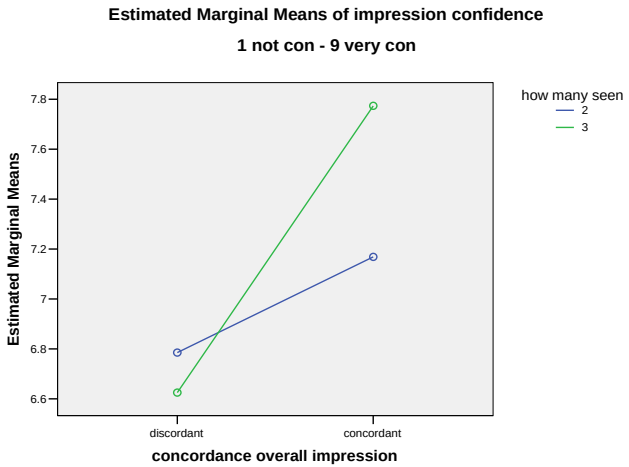
Image	Overall Valence Impression	Classifier	Unianova	Confidence
4 High Valence In-animate Fire-works		Higher	Concordant discordant response / impression confidence F = 9.5 df = 1, 210 p < 0.005	
13 High Valence In-animate Money		Higher	Concordant discordant response / impression confidence F = 4.8 df = 1, 213 p < 0.05	

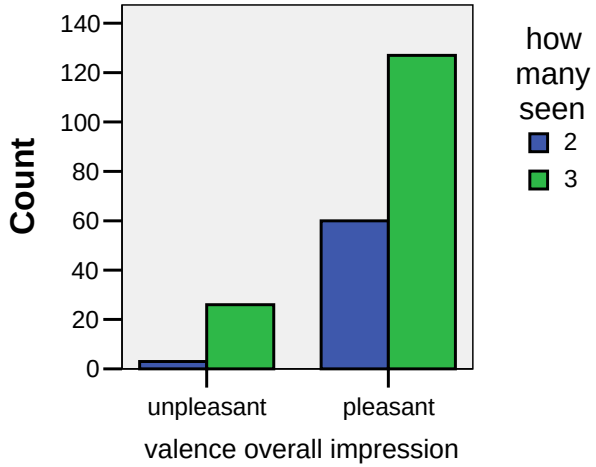
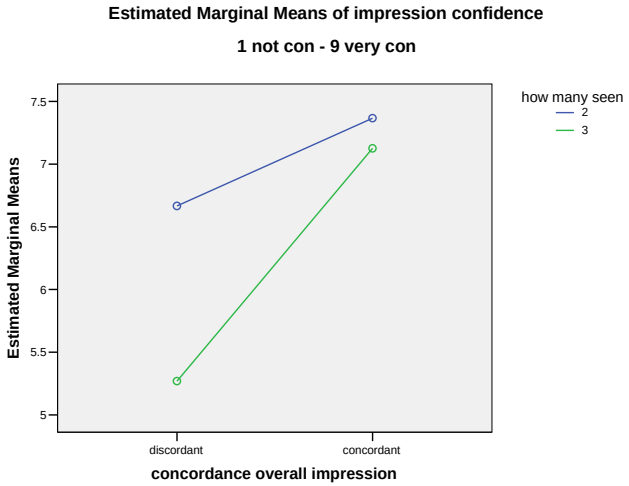
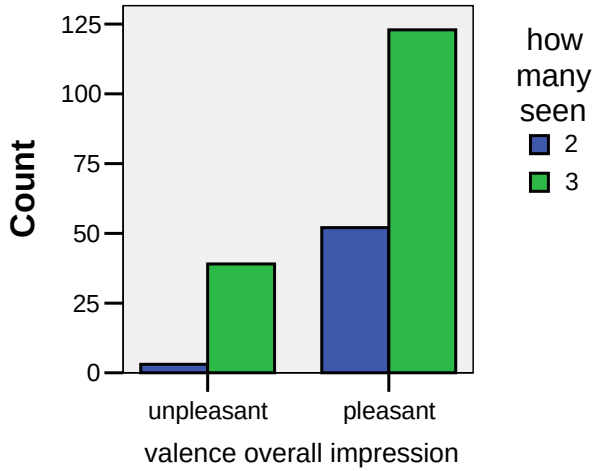
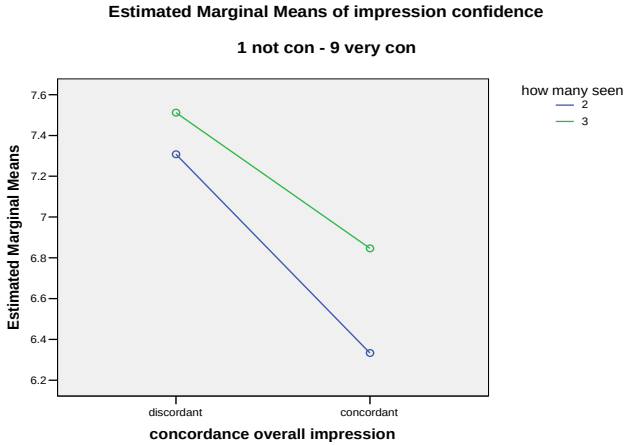
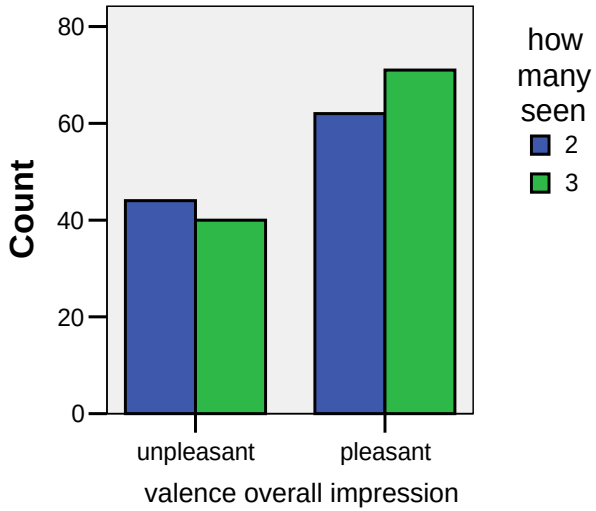
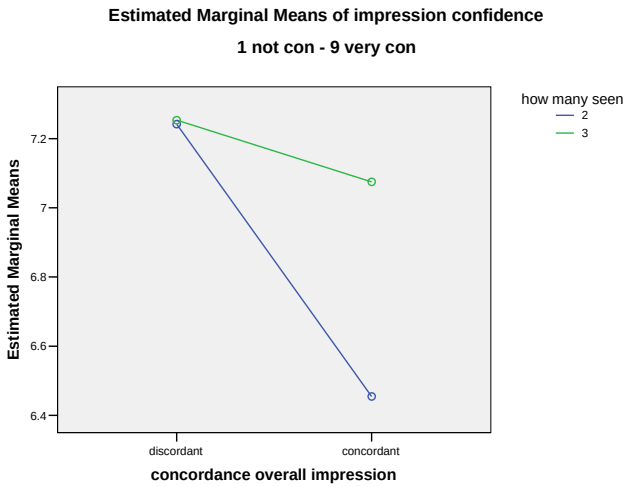
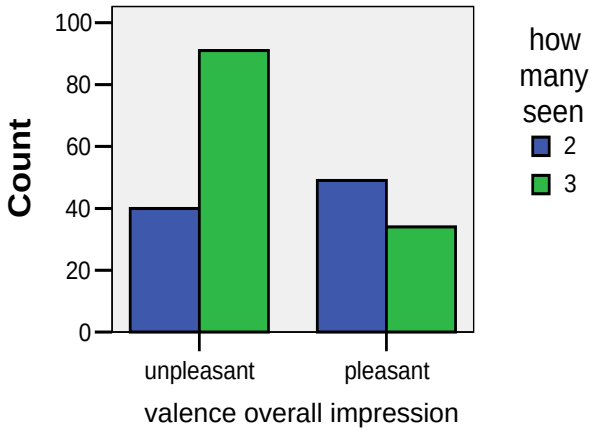
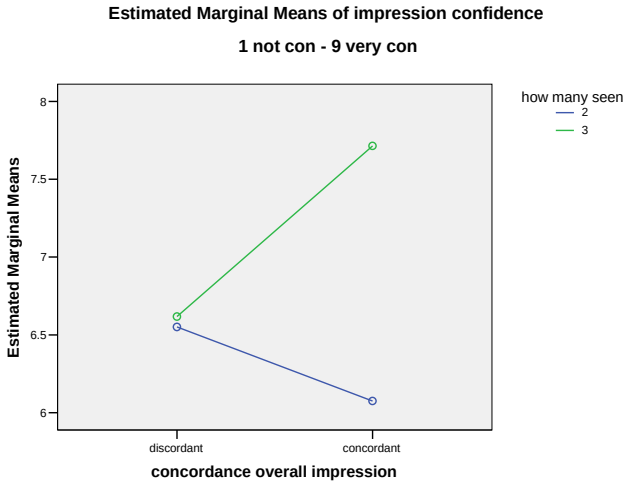
Image	Overall Valence Impression	Classifier	Unianova	Confidence
22 High Valence In-animate Ice cream		Higher	Concordant discordant response / impression confidence F = 5.9 df = 1, 212 p < 0.05	
11 Low Valence In-animate Flies on Pie		Higher	n.s.	

Image	Overall Valence Impression	Classifier	Unianova	Confidence
26 Low Valence In-animate Elec chair		Lower	Concordant discordant response / impression confidence F = 3.9 df = 1, 213 p < 0.05	
36 Low Valence In-animate Toilet		Lower	Number of pictures seen / impression confidence F = 10.8 df = 1, 210 p < 0.005 Concordant discordant response * number seen / seen confidence F = 9.1 df = 1, 210 p < 0.005	

Appendix VII

Initial Screening Form

BRUNEL UNIVERSITY

CCNI

Combined Universities Brain Imaging Centre, Royal Holloway, Egham, Surrey

INITIAL SCREENING FORM

NAME OF PARTICIPANT ..... Sex: M / F

Date of birth..... Approximate weight in kg..... (one stone is about 6.3 kg)

Please read the following questions CAREFULLY and provide answers. For a very small number of individuals, being scanned can endanger comfort, health or even life. The purpose of these questions is to make sure that you are not such a person.

You have the right to withdraw from the screening and subsequent scanning if you find the questions unacceptably intrusive. The information you provide will be treated as strictly confidential and will he held in secure conditions.

Delete as appropriate

1. Have you been fitted with a pacemaker or artificial heart valve?	YES/NO
2. Have you any aneurysm clips, shunts, or stents in your body, or a cochlear implant?	YES/NO
3. Have you ever had any metal fragments in your eyes?	YES/NO
4. Have you ever had any metal fragments, e.g. shrapnel in any other part of your body?	YES/NO
5. Have you any surgically implanted metal in any part of your body, other than dental fillings and crowns (e.g. joint replacement or bone reconstruction)	YES/NO
6. Have you ever had any surgery that might have involved metal implants of which you are not aware? If yes, please give details:	YES/NO
7. Do you wear a denture plate or brace with metal in it?	YES/NO
8. Do you wear a hearing aid?	YES/NO
9. Have you ever suffered from any of: epilepsy, diabetes or thermoregulatory problems?	YES/NO
10. Have you ever suffered from any heart disease?	YES/NO
11. Is there any possibility that you might be pregnant?	YES/NO
12. Have you been sterilised using clips?	YES/NO
13. Do you have a contraceptive coil (IUD) installed?	YES/NO
14. Are you currently breast-feeding an infant?	YES/NO

I have read and understood the questions above and have answered them correctly.

SIGNED..... DATE.....

In the presence of ..... (name) .....(signature)

Address of witness, if not the experimenter:

Please enter here the name and address of your doctor (general practitioner):

Centre for Cognition and Neuroimaging Brunel University Uxbridge UB8 3PH ccni@brunel.ac.uk

Appendix VIII

Information Form

ROYAL HOLLOWAY, UNIVERSITY OF LONDON - MAGNETIC RESONANCE IMAGING UNIT

INFORMATION FORM

These notes give some information about an fMRI study in which you are invited to take part. FMRI is a method for producing images of the activity in the brain as people carry out various mental tasks. It involves placing the participant inside a large, powerful magnet which forms part of the brain scanner. When particular regions of the brain are active, they require more oxygen, which comes from red corpuscles in the blood. As a result, the flow of blood increases. This can be detected as changes in the echoes from brief pulses of radio waves. These changes can then be converted by a computer into 3D images. This enables us to determine which parts of the brain are active during different tasks.

As far as we know, this procedure poses no direct health risks. However, the Department of Health advises that certain people should NOT be scanned. Because the scanner magnet is very powerful, it can interfere with heart pacemakers and clips or other metal items which have been implanted into the body by a surgeon, or with body-piercing items. If you have had surgery which may have involved the use of metal items you should NOT take part. Note that only ferromagnetic materials (e.g. steel) are likely to cause significant problems. Thus normal dental amalgam fillings do not prohibit you from being scanned, though a dental plate which contained metal would do so, and you would be asked to remove it. You will be asked to remove metal from your pockets (coins, keys), remove articles of clothing which have metal fasteners (belts, bras, etc), as well as most jewellery. Alternative clothing will be provided as necessary. Watches and credit cards should not be taken into the scanner since it can interfere with their operation. You will be asked to complete a questionnaire (the Initial Screening Form) which asks about these and other matters to determine whether it is safe for you to be scanned. In addition, you are asked to give the name and address of your Family Doctor. This is because there is a very small chance that the scan could reveal something which required investigation by a doctor. If that happened, we would contact your doctor directly. By signing the consent form, you authorise us to do this. You will also be asked to complete a second, shorter, screening form immediately before the scan.

To be scanned, you would lie on your back on a narrow bed on runners, on which you would be moved until your head was inside the magnet. This is rather like having your head put inside the drum of a very large front-loading washing machine. The scanning process itself creates intermittent loud noises, and you would wear ear-plugs or sound-attenuating headphones. We would be able to talk to you while you are in the scanner through an intercom. If you are likely to become very uneasy in this relatively confined space (suffer from claustrophobia), you should NOT take part in the study. If you do take part and this happens, you will be able to alert the experimenters by activating an alarm and will then be removed from the scanner quickly. It is important that you keep your head as still as possible during the scan, and to help you with this, your head will be partially restrained with padded headrests. We shall ask you to relax your head and keep it still for a period that depends on the experiment but may be more than one hour, which may require some effort on your part. If this becomes unacceptably difficult or uncomfortable, you may demand to be removed from the scanner.

You may be asked to look at a screen through a small mirror (or other optical device) placed just above your eyes and/or be asked to listen to sounds through headphones. You may be asked to make judgements about what you see or asked to perform some other kind of mental task. Details of the specific experiment in which you are invited to participate will either be appended to this sheet or else given to you verbally by the experimenter. Detailed instructions will be given just before the scan, and from time to time during it.

The whole procedure will typically take about 1 hour, plus another 15 minutes to discuss with you the purposes of the study and answer any questions about it which you may raise. You will be able to say that you wish to stop the testing and leave at any time, without giving a reason. This would not affect your relationship with the experimenters in any way. The study will not benefit you directly, and does not form part of any medical diagnosis or treatment. If you agree to participate you will be asked to sign the initial screening form that accompanies this information sheet, in the presence of the experimenter (or other witness, who should countersign the form giving their name and address, if this is not practical). It is perfectly in order for you to take time to consider whether to participate, or discuss the study with other people, before signing. After signing, you will still have the right to withdraw at any time before or during the experiment, without giving a reason.

The images of your brain will be held securely and you will not be identified by name in any publications that might arise from the study. The information in the two screening forms will also be treated as strictly confidential and the forms will be held securely until eventually destroyed.

Further information about the specific study in which you are invited to participate may have been appended overleaf, if the experimenter has felt that this would be helpful. Otherwise, he/she will already have told you about the study and will give full instructions prior to the scan. Please feel free to ask any questions about any aspect of the study or the scanning procedure before completing the initial screening form.

Appendix IX

Second Screening Form

BRUNEL UNIVERSITY

CCNI

Combined Universities Brain Imaging Centre, Royal Holloway, Egham, Surrey

SECOND SCREENING FORM

This form should be completed and signed immediately before your scan, after removal of any jewellery or other metal objects and (if required by the operator) changing your clothes.

NAME OF PARTICIPANT .....

Date of birth..... Sex: M / F

Please read the following questions CAREFULLY and provide answers. For a very small number of individuals, being scanned can endanger comfort, health or even life. The purpose of these questions is to make sure that you are not such a person.

You have the right to withdraw from the screening and subsequent scanning if you find the questions unacceptably intrusive. The information you provide will be treated as strictly confidential and will he held in secure conditions.

BEFORE YOU ARE TAKEN THROUGH FOR YOUR SCAN IT IS ESSENTIAL THAT YOU REMOVE **ALL METAL OBJECTS** INCLUDING:-WATCHES, PENS, LOOSE CHANGE, KEYS, HAIR CLIPS, ALL JEWELLERY, BRASSIERES WITH METAL FASTNERS, METALLIC COSMETICS, CHEQUE/CASH POINT CARDS.

	Delete as appropriate
1. Are you wearing or carrying any metal items such as those listed above?	YES/NO
2. Is there any possibility that you might be pregnant?	YES/NO
3. Do you currently have a contraceptive coil (IUD) installed?	YES/NO
4. Are you breast feeding at the present time?	YES/NO
5. Have your answers to any of the questions in the initial screening form changed? (The initial screening form must be shown to you before you answer this question.)	YES/NO
6. Specifically, please confirm: Have you been fitted with a pacemaker or artificial heart valve?	YES/NO

I have read and understood the questions above and have answered them correctly.

SIGNATURE..... DATE.....

FOR STAFF USE:

I certify that the initial screening form and the consent form have been completed by the person named above and I have attached them to this form. The volunteer has been given the standard information sheet about MRI experiments, together with any necessary study-specific information, and has been given an opportunity to ask questions. I have taken adequate steps to ensure that the volunteer has no ferro-magnetic metal in or on his/her person and I am satisfied that the scan can proceed.

SIGNATURE..... **NAME (print) .....**

Centre for Cognition and Neuroimaging Brunel University Uxbridge UB8 3PH ccni@brunel.ac.uk

Appendix X

Consent Form

ROYAL HOLLOWAY, UNIVERSITY OF LONDON - MAGNETIC RESONANCE IMAGING UNIT

CONSENT FORM

NAME OF PARTICIPANT.....

Please read the following statement carefully and then add your signature. If you have any questions, please ask the person who gave you this form. You are under no pressure to give your consent and you are free to withdraw from the MRI examination at any time.

I agree to participate in an MRI examination conducted for research purposes by .....

(name of operator) on .....(name of project).

I understand that the examination is not part of any medical treatment. I have completed two screening forms and I have been given an opportunity to discuss any issues arising from them. The nature of the examination has been explained to me and I have had an opportunity to ask questions about it. I consent to my general practitioner being contacted in the unlikely event that the scan reveals any suspected abnormality.

Signature ..... Date.....

WITNESS:

Statement by a witness, who must be either an authorised person or a scientific collaborator who is familiar with the experimental procedure and is able to answer questions about it.

I certify that the above participant signed this form in my presence. I am satisfied that the participant fully understands the statement made and I certify that he/she had adequate opportunity to ask questions about the procedure before signing.

Signature..... Date.....

Name .....

Address of witness (if not an Authorised Person):

Appendix XI

Subjective Report Form

Appendix XI Subjective Report Form

Legend:

HV = high valence
LV = low valence
B = big
L = little
F = foveal/peripheral dual image
a= animal
f = face
s = scene
i = inanimate object

Experiment fMRI foveal/peripheral – Subjective Report

Name……

Today's date…….

DOB……Age……..

Gender……

Are you left or right handed……..

I SAY – "PLEASE MAKE SURE YOU CAN SEE THE SCREEN CLEARLY"

I THEN SAY – "Each picture will appear quickly. Please tell me whether the images are pleasant, unpleasant or neutral. Some of the pictures are big. Some are small. Some are big with a small picture in the centre – when these appear please attend to the small central picture only."

I fill in the questionnaire because the experiment goes so quickly.

PRACTICE TRIAL

		PLEASANT	UNPLEASANT	NEUTRAL
TRIAL 1	Big neutral	☐	☐	☐
TRIAL 2	HVLf	☐	☐	☐
TRIAL 3	HVFa	☐	☐	☐

IMAGE 1	Big Neutral	☐	☐	☐
IMAGE 2	Big Neutral	☐	☐	☐
IMAGE 3	Big Neutral	☐	☐	☐
IMAGE 4	HVBa	☐	☐	☐
IMAGE 5	HVBa	☐	☐	☐
IMAGE 6	HVBa	☐	☐	☐
IMAGE 7	Big Neutral	☐	☐	☐
IMAGE 8	Big Neutral	☐	☐	☐
IMAGE 9	Big Neutral	☐	☐	☐
IMAGE 10	HVBf	☐	☐	☐
IMAGE 11	HVBf	☐	☐	☐
IMAGE 12	HVBf	☐	☐	☐

		PLEASANT	UNPLEASANT	NEUTRAL
IMAGE 13	Big Neutral	☐	☐	☐
IMAGE 14	Big Neutral	☐	☐	☐
IMAGE 15	Big Neutral	☐	☐	☐
IMAGE 16	HVBs	☐	☐	☐
IMAGE 17	HVBs	☐	☐	☐
IMAGE 18	HVBs	☐	☐	☐
IMAGE 19	Big Neutral	☐	☐	☐
IMAGE 20	Big Neutral	☐	☐	☐
IMAGE 21	Big Neutral	☐	☐	☐
IMAGE 22	HVBi	☐	☐	☐
IMAGE 23	HVBi	☐	☐	☐
IMAGE 24	HVBi	☐	☐	☐
IMAGE 25	Little Neutral	☐	☐	☐
IMAGE 26	Little Neutral	☐	☐	☐
IMAGE 27	Little Neutral	☐	☐	☐
IMAGE 28	LVLa	☐	☐	☐
IMAGE 29	LVLa	☐	☐	☐
IMAGE 30	LVLa	☐	☐	☐
IMAGE 31	Little Neutral	☐	☐	☐
IMAGE 32	Little Neutral	☐	☐	☐
IMAGE 33	Little Neutral	☐	☐	☐
IMAGE 34	LVLf	☐	☐	☐
IMAGE 35	LVLf	☐	☐	☐
IMAGE 36	LVLf	☐	☐	☐
IMAGE 37	Little Neutral	☐	☐	☐
IMAGE 38	Little Neutral	☐	☐	☐
IMAGE 39	Little Neutral	☐	☐	☐
IMAGE 40	LVLs	☐	☐	☐
IMAGE 41	LVLs	☐	☐	☐

		PLEASANT	UNPLEASANT	NEUTRAL
IMAGE 42	LVLs	☐	☐	☐
IMAGE 43	Little Neutral	☐	☐	☐
IMAGE 44	Little Neutral	☐	☐	☐
IMAGE 44	Little Neutral	☐	☐	☐
IMAGE 45	LVLi	☐	☐	☐
IMAGE 46	LVLi	☐	☐	☐
IMAGE 47	LVLi	☐	☐	☐
IMAGE 48	Foveal Neutral	☐	☐	☐
IMAGE 49	Foveal Neutral	☐	☐	☐
IMAGE 50	Foveal Neutral	☐	☐	☐
IMAGE 51	HVFa	☐	☐	☐
IMAGE 52	HVFa	☐	☐	☐
IMAGE 53	HVFa	☐	☐	☐
IMAGE 54	Foveal Neutral	☐	☐	☐
IMAGE 55	Foveal Neutral	☐	☐	☐
IMAGE 56	Foveal Neutral	☐	☐	☐
IMAGE 57	HVFf	☐	☐	☐
IMAGE 58	HVFf	☐	☐	☐
IMAGE 59	HVFf	☐	☐	☐
IMAGE 60	Foveal Neutral	☐	☐	☐
IMAGE 61	Foveal Neutral	☐	☐	☐
IMAGE 62	Foveal Neutral	☐	☐	☐
IMAGE 63	HVFs	☐	☐	☐
IMAGE 64	HVFs	☐	☐	☐
IMAGE 65	HVFs	☐	☐	☐
IMAGE 66	Foveal Neutral	☐	☐	☐
IMAGE 67	Foveal Neutral	☐	☐	☐
IMAGE 68	Foveal Neutral	☐	☐	☐
IMAGE 69	HVFi	☐	☐	☐

		PLEASANT	UNPLEASANT	NEUTRAL
IMAGE 70	HVFi	☐	☐	☐
IMAGE 71	HVFi	☐	☐	☐
IMAGE 72	Big Neutral	☐	☐	☐
IMAGE 73	Big Neutral	☐	☐	☐
IMAGE 74	Big Neutral	☐	☐	☐
IMAGE 75	LVBa	☐	☐	☐
IMAGE 76	LVBa	☐	☐	☐
IMAGE 77	LVBa	☐	☐	☐
IMAGE 78	Big Neutral	☐	☐	☐
IMAGE 79	Big Neutral	☐	☐	☐
IMAGE 80	Big Neutral	☐	☐	☐
IMAGE 81	LVBf	☐	☐	☐
IMAGE 82	LVBf	☐	☐	☐
IMAGE 83	LVBf	☐	☐	☐
IMAGE 84	Big Neutral	☐	☐	☐
IMAGE 85	Big Neutral	☐	☐	☐
IMAGE 86	Big Neutral	☐	☐	☐
IMAGE 87	LVBs	☐	☐	☐
IMAGE 88	LVBs	☐	☐	☐
IMAGE 89	LVBs	☐	☐	☐
IMAGE 90	Big Neutral	☐	☐	☐
IMAGE 91	Big Neutral	☐	☐	☐
IMAGE 92	Big Neutral	☐	☐	☐
IMAGE 93	LVBi	☐	☐	☐
IMAGE 94	LVBi	☐	☐	☐
IMAGE 95	LVBi	☐	☐	☐
IMAGE 96	Little Neutral	☐	☐	☐
IMAGE 97	Little Neutral	☐	☐	☐
IMAGE 98	Little Neutral	☐	☐	☐

		PLEASANT	UNPLEASANT	NEUTRAL
IMAGE 99	HVLa	☐	☐	☐
IMAGE 100	HVLa	☐	☐	☐
IMAGE 101	HVLa	☐	☐	☐
IMAGE 102	Little Neutral	☐	☐	☐
IMAGE 103	Little Neutral	☐	☐	☐
IMAGE 104	Little Neutral	☐	☐	☐
IMAGE 105	HVLf	☐	☐	☐
IMAGE 106	HVLf	☐	☐	☐
IMAGE 107	HVLf	☐	☐	☐
IMAGE 108	Little Neutral	☐	☐	☐
IMAGE 109	Little Neutral	☐	☐	☐
IMAGE 110	Little Neutral	☐	☐	☐
IMAGE 111	HVLs	☐	☐	☐
IMAGE 112	HVLs	☐	☐	☐
IMAGE 113	HVLs	☐	☐	☐
IMAGE 114	Little Neutral	☐	☐	☐
IMAGE 115	Little Neutral	☐	☐	☐
IMAGE 116	Little Neutral	☐	☐	☐
IMAGE 117	HVLi	☐	☐	☐
IMAGE 118	HVLi	☐	☐	☐
IMAGE 119	HVLi	☐	☐	☐
IMAGE 120	Foveal Neutral	☐	☐	☐
IMAGE 121	Foveal Neutral	☐	☐	☐
IMAGE 122	Foveal Neutral	☐	☐	☐
IMAGE 123	LVFa	☐	☐	☐
IMAGE 124	LVFa	☐	☐	☐
IMAGE 125	LVFa	☐	☐	☐
IMAGE 126	Foveal Neutral	☐	☐	☐
IMAGE 127	Foveal Neutral	☐	☐	☐

		PLEASANT	UNPLEASANT	NEUTRAL
IMAGE 128	Foveal Neutral	☐	☐	☐
IMAGE 129	LVFf	☐	☐	☐
IMAGE 130	LVFf	☐	☐	☐
IMAGE 131	LVFf	☐	☐	☐
IMAGE 132	Foveal Neutral	☐	☐	☐
IMAGE 133	Foveal Neutral	☐	☐	☐
IMAGE 134	Foveal Neutral	☐	☐	☐
IMAGE 135	LVFs	☐	☐	☐
IMAGE 136	LVFs	☐	☐	☐
IMAGE 137	LVFs	☐	☐	☐
IMAGE 138	Foveal Neutral	☐	☐	☐
IMAGE 139	Foveal Neutral	☐	☐	☐
IMAGE 140	Foveal Neutral	☐	☐	☐
IMAGE 141	LVFi	☐	☐	☐
IMAGE 142	LVFi	☐	☐	☐
IMAGE 143	LVFi	☐	☐	☐